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Second Handbook of Information Technology in Primary and Secondary Education

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Editors

Second Handbook of Information Technology in Primary and Secondary Education

With 69 Figures and 44 Tables

Springer

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Preface

Major changes have taken place in the landscape of information technology in educational research, policy, and practice since the publication of the first edition of the *Handbook of Information Technology in Primary and Secondary Education* in 2008. The primary aim of the second edition of this *Handbook* is to update our knowledge of the field since 2008 and synthesize research about Information Technology in education from a broad international perspective. This second edition has 88 chapters written by 138 different authors. The authors come from 27 different countries and spann five continents.

Consensus on the focus and structure of the *Handbook* was reached among the twenty (section) editors during a joint meeting at the headquarters of the United Nations Educational Scientific and Cultural Organization (UNESCO) in Paris in 2016. The editors decided to keep the same structure of the *Handbook* as in the first edition and organized the *Handbook* around two main themes: (1) the potential of information technology (IT) to improve teaching and learning in primary and secondary education; and (2) the support that is required to successfully implement IT in educational practice. These two themes are addressed in the 12 sections of the *Handbook*. Most of the sections in the first edition were kept (often with a slightly different titles) and three new sections were added. These new sections focused on the use of technology in assessment, mobile learning, and game- and simulation-based learning and teaching. The *Second Handbook of Information Technology in Primary and Secondary Education* provides an updated in-depth overview of research to date in the field of information technology in education.

In this introduction chapter of the *Handbook,* the editors-in-chief provide an overview of the main themes of this second edition and highlight the developments in the field since the publication of the first edition of the *Handbook* in 2008. Then in each section, there are between five and seven chapters addressing themes pertinent to a subfield of IT in education. After a brief summary of the chapters in the section, the section editor(s) provide an introduction of the research in their specific field in an overview chapter.

As editors-in-chief, we would like to express our gratitude to the section editors for their valuable contributions to the *Handbook* and their constructive collaboration throughout the editorial process. We also wish to thank all the authors for their efforts in contributing chapters to the *Handbook*, as well as the reviewers of these chapters. As our host at UNESCO, we wish to thank Mariana Patru for her generous hospitality.

Finally, we thank Springer, in particular Yoka Janssen, Audrey Wong-Hillmann, and Sindhu Ramachandran for their support and trust.

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Contents

Volume 1

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Dr. **Joke Voogt** is Professor of ICT and Curriculum at the Faculty of Behavioural and Social Sciences of the University of Amsterdam and Professor of Educational Innovation and ICT at Windesheim University of Applied Sciences. Since the 1980s, she has been investigating the integration of Information and Communication Technology in educational practice in national and international settings. She was part of the coordination team of Second Information Technology in Education Studies (1998–2008) of the International Association for the Evaluation of Educational Achievement and is currently involved as a curriculum specialist in the OECD Education 2030 study: The future of Education and Skills.

Dr. Voogt is Co-editor of the first edition of the *International Handbook of Information Technology in Primary and Secondary Education*. She is Co-founder and Chair of the EDUsummIT, the international Summit for research, policy, and practice that emerged from the first edition of the Handbook. Her areas of expertise are curriculum innovation, teacher learning and development, twenty-first century skills, in particular related to the integration of technology in education. Dr. Voogt has a master degree in Educational Science and Technology (with distinction) and a doctoral degree (Ph.D.) in Educational Sciences from the University of Twente, The Netherlands.

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Dr. Rhonda Christensen is Research Professor in the Learning Technologies Department in the College of Information at the University of North Texas, USA. She is Co-director of the Institute for the Integration of Technology into Teaching and Learning at UNT and a Co-PI and Project Director for the Going Green! Middle Schoolers Out to Save the World (MSOSW) project funded by the US National Science Foundation (NSF) Innovative Technologies Program and the National Aeronautics and Space Administration (NASA) Space Science Education Consortium funded project. She serves as the Chair of the IT Council for the Society for Information Technology in Teacher Education (SITE). She is a Fulbright Senior Scholar recipient working in the Netherlands on a research teaching assignment. Dr. Christensen has participated as a leader and participant in four of the international EDUSummIT meetings focused on ICT in education and was a section editor on the first edition of this *Handbook*.

Dr. Christensen has co-authored and taught a pre-service technology integration course for more than 15 years. She also teaches doctoral courses on research design and analysis. Her research interests are the impact of technology integration education, enhancing STEM education in middle schools and mobile learning in education.

Dr. Christensen received her Bachelors' of Science in Curriculum and Instruction from Texas A&M University, her Masters' of Science in Computer Education and Cognitive Systems and her Ph.D. in Information Science from the University of North Texas.

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The Learner and the Learning Process

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Attitudes, Competencies, and Dispositions for Teaching and Learning with Information Technology

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Professional Learning and Development of Teachers

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The Role of Leadership for Information Technology in Education

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Using Information Technology for Assessment: Issues and Opportunities

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Flexible, Distance, and Open Learning in the 21st Century

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Mobile Learning

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Game and Simulation-Based Learning and Teaching

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Hiroaki Ogata Kyoto University, Kyoto, Japan

Issues and Challenges Related to Digital Equity

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Paradigms for Researching Information Technology in Education

Margaret J. Cox King's College London, London, UK

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International Policies on Information and Communication Technology in Primary and Secondary Schools: Cross-National Policies

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Section I

Introduction

Developing an Understanding of the Impact of Digital Technologies on Teaching and Learning in an Ever-Changing Landscape

1

Joke Voogt, Gerald Knezek, Rhonda Christensen, and Kwok-Wing Lai

Contents

Abstract

In this introduction chapter, we reflect on the contributions of research in the field of digital technologies in education during the last decade (2008–2018). The guiding questions leading these reflections are (1) what progress in understanding the role and impact of digital technologies in education has been made? and

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(2) what emerging themes can be observed that warrant further study? Overall, the progress made in the last decade is promising, and new research themes have emerged. This chapter highlights selected findings and issues that serve as exemplars for those addressed throughout the 2018 *handbook*, within the thematic strands that served as the blueprint for the reference work itself. Whenever possible, brief comparisons and contrasts are made to the evolutions over the past decade, since the first edition of the *handbook* was published.

Keywords
Information technology · Teaching and learning · Leadership · Curriculum · Emerging technologies · Assessment · Research methodologies

Introduction

"There is a wealth of research on information technology (IT) in primary and secondary education. Yet most of it is scattered and a synthesis of the research from a broad international perspective is needed" (Voogt and Knezek 2008, p. xxix). This was the main rationale for the *International Handbook of Information Technology in Primary and Secondary Education*, which was published in 2008. At the dawn of the publication of the second edition of the *International Handbook of Information Technology in Primary and Secondary Education*, we realize that most sections of the *handbook* have substantially changed since the first edition.

The design and impact of technology-supported learning environments focusing on the student learner remain a major focus of the second edition. This line of research studies how learners, learning processes, and learning environments and their interactions change in a digitalized world. An equally important theme deals with the uptake of IT in educational practice. Research topics about the uptake of IT in education are considered from several perspectives: the curriculum, the teacher, the school leadership, the assessment, and the educational policy, while taking into account interdependencies. Equity is an important theme within research on IT in education and therefore deserves specific attention. Finally, valuing existing and evolving research paradigms and methodologies is needed to contribute to a better understanding of how technologies impact teaching and learning.

Since the publication of the first edition of the *handbook,* various terms on the use of digital technologies in education have been used, such as eLearning and mLearning. For pragmatic reasons we will stick with the term information technology (IT) as we did in the first *handbook*. In some chapters authors use the term information and communication technology (ICT) instead of information technology, because it better reflects the discourse in the addressed context.

In this introduction chapter, we reflect on the contributions of research in the field of digital technologies in education during the last decade (2008–2018). The guiding questions leading these reflections are (1) what progress in understanding digital technologies in education has been made? and (2) what emerging themes can be observed that warrant further study?

Overall, the progress made in the last decade is promising, and new research themes have emerged. This chapter highlights selected findings and issues that serve as exemplars for those addressed throughout the 2018 *handbook*, within the thematic strands that served as the blueprint for the reference work itself. Whenever possible, brief comparisons and contrasts are made to the evolutions over the past decade, since the first edition of the *handbook* was published.

Technology and Learners

Compared to the first edition of the *handbook*, there has been a stronger emphasis on the influence of digital technologies on learners instead of learning processes and learning outcomes in this second edition. Overall access to digital technologies by students, at least in the economically more advanced countries, is no longer a major barrier. We recognize that the importance of emotions, motivation, creativity, grit, and other non-cognitive variables related to attitudes toward teaching and learning with digital technologies has increased. Likewise, recognition of the importance of understanding the process of acquiring different kinds of competencies needed to be productive in a modern society (e.g., communication, confidence, collaboration) related to IT in education – rather than simply focusing on the end-goal performance of a mastered IT skill – has become universal.

By using networking technologies to support students working in learning communities, it is critical that students develop knowledge creating capabilities and the skills for knowledge innovation. Online learning communities should be designed not just for information sharing but should support an effective and student-centered way of learning.

Over the past decade, the use of digital technologies and applications has continued to increase, particularly the use of social media. However, research in social media is beginning to recognize that to be successfully engaged in this participatory culture, the learners need to acquire a new form of literacy and deal with cultural and social issues. Also, there is increasing recognition that how social media can be effectively used in the formal school context should be rigorously researched.

Research now clearly shows that digital technologies can support students to engage collaboratively to become innovative and creative learners. These technologies can support the creation of new knowledge and the development of new skills (Ito et al. 2013; Scardamalia and Bereiter 2015). It is still the case, however, that many young people use new technologies only to consume information.

With this focus on the learner, rather than simply the learning outcomes, there are also some alarming issues related to the use of technologies., Negative issues include privacy issues and the lack of attention to the overall well-being (psychological and emotional) of the learners. There are also health and safety issues due to the increase of cyberbullying.

Technology to Support the Learning Process

While the specific impact of digital technologies on students' learning is difficult to demonstrate, some recent meta-analyses of the literature show higher effect sizes for students' learning performance (cognitive, affective, and social skills) when student are learning with digital technologies than without digital technologies (▶ Chap. 75, "Meta-analyses of Large Scale Datasets: A Tool for Assessing the Impact of Information and Communication Technology in Education" by Liao and Lai). These meta-analyses include a broader variety of technologies (including games and mobile learning) than the earlier meta-analyses – and higher effect sizes were found. However, the mechanisms that account for these findings cannot easily be identified.

While technologies are constantly changing, the education field has been trying to choose those that will best support and enhance learning. Games, simulations, and immersive environments are able to provide a great deal of data that can be evaluated for learning but has only been harnessed for feedback in select environments. The next decade should see the large sets of data that are unobtrusively collected become useful for targeting learning needs in near real time.

Since the first edition of the *handbook*, mobile technologies have become ubiquitous. The education field has been working to find ways to harness the power of one-to-one learning with mobile devices. Over the past decade, the smartphone has become a pervasive device that is used by two-thirds of the world's population. Over the past 10 years, mobile devices have gone from supplemental to mainstream for twenty-first century learning in many classrooms.

Also in the last decade, we saw the emergence of new pedagogies such as flipped learning and the use of advanced digital technologies to support distance and flexible learning. There has been huge growth of virtual schools in the USA, but the growth in other countries was primarily in online learning, to support face-to-face learning. Since online learning has been widely practiced in schools, we see the beginning of a reconceptualization of distance learning, with a shift from being on the edge of the educational landscape to the center stage, and fast becoming mainstream, particularly in the USA (Naidu 2016). Supported by Open Education Resources and Massive Online Open Courses, in the last decade, open learning has advanced beyond higher education, into the primary and secondary sectors, and we see examples of learning environments being developed that facilitate open access to content with more open pedagogies. There is also recognition of the importance of designing flexible learning environments to support personalized learning.

There is modest advancement in pedagogy for how to support students to become innovative and creative. In terms of learning theories, social constructivism is still the dominant learning theory underpinning innovative use of technology-enhanced learning. Once considered promising, there has not been much development of connectivism in recent years.

Rapid advances in neuroscience research investigate how neural activities affect learning by using digital technologies such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG). A new discipline called educational neuroscience (Bowers 2016) has been developed aiming to gain a better understanding of how the biology of learning can be used to support classroom practice and specifically in designing technology-enhanced learning (Howard-Jones et al. 2015). The advance of educational neuroscience has been slow, and there are many misconceptions as to how neuroscience research can illuminate learning sciences research. For example, it is not clear how and why immersing in digital technologies may reorganize and restructure the brain to enhance learning (Prensky 2009). There has also been increasing popularity of computer-based brain training software. However, to date it is not clear how or in what way these computer-based training programs can help the learner (Kroeger et al. 2012). Research in educational neuroscience has not advanced to the stage where research findings can be readily translated into practice (Howard-Jones et al. 2015).

Connecting In and Out of School Learning

The notion that learning is a lifelong process which extends beyond schooling and the school curriculum highlights the importance of informal learning and personalization of the curriculum. In the last decade, teachers began to recognize the importance of personal learning experiences taking place in everyday life and the involvement of other actors (e.g., the family and the wider community) in supporting students' informal learning. It is now considered pertinent to align students' experiences in school with their day-to-day digital practices in order to support identity and agency building. However, how formal and informal learning can be effectively connected remains a key research issue.

The maker movement is fast growing as an informal learning environment outside the school context (Peppler and Bender 2013), supporting participants to work on collaborative projects of personal interest but having connections to formal knowledge. Cultural clashes (▶ Chap. 14, "Bridging Formal and Informal Learning Through Technology in the Twenty-First Century: Issues and Challenges" by Lewin and Charania) between formal and informal learning are still unresolved. Mobile technologies provide affordances of informal learning and the opportunities to connect informal learning with formal learning. However, there has been slow advancement of how this can be effectively done. For now, it appears that learners will continue to advance most rapidly through mobile learning in the informal realm (▶ Chap. 53, "Section introduction: Mobile learning" by Norris and Soloway).

Teachers

We recognize that using digital technologies to foster twenty-first century skills such as critical analysis of information and collaboration with peers is often more important than using digital technologies to help students memorize facts. We have moved from standardized paper and pencil tests for teachers to show performance, in recognition that how much teacher knows must be equally important with how well they can foster student learning. Instruments to measure teacher development can best be described as a battery of developmental appraisals rather than a single test.

There are issues of what teachers need to learn about digital technologies and the application of IT in supporting learning in the twenty-first century, since most teachers continue to use IT primarily to support content delivery rather than to engage students in creative activities. Recent research highlights the need for teachers to develop technological knowledge and technical skills, in addition to pedagogical and content knowledge.

However, research has shown that tacit qualities of the teacher (e.g., self-efficacy, positive attitudes, beliefs) are also important to develop, which are, beyond observed teaching performances and mastery of content knowledge or theories of teaching and learning. The instructional strategies teachers use in the classroom are evolving due to the influences and influx of digital technologies. In the case of technology integration, it is important to consider the level of confidence teachers have in the instructional use of technologies to enhance student learning.

How to support teachers in a technology-enhanced environment remains a key issue. This support involves a reconsideration of the role of the teacher, in terms of their agency, and their role in bridging formal and informal learning, with a growing importance of the latter. This is about empowering teachers to exercise agency. It has been suggested that a way of enhancing teacher agency is to engage them in collaborative pedagogical inquiry (▶ Chap. 25, "Information and Communication Technology and Education: Meaningful Change Through Teacher Agency" by Albion and Tondeur). Also, as one of the most important factors affecting student learning, there has been increasing recognition that research should be conducted to clarify the knowledge base of the teacher.

School Leadership

Teacher readiness for technology integration, although important, also depends on a school's readiness to support the use of digital technologies in teaching and learning (Petko et al. 2018). The role of school leadership therefore is important for fostering teachers' use of technology in daily teaching and learning processes.

We now know more about the benefits of a school-level perspective to technology integration, including leaders' roles in IT integration. Research has provided evidence that by adopting a distributed leadership perspective, the main functions of leading technology innovations, including developing vision, supporting integration, and ensuring the accountability of technology initiatives in terms of ownership and outcomes, can be framed.

The distributed leadership perspective and some key functions for IT leaders are still considered important to promote IT further in schools, but there is now a more fine-grained emphasis on practices – *how* leaders do their work. Research-based strategic interventions have been developed for leaders to coordinate actions across their schools so that multiple leaders' areas of expertise are used to facilitate and support teachers in using IT in classrooms. Thus, a shift can be observed from an emphasis on instrumental actions of leaders from an accountability perspective, toward transformative and instructional leadership actions aiming to change the culture in schools regarding teachers' collaborative learning to fuel the design and enactment of IT in classrooms.

Curriculum and Assessment Challenges

In the first edition of the *handbook*, the focus of IT in the curriculum emphasized on the use of digital technologies to enhance the learning of traditional subjects as well as the use of digital technologies in cross-curricular themes. However in the last decade, we have witnessed a renewed discourse on the question of what should be taught in the twenty-first century society – which is the classical curriculum question (e.g., OECD 2018). Because of technological advancements and their implications for living, learning, and working, many countries and states worldwide are now redesigning their curricula. In the process of curriculum redesign, the need to pay attention to the knowledge, skills, attitudes, and values, often referred as the twenty-first century competencies, is recognized, as they are important in a global and digitalized society. Technology is seen as a driver of change as well as a tool to develop twenty-first century competencies. Emerging domains are important in the twenty-first century such as the development of new literacies, the notion of digital citizenship, and the importance of computational thinking as an integral part of digital literacy. These new domains are theoretically conceptualized and discussed in the *handbook*. However, empirical research evidence on these new domains is still scarce and further study is needed.

While curriculum deals with what needs to be learned, assessment is about what has been learned. Technology-based assessment is a dynamic field that has been advancing rapidly with growth set to accelerate with emerging opportunities for automatic data collection as well as increased possibilities of communication and interaction mediated by IT. In order to continue moving forward in a constructive manner for education, assessment discourse needs to involve designers, teachers, and learners working together to support twenty-first century curricula and pedagogies. This shared vision among stakeholders allows that data can be collected and represented to enable learners and teachers to identify achievements, collate evidence of achievements, diagnose needs – both cognitive and affective – and decide on suitable pedagogical approaches for enabling the next steps in learning.

IT Policies

Moonen (2008) concluded in the first edition of the *handbook*, in his review of IT policies of different regions of the world, that in the developed regions the emphasis had shifted from a concern about the IT infrastructure to the incorporation of IT into the teaching and learning process. As a result IT policies in education were no longer explicit but had become implicit in the educational policy in many countries. However, a decade later the opposite seems to be true. Many countries are now renewing their IT policies in education. Current policy developments result in the inclusion of a computing (computer science) curriculum in schools (Fluck et al. 2016). However, in practice, there is little evidence to show that digital technologies have been used in a creative way globally.

Eickelmann (▶ Chap. 81, “Cross-National Policies on Information and Communication Technology in Primary and Secondary Schools: An International Perspective”) observes that in the last decade while variability of IT policies across regions was the norm, some commonalities as follows could be identified:

- Developing ICT infrastructures that reflect pedagogical aims, especially the fostering of one-to-one and BYOD (“bring your own device”) concepts, often in combination with personalized learning
- Focusing on access, equity, and participation
- Reaching all students and improving teacher training
- Bridging and linking formal and informal learning
- Integrating the aims of (subject-specific) learning with ICT with more general education goals such as creating a skilled workforce for the twenty-first century
- Introducing new topics (e.g., computational thinking) and modernizing curricula
- Pointing to new potentials such as those afforded by new forms of online learning and online assessment as well as to risks and more critical issues like data privacy

These common aspects in IT policy show that the high expectations at the turn of the century that IT would transform education seem to have now changed toward the more realistic opportunities IT may offer to solve some prominent challenges in the digital society. For IT in primary and secondary education, the challenge is to transfer the plans and core ideas of IT policies into practice, because realization of developing school systems in the digital age is still pending and not automatically assured by simply having policies. Having a vision and shared aims captured in IT policies is indispensable and especially valuable when they do not only outline goals but also give direction on how goals can be translated into practice and how supportive conditions can be facilitated.

The focus on access, equity, and participation is a common concern of IT policies globally. The evolving nature of digital equity is a complex topic, and depending on the point of view, there is both an increase and a decrease in digital equity. Regarding digital equity for learning with technology, there have been attempts to close the gap or bridge the divide regarding gender, race, social class, learning disabilities, etc. However, the focus is not on the amount of access that students have but on technology as a potential agent for social inclusion and strategies in moving toward digital equity for classroom teachers.

Research

From a superficial point of view, the time consuming and slow research process often do not seem to align with the rapid development of technologies and their potential for teaching and learning. However, research that helps to understand why specific technologies work and under which conditions might better predict the potential and issues of new technologies for improving student learning. For this reason we think it is important to review the history of educational IT research to better understand the issues at stake.

One important issue that remains essential in educational IT research is acknowledging the importance of context in which IT applications are used to foster teaching and learning. Unraveling the context is seen as a challenge for educational IT research. It requires researchers to think of research methods as being complementary to each other instead of hierarchical. Thus in addition to a clear theoretical basis guiding research on IT in education, deliberately making use of the diversity of research methods may help to better understand not only if specific technology interventions have impact but also why the outcome is realized. Even stronger than in the 2008 handbook, there is a call for further integration of research paradigms and of quantitative and qualitative research designs.

Since 2008, the technology landscape has tremendously changed. IT has now become a ubiquitous aspect of life. Many IT tools can be used for learning purposes, but they are typically not designed with student learning in mind. In addition, technology potentially can create learning environments everywhere, including outside the traditional education systems. However, how best to make use of technology to foster student development (including their well-being) yet mitigating its threats is a challenge for the design and evaluation of IT tools which requires close collaboration of researchers with key stakeholders. Much progress in understanding the evolving role of digital technologies in education has been made, but much that is unknown still remains regarding the impact of digital technologies on teaching and learning in an ever-changing landscape.

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Section II

Curricular Challenges of the Twenty-First Century

Section Introduction: Curricular Challenges of the Twenty-First Century

2

Joke Voogt and Ola Erstad

Abstract

Rapid technological developments ask for so called 21st century skills or competences to prepare citizens for living, working and learning in our current society. Due to these changes many countries worldwide are in the process of redesigning their curricula. This section elaborates on the role of technology in 21st century curricula. First the notion of 21st century competences is elaborated upon. This is followed by research on emerging domains in 21st century curricula, such as new literacies, digital citizenship, digital literacy and computational thinking. The section finishes with pointing to the need to align school curricula with students' digital practices.

Keywords

21st century skills · Key competences · Curricular challenges

This section elaborates on the role of technology in twenty-first-century curricula. Recently international organizations such as OECD and the European Union as well as national policies in many countries are reconsidering curriculum frameworks

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from the perspective of competences that are found relevant for living in and contributing to a global and digitalized society. These competences are generic and often referred to as twenty-first-century skills (North America), lifelong learning competences (OECD 2005), or key competences (EU 2007). According to Klieme, Hartig, and Rauch, competences are "context-specific cognitive dispositions that are acquired by learning and needed to successfully cope with certain situations or tasks in specific domains" (p. 9). They have cognitive, behavioral, and affective components. Twenty-first-century competences or skills are certainly not new (Voogt et al. 2013). For instance, already in 1910 Dewey (1910) mentions critical thinking as an important skill to be taught. What is different is that twenty-first-century competences should not be taught separately, but in conjunction with each other. Technology plays a specific role in the acquisition of twenty-first-century skills, not only because the ubiquitous use of technology in society also requires students to be digital literate but also because technology may facilitate the acquisition of twenty-first-century skills. A second important issue, related to the role of technology in twenty-first-century curricula, refers to the potential of technology to better align curricula with students' needs. From the perspective of personalization of the curriculum, the curriculum is not bound to formal learning only but is considered a lifelong learning process, including informal learning experiences. It implies that curricula need to become more aligned with students' out-of-school digital practices.

In this section we present research on some prominent twenty-first-century competences. We discuss conceptualizations of these twenty-first-century competences and the implications for schooling in the twenty-first century.

In ▶ Chap. 3, "The Twenty-First Century Curriculum: Issues and Challenges," Erstad and Voogt introduce the concept of twenty-first-century competences. They present four meta-reviews that analyzed major conceptual frameworks that aim to provide an answer to the question of what should be taught and learned in the twenty-first century. The second part of the chapter focuses on the specific roles for new technologies to facilitate the implementation of twenty-first-century competences in the curriculum. The chapter finishes with recent research on barriers of and drivers for changing curricula in preparing students to live, learn, and work in the twenty-first-century society.

Based on the assumption that the nature of reading and writing is changing due to technological developments, Larson, Forzani, and Leu, in ▶ Chap. 4, "New Literacies: Curricular Implications," elaborate on the implications of a new literacies perspective for literacy research and practice. They argue that schools today need to prepare students who can navigate and participate online in a global society. Two specific challenges are addressed: research on the need to be able to critically evaluate online texts and research on the potential of collaborative online learning across national and cultural borders. Research about implications for instruction and school curricula is presented.

Because of the pervasive use of social media and its global implications, the concept of citizenship is changing in the twenty-first century. Law, Chow, and Fu ▶ Chap. 5, "Digital Citizenship and Social Media: A Curriculum Perspective," conceptualize digital citizenship and discuss research on the implications for citizenship education, in terms of curriculum, and the challenges for implementation.

In ▶ Chap. 6, "Students and Their Computer Literacy: Evidence and Curriculum Implications," Ainley conceptualizes computer literacy and related concepts such as ICT literacy. In his contribution he reports about large-scale assessment studies measuring computer literacy of students. Results show large differences between students. Ainley discusses how curriculum development can be informed by such assessment studies.

An important aspect of digital literacy is computational thinking. Computational thinking is rooted in computer science and considered an important twenty-first-century competence (The Royal Society 2012; Wing 2006). In ▶ Chap. 7, "Computer Science and Computational Thinking in the Curriculum: Research and Practice," Yadav, Sands, Good, and Lishinki describe how computer science education in schools has developed in a number of countries. The chapter finishes with implications for the knowledge teachers need to have to be able to teach computing, and factors that influence students' learning to program are discussed.

Finally, in ▶ Chap. 8, "Dissolving the Digital Divide: Creating Coherence in Young People's Social Ecologies of Learning and Identity Building," Kumpulainen, Mikkola, and Rajala discuss current research on the ways in which school can become a space in which students' digital practices can be aligned with teaching and learning and how this can contribute to students' identity building. They show promising findings on how digital technologies and media can be used to encourage engagement and learning across sites and contexts.

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The Twenty-First Century Curriculum: Issues and Challenges

3

Ola Erstad and Joke Voogt

Contents

Abstract

In this chapter we review key conceptual frameworks that address the challenges of society in contemporary discussions about the curriculum. The central question

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guiding the chapter is "What should be taught and learned in school curricula in the 21st century." Four meta-reviews are presented that analyze the contribution of major conceptual frameworks to this discussion. After identifying the key competences important for the twenty-first century, the focus of the chapter shifts to roles for new technologies in the curriculum. Issues that hamper the curriculum to change in directions that are considered important for teaching and learning are identified. We finalize with new perspectives on curriculum and curriculum development in the twenty-first century society.

Keywords
21st century curriculum · Key competences · Information and communication technologies · Meta-reviews · Curriculum development

The Curriculum in Times of Change

A school curriculum usually refers to the content, objectives, and organization of learning (Walker 2003). In studying a curriculum, the classical question is about what should be learned by the students and taught by the teacher and why; it is a quest for the right balance of knowledge domains that are considered important for the development of the society as well as the students (Tyler 1949). Within societies the "curriculum therefore expresses simultaneously a legacy from the past and aspirations and anxieties about the future" (Williamson 2013, p. 2). As such, it is an important instrument for change and societal development.

A curriculum expresses the educational policies, strategies, priorities, and ideas of an education system. At its narrowest sense, it specifies the goals of learning. More broadly it describes the values, content, and aims used to justify the program of an education system or an institution and all of the educational processes and learning that go on within it (Williamson 2013). Curricula are defined at various levels, the state (macro) and school/classroom (meso/micro) level being the most well known. Because of this, curriculum is not only a concern of governments but also of schools and teachers. However, increasingly due to globalization, curriculum questions are also a concern of supranational organizations such as the Organisation of Economic Co-operation and Development (OECD) and the European Union (EU) and because of the attention to individualization in the postmodern society curriculum as a means to contribute to personal development are called for as well (van den Akker 2003).

Due to the rise of the knowledge society and in particular, the developments of information and communication technologies, there is a call for redefining the role and function of the curriculum as well as a means to facilitate the enactment of the curriculum in practice (cf. Voogt et al. 2013). Surprisingly however, not much has been written about what a curriculum should be in the digital age (Williamson 2013). Rather, the main focus for the last decades, across different countries and cultures, has been on the "core curriculum content standards" (Binkley et al. 2012) and ways that curricula as political documents define educational models and practices (Alexander 2001).

The important question for this chapter is "What might be (the future of) the curriculum in the digital age?" (cf. Williamson 2013, p. 2). In this chapter we will explore this question by reviewing some of the key conceptual frameworks defining future competences that contemporary curricula may need to address and discuss some of the main issues and challenges of curriculum and curriculum implementation within broader perspectives of schooling and learning in the twenty-first century.

Rationales Guiding Curriculum Change in the Twenty-First Century

On a global scale, there are changes in labor markets and the competences needed for future working life. According to Trilling and Fadel (2009), the year 1991 marked a shift of the American economy since it was the first year when the United States spent more financial capital on infrastructures and initiatives needed for a knowledge society than on infrastructure and initiatives for an industrial society. Because of this they argue that changes are needed for the future workforce and thus the curriculum. Consequently, in many countries around the world, greater emphasis is put on education to teach socio-cognitive skills associated with knowledge work, with the production of ideas, knowledge, and information rather than material things (Williamson 2013).

Another important influence on the curriculum in the transition to the twenty-first century has been the growth of the learning sciences since the 1990s (Sawyer 2006). This field of research brought together key insights from research on "how people learn" (Bransford et al. 2000). An important point was that there seemed to be a mismatch between what research could document about the ways people learn and the ways schools and curricula were organized around core content, age-based classes, specific subject domains, and test-oriented assessment procedures. These tensions also raised issues about how prepared our education system is for the twenty-first century living and learning (Wells and Claxton 2002; Sawyer 2006; CERI 2008; Thomas and Brown 2011). Related to designing for twenty-first century learning, some key issues and principles are often emphasized based on the influence from the learning sciences. Some of the key issues are deep learning, collaborative problem-solving, personalized/adaptive learning, computational thinking, and critical thinking (Binkley et al. 2012; Pellegrino and Hilton 2012; Voogt et al. 2013).

Curricula for Twenty-First Century Learning: What Should Be Taught and Learned in School

One of the key issues in many countries around the world is about how to prepare children and young people for future societal challenges and the role of education to provide the skills and competences they need. Social transformations are rapid, while educational processes including curriculum development is slow. This tension of timescale for change is a major challenge since the needs for new skills and competencies are already existing in society, while the youngsters entering the school system now will be leaving this system and entering the labor market in 10–15 years. So how can we design for learning that is adjusted to the needs of societies in the twenty-first century? This question led to various initiatives to develop frameworks, which aimed to guide curriculum development for the twenty-first century. In many of these frameworks, the concepts of "skills," as in twenty-first century skills (Griffin et al. 2012), and "competences," as in "key competences" (EU Commission 2006) or lifelong learning competences (OECD 2005), are being used predominantly and interchangeably. The following working definition related to both skills and competences will be used in this chapter: "context-specific cognitive dispositions that are acquired by learning and needed to successfully cope with certain situations or tasks in specific domains" (Klieme et al. 2008, p. 9). Thus, the notion of competencies encompasses cognitive but also motivational, ethical, social, and behavioral components. It combines stable traits, learning outcomes (e.g., knowledge and skills), belief-value systems, habits, and other psychological features (Rychen and Salganik 2001). Conceptually, however, the field of future competences is unclear, because frameworks describing twenty-first century competences use the same concepts in different ways and sometimes use different concepts for the same phenomena.

The conceptual discussions about what skills are needed in the twenty-first century, and why, point back to OECD's work with DeSeCo (the Definition and Selection of Competencies) during the end of the 1990s and the beginning of the 2000s, which has become important for curriculum development including the role of technology during the last decade. DeSeCo's work was linked to the PISA study by the OECD in 1997. The strategy was that the PISA study would test and compare students' knowledges and skills within defined subject domains in schools across different countries, while DeSeCo would address a broader set of competences related to "What competencies do we need for a successful life and a well-functioning society?" (OECD 2005, p. 3) and "knowledge and skills related to outcomes of education in a broad sense" (Salganik et al. 1999, p. 13).

These questions are further elaborated in key curriculum documents during the 2000s. There are four key meta-reviews which are relevant to the discussion in this chapter. These meta-reviews are Dede (2010), Binkley et al. (2012), Voogt and Pareja Roblin (2012), and Kereluik et al. (2013). Together these meta-reviews provide a systematic overview of the key concepts and international initiatives within this field. All together they cover 28 different frameworks from different parts of the world, about future competence needs and curriculum changes and numerous research articles. We will give a short summary of each meta-review.

Dede (2010): Comparing Frameworks for Twenty-First Century Skills

This meta-review was initiated by the American organization "Partnership for 21st Century Skills" (P21). The aim of this meta-review was to discuss the concept "twenty-first century skills" and explore differences and similarities between different frameworks. This meta-review is based on eight frameworks, where four of them explicitly deal with twenty-first century skills, while the other four deal more with information and communication technologies specifically. The framework developed by the "Partnership for 21st Century Skills" is defined as the most detailed and broadest in scope.

Dede (2010) emphasizes collaboration, increasingly done through digital media, and the ability to rapidly filter huge amounts of incoming data, extracting information valuable for decision-making, what he describes as “contextual” capability, to be important aspects of twenty-first century skills. Based on his review, Dede (2010) defines five key competence areas. These are core subjects, twenty-first century content, learning and thinking skills, ICT literacy, and life skills. In comparison to other frameworks, Dede emphasizes that core subjects and knowledge orientation are very important, particularly in relation to the need for deep learning.

Dede (2010) discusses several important issues and challenges in the way major frameworks for twenty-first century skills around 2010 were addressed. One important challenge is that the lack of professional development is a reason why twenty-first century skills are underemphasized in contemporary schooling, which is still relevant today. Another matter he points out is the overcrowdedness of the curriculum and that a major political challenge is to articulate what to deemphasize in order to make room for students to deeply master core twenty-first century skills. As a way of summary, Dede (2010) argues that the twenty-first century skills frameworks are generally consistent with each other in terms of what should be added to the curriculum:

> The stress on what may be underemphasized, because those skills are inconsistent with current classroom culture, highlights a substantial challenge to infusing these 21st century skills frameworks into educational practice and policy. At this point in history, the primary barriers to altering curricular, pedagogical, and assessment practices are not conceptual, technical or economic, but instead psychological, political, and cultural. We now have all the means necessary to move beyond teaching 20th century knowledge in order to prepare all students for a future quite different from the immediate past. Whether society has the professional commitment and public will to actualize such a vision remains to be seen. (p. 68)

Dede makes an important contribution in his meta-review that has been followed up in later meta-studies and frameworks.

Binkley et al. (2012): Defining Twenty-First Century Skills

The background for this meta-review is the international project “Assessment and Teaching of 21st Century Skills” (ATC21S). Twelve different frameworks, both international and national, on twenty-first century skills are presented and discussed. As an introductory part Binkley et al. (2012) outline some tensions in the transformations our societies are going through, especially the impact of new technologies. This relates partly to changes in working life, with increased automatization and robotics, and partly to changes in the everyday lives of young people growing up in a rapidly changing media culture. They write:

> No longer can students look forward to middle class success in the conduct of manual labor or use of routine skills – work that can be accomplished by machines. Rather, whether a technician or a professional person, success lies in being able to communicate, share, and use information to solve complex problems, in being able to adapt and innovate in response to new demands and

> changing circumstances, in being able to marshal and expand the power of technology to create new knowledge, and in expanding human capacity and productivity. (Binkley et al. 2012, p. 17)

The important input from this meta-review is the definition of key concepts and the operationalization of what each implies for pedagogical practice. They group and define the key concepts as:

- *Ways of Thinking:* (1) Creativity and innovation; (2) critical thinking, problem-solving, decision-making; (3) learning to learn, metacognition
- *Ways of Working:* (4) Communication; (5) collaboration (teamwork)
- *Tools for Working:* (6) Information literacy; (7) ICT literacy
- *Living in the World:* (8) Citizenship (local and global); (9) life and career; (10) personal and social responsibility – including cultural awareness and competence

Each of these concepts is then linked to specific knowledge, skills, attitudes, values, and ethics, in what has been defined as the KSAVE model. Since these competences are specified and operationalized, they provide a good foundation for measuring and evaluating these competence areas related to both research and practice. Based on this model the authors argue that:

> New conceptions of educational standards and assessment . . . are a key strategy for accomplishing the necessary transformation. Such standards and assessment can both focus attention on necessary capacities and provide data to leverage and evaluate system change. Technology too serves as both a driver and lever for the transformation. (Binkley et al. 2012, p. 18)

And the assessment system as a key part of the curriculum is considered the most important element in making the transformations needed.

Voogt and Pareja Roblin (2010, 2012): A Comparative Analysis of International Frameworks for Twenty-First Century Competences – Implications for National Curriculum Policies

This meta-review of conceptual frameworks about twenty-first century skills compared underlying rationales and goals, definitions of twenty-first century competences, and the recommended strategies for the implementation and assessment of these skills in educational practice. Voogt and Pareja Roblin included five frameworks, namely, Partnership for 21st Century Skills (P21), En Gauge, Assessment and Teaching of 21st Century Skills (ATC21S), National Educational Technology Standards (NETS/ISTE), and the National Assessment of Educational Progress (NAEP) in their review. In addition, three international studies were examined to analyze how supranational organizations (key competences, EU; DeSeCo, OECD and UNESCO) deal with twenty-first century competences.

In the review 32 documents were analyzed; they are mainly working papers, international standards for ICT competences, and reports from international studies.

The aim was to identify key issues across frameworks and come up with strategies and recommendations on how to support the implementation of twenty-first century skills (Voogt and Pareja Roblin 2010). Travers and Westbury's framework (1989) of the intended, implemented, and attained curriculum was used to identify differences between frameworks (horizontal consistency) and alignment between intentions and realizations (vertical consistency). The findings indicate a large extent of alignment between the frameworks about what twenty-first century competences are and why they are important (horizontal consistency), but intentions and practice seemed still far apart, indicating lack of vertical consistency. The study led to several recommendations to support the implementation of twenty-first century competences curricula:

- To be able to design learning trajectories that support the acquisition of twenty-first century competences, operational definitions – in terms of knowledge, skills, attitudes, and values – of twenty-first century skills are needed as well as indications of what can and should be attained by students of different ages and across educational levels.
- Opportunities for learning twenty-first century competencies in core subjects need to be identified. In addition interdisciplinary themes, to be addressed within and across subjects, may help to make the connections between the twenty-first century competencies stronger. Because the interdisciplinary themes are dynamic and in continuous change, they may reflect contemporary societal issues and can foster learning that is adjusted to the needs of the current society.
- To assure learning about and learning with information and communication technologies digital literacy competencies should be embedded in the curriculum.
- Twenty-first century competences are not only learned in schools but also at the workplace and in informal learning settings outside the school. To support the learning of twenty-first century competences, strategies to closely link what is learned in and outside the school should be developed.
- Simultaneously with the development of curricula that include twenty-first century competences, strategies need to be defined that facilitate the implementation and assessment of twenty-first century competences.

Kereluik et al. (2013): What Knowledge Is of Most Worth – Teacher Knowledge for Twenty-First Century Learning

The main objective of this meta-review is to identify important areas and recommendations across different twenty-first century learning frameworks that can say something about types of knowledge that are emphasized. The authors review 15 reports, books, and articles and look at methods used in the different frameworks. In comparison to other meta-reviews, this article offers a more critical review of the literature on twenty-first century knowledge frameworks, with a particular focus on what this means for teachers and teacher educators.

The title of the article alludes to the classical curriculum question of what knowledge is of greatest worth at a time of flux and change. The authors argue that seemingly disparate frameworks converge on three types of knowledge, as necessary for the twenty-first century: foundational, meta, and humanistic. Although twenty-first century frameworks are thought to advocate new types of knowledge, little has actually changed in the new century with respect to the overall goals of education. Despite this sense of continuity, significant changes related to how technologies change all three types of knowledge need to be conveyed.

As a summary they argue that “though the manner in which we represent knowledge and act upon it may change, the core idea of what we do as educators has not” (Kereluik et al. 2013, p. 133).

Looking across these four meta-reviews, it is interesting that all emphasize three main categories of competences: foundational, meta, and life. Digital competence, as we will discuss in more detail below, is defined as key for all competencies as well as an important competence area in itself. The main competencies across different frameworks are collaboration, communication, ICT literacy, and social and/or cultural competencies including citizenship, as well as creativity, critical thinking, and problem-solving. The differences across frameworks are mainly about ways of categorizing these competencies and about the relationship between the more generic and transversal competencies and foundational knowledge and the core subjects.

A basic tension is the relation between twenty-first century competences and core knowledge domains, often related to the discussion whether “know-how” is nowadays more important than “know-what.” The argument put forward is that most knowledge that has to be learned at school – as prescribed in the curriculum – is likely to become outdated very quickly in today’s world (Williamson 2013). Young (2008) opposes to this argument and advocates the necessity to “bring knowledge back in” schools. He introduced the concept of powerful knowledge emphasizing the importance of disciplinary knowledge in the curriculum as opposed to everyday knowledge. He argues that powerful knowledge is needed to foster deep learning. At first sight these two positions seem incompatible, but McEneaney (2015), while showing how the Internet can be used for learning, offers a more subtle view when she argues that “in recognition of the existence, elaboration and wide accessibility of the Internet, curricula need to differentiate between comprehension and familiarity, with teacher-led support for querying and expert curation of virtual spaces as the surest connection to specialist communities and powerful knowledge for the next generation of learners” (p. 817).

New Technologies in the Curriculum

Moving from these broader meta-reviews of twenty-first century skills, we now turn to more specific issues of the role of new technologies in these recent curriculum developments. What is interesting is to look at the role of technology in the curriculum as learning with, through, and about new technologies. Technology is considered key for realizing twenty-first century curricula.

First, technology as a social factor is embedded in the preconditions and arguments for new curriculum developments, as mentioned earlier in this article, since our societies are becoming more and more digital in all facets of social life.

Second, technology is defined as a tool that can support the acquisition and assessment of twenty-first century skills (Voogt and Pareja Roblin 2010). What is important across the frameworks, referred to in the meta-studies above, is that technologies are not only linked to specific skills, but relate to all of them as an important skill in a technology-saturated society. For example, technological developments increase the need for skills in self-regulated learning (Kereluik et al. 2013). Also, this draws on research and development work on how different technologies can support knowledge work in different domains and strengthen different skills among students (e.g., Eseryel et al. 2014; Lee et al. 2010). In the "Assessment and Teaching of 21st Century Skills" initiative (Griffin et al. 2012), one of the main focus areas was about how technologies are linked to assessment of such skills. The argument is that technology holds the potential of changing educational assessment, especially toward formative assessment methods, and thereby supporting development of important skills for the twenty-first century. More recently there has been a movement in many countries toward including issues of "coding" and "computational thinking" as part of curricula for schools (see also ▶ Chap. 7, "Computer Science and Computational Thinking in the Curriculum: Research and Practice" by Yadav, Sands, Good, and Lishinki).

Third, a factor of growing importance for curriculum development is the growth of a new skills area presented as "digital literacy," "ICT literacy," or "digital competence." In all the reviews referred to above, this has become part of curricula in different countries. As a skill it has moved from the periphery of the curriculum, as part of media education programs and skills in programming software for computers, to the core of the skills agenda addressing twenty-first century challenges (Erstad 2013). There are different definitions of such literacies or competencies, but most of them cover abilities to handle information in critical ways, to communicate/collaborate, and to create, as shown in this definition: "To be digitally literate is to have access to a broad range of practices and cultural resources that you are able to apply to digital tools. It is the ability to make and share meaning in different modes and formats; to create, collaborate and communicate effectively and to understand how and when digital technologies can best be used to support these processes" (Hague and Payton 2010, p. 1). Efforts have also been made to develop tests that could measure this skill and how it progresses among students, on both national and international levels, like the ICILS study (see also ▶ Chap. 6, "Students and Their Computer Literacy: Evidence and Curriculum Implications" by Ainley). In addition, digital citizenship, or what some countries term as "digital bildung" (Erstad 2013), has become increasingly important linked to democratic participation in social and cultural practices of importance for oneself and others, as well as ethical aspects of technology use (see also ▶ Chap. 5, "Digital Citizenship and Social Media: A Curriculum Perspective" by Law, Chow, and Fu).

In a meta-study of digital competence initiatives (Ferrari 2012; Ferrari 2013; Ferrari et al. 2014), covering 15 frameworks, the common elements of digital competences were defined as: "the set of knowledge, skills, attitudes (thus including abilities, strategies, values and awareness) that are required when using ICT and digital media to perform tasks; solve problems; communicate; manage information; collaborate;

create and share content; and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, leisure, participation, learning, socialising, consuming, and empowerment" (Ferrari et al. 2014, p. 2). This study shows that the majority of frameworks on digital competence are based on skills development and on the ability to use a specific set of tools and/or applications. However, the recommendation is that the ability to use specific tools or applications is just one of the several competence areas that need to be developed by users in order to function in a digital environment. Further, this study concludes that:

> It should, however, be said that the identification and description of competence areas is a first step towards the development of learning objectives. As the analysis in this report shows, different frameworks do not necessarily translate the same competence area into the same learning outcomes. As a matter of fact, a huge difference can be seen between cognitive approaches and application-oriented frameworks. Several frameworks of the latter type tend to apply operational skills to each area. We therefore suggest that, apart from the competence area "technical operations", competences should not be centred on a tooloriented perspective only. (Ferrari et al. 2014, p. 13)

Fourth, in order to better serve the diversity of students, technology can also be used to tailor the curriculum to individual learners' personal learning trajectories. A tailor-made curriculum may refer to different aspects of curriculum such as place, pace, level, and goals of learning. Technology is seen as indispensable to realize such personal learning trajectories. Bray and McClaskey (2013) distinguish between three different forms of a tailor-made curriculum. Individualized learning trajectories refer to a curriculum in which learners can learn in their own pace using adaptive technology applications. Differentiated learning trajectories point to matching instruction to pupils' learning needs. With technology it is easy to provide students with scaffolds that support the way students learn (e.g., Devolder et al. 2012). Personalized learning trajectories relate to a curriculum that is tailored to students' preferences and interests. The virtual high school (Roblyer 2008) is an example as it offers students opportunities to choose their own curriculum components on top or instead of regular education. However, far-reaching forms of individualization of the curriculum may be contrary to another important function of curriculum, viz., the need to prepare all students for living and contributing to a democratic and coherent society (▶ Chap. 5, "Digital Citizenship and Social Media: A Curriculum Perspective" by Law et al. in this Handbook).

Implementation Issues and Change Forces

Only a few frameworks explicitly deal with more practical issues related to implementation and assessment. Those frameworks that do address such issues refer to three critical factors in the implementation of twenty-first century skills: (1) the integration of the skills in the curriculum, (2) the need for professional development, and (3) the involvement of stakeholders from various sectors. In addition, the adoption of new assessment models in line with the cross-curricular and complex nature of twenty-first century skills is regarded as crucial to ensure the implementation of these skills.

A critical factor is how curricula get implemented within education systems and the implications they have on educational practices. In their meta-review, Voogt and Pareja Roblin (2012) emphasize that "most frameworks recommend integrating 21st century competences across the curriculum due to its complex and cross-disciplinary nature" (2012, p. 310). The point is that all frameworks demand changes in the curriculum, both in ways of restructuring the curriculum and new teaching methods to provide for the growth of such skills and assessment procedures.

Law (2009) found, in data from the international Second Information Technology in Education Study (SITES), that although many teachers reported to have curriculum goals that were in favor of twenty-first century competences, they did not apply them in classroom practice. This finding aligns with findings of Voogt and Pelgrum (2005) who studied international case studies of innovative pedagogical practices using technology in schools and found that only a minority of schools had adopted a curriculum that facilitated students' acquisition of twenty-first century competences. These schools had restructured their school to realize the curriculum. Using technology was essential in the new structure and had become a routine for teachers and students. As we know from research on innovative practices using technologies in schools, there are challenges in most countries of scaling up from single schools and classes to whole education systems (Kozma 2003; Dede et al. 2005). The introduction of frameworks on twenty-first century skills and key competences might help to facilitate scaling of twenty-first learning in schools. Curricula that are developed now are more specific in the way technologies are embedded both in general ways as preconditions and levers for change and as new conditions for knowledge work among students and teachers. The challenges of implementing new frameworks and curricula in educational practices include:

- Access to and availability of different technologies in schools, which is still lacking in many countries
- Way to prevent curriculum overload to be able to give more space to the learning of twenty-first century competencies (Voogt et al. 2017)
- Ways in which the new frameworks are presented as new sets of skills, while many of them are also known from former curricula but redefined in the context of twenty-first century challenges (Dede 2010; Kereluik et al. 2013)

The second issue concerns the role of teachers and their professional development. The key role of teachers in the implementation of curriculum is widely documented in research (Fullan 2007; Liebermann and Pointer Mace 2008). In many ways the twenty-first century competences pose pedagogical challenges for teachers – in their own abilities in these skills, in using various methods with students, understandings of subject content and interdisciplinary content orientation develop technology-enhanced learning environments and ways of using a variety of assessment tools. There are similar challenges for teacher education institutions in developing professionalism around such skills and competences for pre-service teachers (Voogt and Pareja Roblin 2012).

The third issue is related to the involvement of stakeholders in the decision-making process of curricula for our current societies. This points to the complexity of the curriculum design process, or as Karseth and Sivesind (2010) state “curriculum is about meaning-making and negotiation among different actors in different positions” (p. 114). Stakeholders from the public, educational, and private sectors want to have a say about the curriculum and exert their influence on what is being taught in schools. In order to monitor the process of meaning making and negotiation, Davis, Eickelmann and Zaka (2013) advocate an ecological approach to guide change processes, including curriculum, in education systems in which actors in- and outside the system are recognized and codesign. Increasingly technology plays its role in the process of meaning making and negotiation about new curricula, either planned, with the intention to share, be transparent, and offer ample opportunities for active involvement (Nieveen et al. 2014), or unplanned in which proponents and opponents of change actively discuss and influence the decision-making process through applications such as Twitter (Supovitz et al. 2015).

Several studies have shown that assessment is still one of the weakest points in many country’s efforts to integrate twenty-first century competences in the school curricula (Ananiadou and Claro 2009; Gordon et al. 2009). For example, Gordon et al. (2009) identified four different approaches to the assessment of key competences across 27 Member States from the European Union: (a) assessment of cross-curricular competences explicitly, (b) assessment of cross-curricular competences implicitly, (c) assessment of subject-specific competences, and (d) assessment of knowledge rather than competence. While the first two approaches show some progress in the assessment of twenty-first century competences, the other two were more common across most countries participating in the study, revealing that the need to assess these competences is not yet fully acknowledged in many countries (Voogt and Pareja Roblin 2012).

Toward Twenty-First Century Curricula: Perspectives

In a recent project, called “KeyCoNet,” the implementation of the European eight key competences was studied. The “Key Competence Network on School Education” (KeyCoNet 2012–2014) (Ola Erstad was part of the research team of this project), organized by European Schoolnet, was a European policy network focusing on identifying and analyzing initiatives on the implementation of key competences in primary and secondary school education. It was a network of more than 100 members from 30 countries including Ministries of Education/related agencies, universities/research institutes, European organizations, and practice related partners. The aim was “to analyse and map emergent strategies in implementing key competences in education across Europe, and to develop recommendations to strengthen policy and practice in different country contexts” (Looney and Michel 2014, p. 4). This was done by different exercises such as case studies from different countries, transversal analysis of the KeyCoNet case studies, mapping of initiatives, several literature reviews, country overviews, and peer learning visit reports.

The conclusions from this project indicate that on the policy level "no country has made a complete shift toward competence-based education" (Looney and Michel 2014, p. 14) but that many countries had made significant progress. The strategies used were on different levels and targeting different factors for change such as legal frameworks for key competences, elaborating and operationalizing competence-based curricular frameworks, new and innovative partnerships, dedicated funding, capacity building, and monitoring and evaluation of new initiatives (Looney and Michel 2014). Further, the principles for effective school implementation and practice that emerged from the KeyCoNet case studies included a central focus on teaching, learning and assessment, effective communication with stakeholders, engagement with the broader community, school plans that incorporate key competences, and evaluation of progress. The theme of collaboration and engagement runs throughout these principles.

There are large differences between countries concerning the implementation of new frameworks within twenty-first century curricula and practices in schools. Concerning digital competencies specifically, there are a few countries where this has been addressed explicitly in national curricula. For example, in 2006, Norway was among the first countries in the world to define digital skills/competencies as one of five key competences traversing all subjects and levels of compulsory schooling (the other four being reading, writing, numeracy, and oral skills/competencies). This has been implemented in all schools through strategies and plans following up on the curriculum. In 2016 this was followed up with national strategies on the future of Norwegian schools emphasizing deep learning and a few competencies following different international frameworks on twenty-first century skills and key competencies. Similar developments have recently been implemented in Finland, where the European framework of key competencies has been the foundation of a new national curriculum. Of special interest for our discussion in this article is the emphasis on multiliteracies and coding as traversal skills/competencies that all Finnish students have to engage with, as related to technological developments and what is defined as new competences emphasized in the national curriculum.

Currently the OECD2030 Future of Education and Skills study is working on a follow-up of DeSeCo's work (see http://www.oecd.org/edu/school/education-2030.htm), which involves more than 20 countries. The Learning Compass that is being developed has as its core mission that learners need to "Being able to navigate in time and social space, to manage their lives in meaningful and responsible ways by influencing their living and working conditions" (see link above). In addition data are collected with the aim to analyze how countries cope in their curricula with the challenges of twenty-first century societies. The results of the analysis are expected by the end of 2018.

As a way of concluding about the perspectives on new curricula on twenty-first century skills and competencies, the few studies that have been done show that many countries are in the process of changing their curricula to adapt to twenty-first century challenges. However, countries are nevertheless at very different stages in terms of integrating key competences and skills in curricula, engaging stakeholders, and in investing in teacher and school capacity.

The Future of the Curriculum in the Digital Age

In this chapter we have presented some perspectives on the curriculum in times of rapid change addressing twenty-first century challenges. On a fundamental level, such evolving perspectives on education and the curriculum in the twenty-first century raise questions about the models we have been using and whether they are appropriate to deal with the societal changes that we are experiencing. In order to explore this further we need to deal with questions and issues like:

- How the integration of twenty-first century skills/competences in the curriculum changes the what and the how of what is being taught at schools?
- What the implementation of twenty-first century skills demands from teachers, students, administrators, and educational leaders?
- How different educational contexts – beyond the formal education system – support the acquisition of twenty-first century skills?
- How ICT can contribute to bridge formal and informal educational contexts?
- What specific types of support teachers and schools need to facilitate the acquisition of twenty-first century skills?
- To what extent are teachers and students prepared to adopt the new forms of assessments demanded by twenty-first century skills?
- We propose that these questions should be addressed in a public debate about the implementation of twenty-first century skills.

It is important to remember that the novelty of twenty-first century competences is questionable. Competences such as problem-solving and critical thinking have always been associated with key objectives of education (Voogt and Pareja Roblin 2012: 316). This point might actually help in working with teachers and teacher education institutions in convincing that this is not a matter of replacing the old with something completely new. Teachers have for a long time been dealing with several of the key competencies mentioned in recent frameworks. What is new is the way they are contextualized and emphasized. For example, by stating that the way curricula have developed in most countries they have become overcrowded with content in all subject areas. Ways of deemphasizing and taking out content from the curriculum is a major political challenge. The same goes for changes in the assessment system that has to be done in order to assess these competences and skills that are not measurable by high-stakes tests the same way as regular cognitive skills of memorization and reproduction of content knowledge are. These aspects to the education system are important to reevaluate in order to make room for students to deeply master core twenty-first century understandings and performances. The demands are also related to the professional development of teachers to provide for the development of such competences in technology-enhanced learning environments.

Still, there are important issues and challenges in these developments that make us reflect on more fundamental transformations in moving from the twentieth to twenty-first centuries, especially when exploring the role of technological developments. As Dede (2010) has pointed out, “current approaches to using technology in schooling largely reflect applying information and communication technologies as a means of increasing the effectiveness of traditional, 20th century instructional approaches" (pp. 8–9). The disruptive innovations that have happened in different sectors of society (see http://www.claytonchristensen.com/key-concepts/) have not manifested itself within the regular school systems, as manifested in the disruptive expectations with Massive Open Online Courses on higher education. This is still a major challenge in the ways ICT is implemented and used in most schools around the world.

Several of the recommendations stated in existing frameworks on twenty-first century competences express some of the decisions that need to be done, like: "defining goals and standards in national documents regulating the curriculum, embracing a powerful vision, encouraging collaboration between different sectors, building on already existing work and focusing on what is 'do-able', ensuring equitable access to education in present and future society, stimulating teacher collaboration, creating learning environments that enhance competence development, and aligning assessment methods and goals" (Voogt and Pareja Roblin 2012, p. 312).

Further, related to curriculum development, we might need to develop new metaphors to guide us in moving toward school systems framed by twenty-first century competencies. In his writing on this, Williamson (2013) has developed what he terms "centrifugal schooling" (2013, p. 7). By this he means:

> Centrifugal schooling expresses a vision of the future of education and learning that is decentered, distributed, and dispersed rather than narrowly centered, channeled, and canalized. . .. Recast as a response to these technological changes, the kind of prototypical curriculum of the future associated with centrifugal models of schooling may be imagined as a more "open source" process rather than a fixed product, as embodied in the "wiki" format of open authorship, collective editing, and collaborative production. Crudely caricatured, the traditional centered curriculum was a curriculum based on a standardized mass-production model of "reading" that positioned teachers as broadcasters and learners as receivers, as embodied by school textbooks. In comparison, the decentered curriculum is a post-standardized, mass-customizable "read-and-write" curriculum that repositions teachers and learners as peer-to-peer producers, participative authors, and active creators of curriculum content, processes, and outcomes in a distributed meshwork of joined-up learning. (pp. 7–8)

These metaphors of the curriculum as more open, network-based, and process-oriented are interesting as a way of creating new models directly adjusted to the needs of learning in the twenty-first century.

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New Literacies: Curricular Implications

4

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Contents

Abstract

This chapter explores the implications of a new literacies perspective for literacy research and practice, focusing on two specific challenges. First, it explores the challenges posed by the increased need to critically evaluate online information. With a diverse set of voices online, the absence of traditional gatekeepers requires an especially sophisticated level of critical evaluation by every reader and thus challenges each of us to read and think more critically. The new chapter addresses perspectives on critical evaluation in online environments, the importance of critically evaluating online texts, and the instructional implications of recent research in this area. Second, it explores challenges posed by the effective use

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of collaborative online learning projects that cross national and cultural borders. Today, schools are challenged to prepare students who can navigate and participate in a global society. The chapter addresses recent initiatives in online learning, the need for new literacies for successful global communication and collaboration, and the instructional implications of global collaborations. Developing critical users of information who can also interact with others on a global scale requires a focused commitment of schools to ensure that online information is integrated into the literacy and learning curriculum in effective ways.

Keywords
New literacies · Critical evaluation · Credibility · Collaborative online learning · Global learning

New Literacies: Curricular Implications

Today, new information and communication technologies continuously appear online, creating additional opportunities and challenges for the education of students in primary and secondary grades. In recent years, one response to these developments has been the "new literacies movement" with its focus on how the nature of reading and writing is changing due to technological developments and how we might integrate these changes into the curriculum in effective ways. This chapter will explore the implications of a new literacies perspective for a better understanding of literacy as well as literacy research and practice. It will begin with a brief theoretical definition of new literacies. It will then focus on two of the challenges that have become especially important to literacy and learning with online information: the critical evaluation of information and the effective use of collaborative online learning projects that cross national and cultural borders.

New Literacies and the Challenge of Change

We have entered a period in which the nature of literacy has become deictic (Leu 2000) as the Internet makes rapid, online distribution of new technologies for literacy possible. New technologies add additional dimension to literacy, requiring additional literacy practices, skills, strategies, and dispositions to fully benefit from online information (Lankshear and Knobel 2011). Moreover, these additional social practices, skills, strategies, and dispositions themselves change and initiate the development of additional online technologies for literacy. In short, continual change now defines literacy.

Continual change in the nature of literacy presents an especially problematic conundrum for research and theory. How do we study literacy when it continually changes? By the time we have a sufficient body of research in any set of new literacies, the nature of the technology on which the research is based has likely changed, sometimes in subtle and sometimes in important ways. In short, the speed of change in technologies, and on the literacy practices they engender, is often faster than we can keep up through careful research.

To respond to the conduct of research during a time when literacy rapidly changes, a dual-level theory of new literacies has been proposed to include both lowercase new literacies and uppercase New Literacies (Leu et al. 2013). Lowercase theories explore a specific Internet technology, such as text messaging, or a focused disciplinary base, such as the semiotics of multimodality in online media or gaming. As such, research based on lowercase theories is able to stay more closely in touch with rapid changes taking place in specific technologies. Common findings across multiple lines of lowercase research may then be integrated into a broader, uppercase theory of New Literacies. This uppercase theory is likely to be more stable since it only includes those elements common across the landscape of many, continuously changing technologies.

Reciprocity defines the relationship between the two levels. The greater stability of New Literacies theory provides theoretical direction to inform the design of studies in rapidly changing contexts at lowercase levels, while the greater sensitivity to change at multiple, lowercase levels helps to identify those common, and more stable, elements for the uppercase level. One important aspect of all of these new literacies is that they enable us to read, communicate, and learn with the nearly unlimited information that is now available online.

One of these lowercase new literacies is used to frame this chapter, the new literacies of online research and comprehension. The new literacies of online research and comprehension seek to describe what happens when we read online to learn (Leu et al. 2013). It defines online reading as a process of problem-based inquiry using information on the Internet. It includes the skills, strategies, dispositions, and social practices that take place as we read online information to learn. During online research and comprehension, readers construct texts, meaning, and knowledge while engaged in several online reading practices: reading to identify important problems, reading to locate online information, reading to critically evaluate online information, reading to synthesize online information, and reading and writing to communicate online information. Online research and comprehension is not limited to lengthy and formal research projects. It also includes shorter tasks when one needs to know the answer to a question such as "When was Abraham Lincoln born?" or "What is the easiest way to get to central London from Heathrow?" Information queries, both large and small, initiate online research and require the use of new technologies to read, comprehend, and learn.

The ability to read and learn with online information is essential for full participation in today's society (Organisation for Economic Co-operation and Development [OECD] 2011), but our students are not especially skilled at reading and learning from complex, online information (Kuiper and Volman 2008). Although today's students live in an online world and are developing skills in gaming, social networking, video creation, and texting, research is showing how limited students' skills are with online reading, especially with critically evaluating online information (e.g., Forzani 2015; Walraven et al. 2008). Many students find it difficult to judge the accuracy, reliability, and bias of information that they encounter during online research (Kiili et al. 2008; Kuiper and Volman 2008; Leu et al. 2015). In fact, adolescents overgeneralize their ability to read and evaluate online information effectively, a perception informed by their ability to engage successfully with online social networking, texting, and video games (Kuiper and Volman 2008).

Online reading also presents special challenges in relation to income inequality, according to data from the United States. A separate achievement gap appears to exist for online reading, independent of the offline reading achievement gap (Leu et al. 2015). Yet, current assessments only measure offline reading ability. Since reading now takes place in both offline and online contexts, the reading achievement gap is likely to be greater than we currently recognize. If we are to address an achievement gap that is larger than national assessments suggest, it becomes essential to develop interventions that support proficiency with online reading so that we can provide teachers with the effective new tools they require.

There is also another important challenge. As online experiences push the world closer together, we must begin to consider how we can take advantage of this opportunity to prepare youth to learn from others around the world and benefit from the advantages that diversity provides. Online learning projects, between students and classrooms in different parts of the world, enable students to develop a more complete understanding of the differences that define our world as well as ways those differences may be used to enrich literacy and learning. Increasing students' global awareness, developing a richer understanding of global citizenship, and improving students' ability to work collaboratively with others, across national and cultural contexts, are beginning to become important new curricular objectives.

These issues are especially important because we have just reached a tipping point for literacy. As we write this chapter, 50% of the world's population has Internet access (Internet World Stats: Usage and Population Statistics 2017), a figure that continues to rapidly grow. This singular development carries profound implications for literacy and the literacy curriculum. If the Internet adoption rate continues to increase at the current rate, all, or nearly all, of the world's population will have access to online information within 10 years (UNESCO 2014). Thus, children who are just beginning formal schooling today will enter a ubiquitous world of online information when they graduate from secondary school. This makes it essential that they be prepared, at an early age, for online reading.

In every nation, the literacy and learning curriculum will have to radically change if we are to accomplish this preparation (Kervin et al. in press). We argue that two lowercase areas are particularly important: the critical evaluation of online information and the effective use of collaborative online projects that cross national and cultural borders. This chapter will explore both of these areas. Developing a better understanding of each will help us to respond to the challenges of the changing landscape of literacy in primary and secondary classrooms today.

The Critical Evaluation of Online Information

The first challenge we face with greater access to the Internet is developing the skills needed to evaluate online information. Reading online information requires an even greater degree of scrutiny, as recent events regarding "fake news" suggest (see Stanford History Education Group 2016). It is particularly essential, therefore, that students become skilled at evaluating online information to become better online readers. Students need these skills for personal and professional knowledge, decision-making, and problem-solving both while they are in school and throughout their lives. Without them, we risk students making decisions based on misinformation. This can have significant negative consequences both for individuals and for society.

Perspectives on critical evaluation in an online context. Critical thinking has long been an area of interest for teaching and learning. Critical thinking, for example, was a central aspect of Socrates' instructional practice. In the "Socratic method," a teacher questions a student to aid the student in deeply questioning the credibility of information, even when the information comes from an "authority." Students are taught to identify underlying assumptions before accepting information as true. Later on, Aristotle also was interested in credibility. Metzger and Flanagin (2013) point out that Aristotle's writings on rhetoric addressed three aspects of credibility: ethos (appealing to an audience using the character of the speaker), pathos (appealing to an audience using emotion), and logos (appealing to an audience using logic or reason). The author's qualifications, the author's emotions and biases, and the logic of an author's argument are still the essential tools we use to investigate information credibility today.

Recently, policymakers have focused attention on teaching students to approach text critically (see, e.g., Australian Curriculum, Assessment and Reporting Authority n.d.), emphasizing critical thinking skills above simply learning facts. While there is some debate over whether critical thinking requires additional skills in an online environment or whether it requires the same skills used with greater frequency (Metzger and Flanagin 2013), the importance of critical thinking skills is heightened in an online environment, where credibility varies greatly.

Judd et al. (2006) define credibility as the expertise and trustworthiness of the source of information. This includes the accuracy, or reliability, of the information (Kiili et al. 2008). The more credible a source is, the more likely it is to contain accurate information. Here, we define the critical evaluation of online information as the process of evaluating the accuracy of online information. This includes evaluating two main aspects of credibility: knowledge claim credibility and source credibility (Forzani 2016). Knowledge claim credibility refers to the credibility of the information itself, including the logic of the argument and the quality of the evidence used to support that argument. Source credibility refers to the credibility of the source of the information, such as author or publisher, and includes questioning and assessing authors' biases, assumptions, and points of view. Highly effective evaluation involves evaluating both aspects of credibility in order to fully evaluate the accuracy of information.

The importance and difficulty of critical evaluation in an online environment. The importance of critically evaluating texts is especially relevant in an online environment, where there are few vetting processes compared to an offline environment. In an offline environment, texts typically undergo scrutiny from editors, publishers, and even sellers before arriving in readers' hands. In an online environment, however, there are few checks such as these. Moreover, there are few uniform standards for publishing in an online environment (Metzger and Flanagin 2013), and many sources are commercially biased (Flanagin and Metzger 2010). This results in information of varying degrees of credibility. Thus, critical thinking skills are especially important in an online environment, where effective research hinges on a reader's ability to evaluate information accuracy and reliability (Goldman et al. 2012).

Unfortunately, today's youth are particularly challenged by the changes to literacy with respect to the critical evaluation of online information. In a recent study, fewer than 4% of students successfully completed all four tasks required to read and evaluate the source reliability of a single website (Forzani 2015). Another study showed that seventh-grade students performed successfully on only half of the items required to read and complete an online research task (Leu et al. 2015). A report from the Stanford History Education Group (2016) revealed that most middle school students in a study in the United States did not know when news was "fake" and that 82% of them could not tell the difference in an advertisement labeled with the words "sponsored content" and a legitimate news story. Finally, in a study by the eSeek Project at the University of Jyväskylä in Finland, fewer than 20% of 12- and 13-year-olds could recognize bias at a commercial website on energy drinks (Kiili et al. 2017).

Many students do not question the accuracy of online information (Zhang 2013) and do not critically evaluate websites when reading online (Kiili et al. 2008). When students do attempt to employ online critical evaluation skills, they often fail to do so effectively. Many students tend to use surface level cues alone to help them determine the accuracy of information or have misconceptions about how to evaluate sources (Coiro et al. 2015). Eastin et al. (2006), for example, found that third, fourth, and fifth graders were not skilled at judging the reliability of online sources and often based their evaluations on superficial or irrelevant cues. Students in this study viewed websites with more graphics as more credible than websites with fewer graphics. Moreover, younger adolescents often overestimate their abilities to critically evaluate online information (Flanagin and Metzger 2010). This may mean that students are less aware of the skills they need to obtain in order to read online effectively and thus may be less likely to acquire these skills.

Online critical evaluation in science and civics. Arguably, two of the most important areas today for the use of critical evaluation skills online are in the disciplines of science and civics. Science has become a priority for many nations (OECD 2016), and much scientific information is found online. It is also increasingly important for students to understand basic scientific concepts, so they can acquire information useful for a wide variety of personal issues, such as researching health issues on the Internet (Stadtler and Bromme 2014) or gathering information about science-related controversies that impact their lives (Zeidler 2009). Students also need to understand basic scientific concepts if they plan to pursue a career in science.

Critical evaluation is a particularly important skill for learning during online inquiry in science (Goldman et al. 2012; Wiley et al. 2009). Scientific information is often inconsistent and conflicting (Longino 2002), a problem that is compounded by the Internet (Stadtler and Bromme 2014). Thus, in an online environment, the ability to evaluate the credibility of scientific information is even more important than in an offline environment. Without the ability to evaluate the credibility of information, students may develop misconceptions about science (Wiley et al. 2009), which may make it difficult for students to develop accurate understanding later on.

Several studies of secondary and college students have found that students are not especially skilled at critically evaluating online information in science, specifically. Halverson et al. (2010) found that students mostly used websites that were easily accessible and website evaluation criteria that were focused on superficial features rather than on website content. The researchers concluded that students did not engage in much evaluation of websites and, when they did, were not especially skilled at evaluating. Even when students know about evaluation strategies, they may not use this knowledge in practice (Hogan and Vernhagen 2012). Research on undergraduate students reading information in science has found that while students may be aware of source information, they may not use this when evaluating credibility (Strømsø et al. 2013).

In addition to understanding science, understanding civics is also a highly important educational area for many nations (see, e.g., U.S. Department of Education 2012). Students need to be able to understand social and political issues that affect them on personal, societal, and professional levels in order to be engaged citizens. Moreover, when people fail to evaluate the credibility of online information, it is easy for disinformation to spread, jeopardizing democracy (Stanford History Education Group 2016). In an online environment, readers are particularly susceptible to finding misleading information since there is a great deal of bias involved in reporting political issues and since these issues are often reported in news media, some of the most ubiquitous online information sources.

Instructional implications of research in online critical evaluation. The growing body of research in online critical evaluation has demonstrated the importance of online critical evaluation skills for comprehending information across multiple texts, as during Internet research (Braten et al. 2009). Unfortunately, many students are not especially competent in this area (Forzani 2016; Goldman et al. 2012; Stanford History Education Group 2016), highlighting the need for instruction aimed at teaching students effective critical evaluation skills. Importantly, students of varying ages lack the ability to judge the relevancy and credibility of search results (Brand-Gruwel and Gerjets 2008). This is problematic, since the ability to do so is a gatekeeping skill for evaluating the credibility of online texts, as students must first navigate to online texts by selecting them from a list of search results. Thus, instruction should begin with teaching students how to effectively evaluate the potential relevancy and credibility of search results. However, it is important to keep in mind that students may learn evaluation strategies best when they have the opportunity to engage with these skills within the context of a larger research task (Walraven et al. 2008).

Research also has begun to identify particular areas of weakness for students on which teachers should focus during instruction. Students need to think beyond the "face" of the text. Rather than merely looking at surface level clues, such as the quantity of information (Wallace et al. 2000) or the design of a website, students need to investigate the quality of the information itself, including the logic of arguments and the quality of evidence (Forzani 2016), as well as the trustworthiness and credibility of the source of the information (Goldman et al. 2012). In doing so, it is important for students to assess multiple aspects of a website rather than using just one piece of evidence to evaluate information credibility (Coiro et al. 2015).

Lessons on critically evaluating information can be an integrated part of the science and social studies curricula, grounded in the needs of the discipline. Different disciplines, including science and civics, have different needs and values (Shanahan and Shanahan 2008). As a result, different disciplines use critical evaluation skills in different ways (Shanahan et al. 2011). Students need to learn ways of investigating credibility specifically for a given discipline and within an online context. For example, evaluating a news article reporting on federal laws and policies involves somewhat different skills and strategies than does evaluating an article reporting on a scientific study. Moreover, evaluating the credibility of an article reporting on federal laws and policies in an online environment is likely to include additional skills compared to evaluating an article found in an offline environment. Teaching students ways of evaluating information credibility within different disciplines and within online contexts can provide students with an arsenal of tools for engaging effectively with information for varying disciplinary purposes.

Finally, research indicates that students with different individual characteristics may perform differently when critically evaluating online information (Forzani 2016). It is especially important, therefore, that educators consider the ways in which certain teaching practices may be more or less effective with different ages and types of learners. For example, young children may need particular support evaluating online text, since online text may be above their reading ability. Teaching with students' strengths and weaknesses in mind can help all students gain the skills they need to make decisions in their personal lives and be informed citizens.

Global, Online Collaborative Learning

New technologies and increased access to the Internet bring a second challenge to the curriculum. Today's students face an unprecedented future in which they will navigate a global society. In a "flat" world (Friedman 2007), economies become increasingly interdependent, and global challenges – including migration, poverty, and natural disasters – grow in complexity. Regardless of future professions or place of residence, our students will interact and coexist with people of diverse cultures, faiths, and perspectives. For example, 61 million immigrants and their US-born minor children (Camarota and Zeigler 2016) currently reside in the United States, and over one-fifth of the US population speak a language different than English at home (National Center for Education Statistics [NCES] 2016). Worldwide, the number of international migrants reached an all-time high in 2015, with 244 million people living in a country other than their birth nation (International Organization for Migration [IOM] 2016). Current migration trends indicate a drastic increase in the number of refugees, asylum seekers, and internally displaced people. In fact, by mid-2015, the world housed over 15 million refugees, the highest levels of forced global displacement since World War II (IOM 2016).

Instructional outcomes and initiatives in global, online learning. Undoubtedly, we can no longer debate if global awareness is essential. We do, however, need to carefully consider how to prepare students to thrive in a malleable world that will continue to evolve. To successfully live, flourish, and compete in an interconnected world, students must develop aptitudes beyond reading, writing, and arithmetic and learn how to embrace tolerance, value cultural and linguistic differences, and communicate across cultures and languages (Mansilla and Jackson 2014). Raising globally aware students who can thrive in an interconnected world is a common component reflected in current initiatives and curricular outcomes. For example, the Partnership for 21st Century Learning (P21) argues that high school graduates must be "prepared for twenty-first century citizenship" and should "develop the attitudes, skills, and knowledge to understand and participate in a globally connected world" (2014, p. 1). To successfully navigate a global society, students will need skills and competencies required to cope with disparate values and attitudes, along with a deluge of new scientific and technological knowledge. In fact, to help define requisites for global competence, OECD (2016) recently proposed adding a global competence assessment to the 2018 Program for International Student Assessment, commonly known as the PISA. The proposed assessment of global competence would provide an essential overview of education systems' progress in cultivating students' global competence for an interconnected world.

Online communication tools (e.g., blogs, message boards, social media apps, Skype, Google Classroom) provide a viable, and often free, gateway for global collective dialogue and collaboration. Hence, curricular objectives relating to technology and digital competencies are also relevant. The International Society for Technology in Education (ISTE 2016) recently revised their student standards to promote "future-ready learning" where students assume roles as global collaborators who "use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally" (n.p.). Similarly, the National Council of Teachers of English (NCTE 2008/2013) emphasizes that to become successful members in a global society, students need to be fluent users of technology tools, "build intentional cross-cultural connections and relationships with others so to pose and solve problems collaboratively and strengthen independent thought" and "design and share information for global communities to meet a variety of purposes." (n.p.).

Global, online learning demands new literacies. As traditional literacy practices are combined with new literacies of the Internet and other ICTs in complex and sophisticated ways, students need supplementary skills, strategies, dispositions, and social practices to fully benefit from the affordances of these technologies (Dalton and Proctor 2008; Leu et al. 2013). In the past, teachers thought of the Internet as something students learned *from*; today, forward-thinking teachers explore how students can learn *with* the Internet. Lindsay (2016/2017) explains that since its inception, global online collaboration has evolved from a simple exchange of information (Global Collaboration 1.0) to co-creation of artifacts and shared knowledge. Twenty years ago, as the possibilities of the Internet emerged, Global Collaboration 1.0 began as forward-thinking educators explored possibilities for collaboration. Using low-level technology (e.g., e-mail) tools to primarily exchange information, interaction between students were limited. With advanced technology tools and enhanced Internet availability and speeds, educators engage students in Global Collaboration 2.0, which involves both information and artifact exchange using common Web 2.0 tools. Today, as both connectivity and communication tools improve, the focus shifts to student-centered learning in Global Collaboration 3.0. Here, students exchange information and co-create multimedia-rich products. They use a wide array of social media tools to communicate and collaborate with peers, educators, and experts from around the world (Lindsay 2016).

Given that online experiences are already pushing the world closer together, we must focus on providing students connected learning opportunities across space, time, and diverse cultures. Connected learning occurs when teachers and students use new literacies and common online tools that afford them abilities to connect, collaborate, and communicate on a global scale (Lindsay 2016). Digital tools offer students access to a wealth of information, along with the ability to be active participants and creators in self-directed inquiry and socially constructed learning (Dwyer and Larson 2014; Leu et al. 2013). Connected learning projects may cultivate students' understanding of both differences and commonalities that define our world while building critical literacy skills through the exposure of diverse (and often contradictory) perspectives and ideas. In early 2017, there were over 1.86 billion monthly active Facebook users worldwide; the *like* and *share* buttons were viewed across almost ten million websites daily (Facebook 2017). As youths are constantly bombarded with both facts and fiction from around the world, it is no longer enough to critically evaluate information from a local, or even national, perspective.

As discussed earlier in this chapter, students are particularly susceptible to encountering misleading or biased information in online environments. They need to understand global viewpoints in order to make sense of online information and negotiate shared meaning through cultural differences, rather than allowing online media to propagate divisions and dislikes (Kist 2013). More than ever, students need the ability to select sources that provide accurate information and, in turn, create and contribute to those channels (Richardson 2016/2017). Farmer (2015) argues that ICTs have "collapsed time and space" as people have more access to global knowledge, can exchange ideas instantly and spontaneously, and can respond to one another more easily than ever before (p. 6). In other words, while recent digital advancements have opened doors for global collaborations and communications, technology prowess alone is not enough. For ICTs to become effective in the context of global learning, global literacy is critical. Students need to effortlessly toggle between local and global perspectives while having a firm grasp of global competencies, including the capacity to communicate ideas effectively with diverse audiences as they bridge linguistic and cultural barriers and recognize and communicate multiple viewpoints (Mansilla and Jackson 2014; Tolisano 2014).

Instructional implications of global collaborations. Raising global-ready students is unarguably a conspicuous goal. Fortunately, new mobile technologies and social networking tools offer teachers and students broadened opportunities to engage in authentic, borderless learning experiences in which students can learn *with* the world, rather than *about* the world (Lindsay 2016/2017). Global learning should not be viewed as an additional subject to be taught, but rather as an integrated approach to pedagogy where students encounter daily opportunities to engage in global collaborations, consider diverse perspectives, and inquire about the world (Dwyer 2016). Advancements in digital tools and Internet speed afford new ways of constructing, sharing, and accessing ideas and content with others across the globe (Knobel and Lankshear 2014). The creation of ideas and products call for habitual coordination, contribution, and shared conception, within the context of shared ownership of co-created outcomes (Laurillard 2012). Hence, moving toward online collaborations means recognizing changes in social practices and learning strategies, along with an increased need for teachers who can orchestrate global learning opportunities and assist students who need support in developing social learning abilities in online environments (Larson 2009; Leu et al. 2013). Many educators use the Internet to globalize their classroom through collaborations among students across the world. Often, these collaborations involve reading common texts and using digital tools to communicate and socially construct knowledge (Kist 2013; Larson and Dwyer 2015). For example, when teachers move traditional literature discussions, or book clubs, into online learning spaces, opportunities for global collaboration occur.

Recently, sixth-grade students in the United States and Ireland engaged in online literature circles while reading award-winning literature for young adults (Dwyer and Larson 2014; Larson and Dwyer 2015). The two groups wrote blog posts in response to readings, created discussion prompts, and engaged in online conversations about the books. Findings from these collaborations suggested socially constructed understanding of the texts, in addition to heightened levels of global awareness and diverse perspectives. While the sixth graders engaged in literature discussions, they interminably constructed community identity and affinity space (Alvermann et al. 2012). In a current study, preservice teachers in the United States engage in online book discussions with ninth-grade students in Sweden who are studying English as a foreign language. In addition to reading and responding to quality literature, the Swedish students improve verbal and written communication skills in English. The American preservice teachers learn how to instruct students whose native language is not English while gaining important experience in online teaching. Both groups cultivate global awareness and learn how to use digital tools to communicate and socially construct knowledge (Larson and Brown 2017). Configurations of online global literature circles vary, as do the digital tools used to collaborate. To form a suitable partnership, teachers can use services such as ePals (www.epals.com), a global community where teachers can form connections from all over the world. Alternatively, the *Global Read Aloud* project (https://theglobalreadaloud.com) has engaged over a million students in a worldwide book club since its inception in 2010. According to Pernille Ripp (n.d.), teacher and project founder, "…we pick a book to read aloud to our students during a set 6-week period and during that time we try to make as many global connections as possible" (n.p.). Participants use a wide variety of tools, including Skype, Edmodo, and Twitter, to engage in a global reading experience with others from around the world. Each year, there are several book choices, allowing teachers to match literature to students' needs and abilities. Furthermore, using social media or audio/video apps, students can "meet" authors or experts in the field that can help them make sense of texts and gain multiple perspectives (Kist 2013; Larson and Brown 2017).

There is no doubt that today's students are exposed to rich cultural and linguistic diversity, both in and out of school. While diverse classrooms are worth celebrating, they pose tremendous challenges for teachers aiming to differentiate instruction, promote language learning, and honor divergent viewpoints. Tolisano (2014) cautions that the process of moving from a traditional educator, who primarily operates within the confines of her own classroom, to a globally connected educator occurs in small steps of raising awareness, making a commitment, developing digital competence, building a learning network, and amplifying the curriculum. Educators at all levels must gain proficiency with online technologies and find opportunities for connecting with others beyond classroom borders (Larson and Brown 2017; Lindsay 2016/2017).

The Journey Forward

New literacies that are important to learning and emerge with the Internet and other technologies continually challenge us with changes. We have explored two lowercase areas that are increasingly important for curriculum in both primary and secondary education: the critical evaluation of online information and global online collaborative learning. From a research and theory perspective, this suggests that other lowercase perspectives should begin to determine if the kinds of patterns we find in the two lowercase areas explored here are also found in other lowercase contexts, with other technologies. If they are, it would call for their inclusion in the common elements included in the uppercase theory of New Literacies and call for even greater attention into studying these elements.

From a practice and curricular perspective, it is important to recognize that these elements already require attention. Recent fake news episodes (Wallace 2017) tell us that important threats to national sovereignty can appear through online disinformation campaigns. In addition, rapid access to global information makes it easier to encounter people who are substantially different from us, and this may make us open to political campaigns that drive us apart rather than bring us together. Both outcomes lead to a more troubled and threatened planet.

We cannot legislate solutions to either challenge, nor can we avoid them. Everyone, or nearly everyone, will have access to online information within the next decade (UNESCO 2014). Our only hope, and the only solution, is to prepare a new generation of citizens who are better prepared for the challenge of changes in the nature of literacy and learning in an online world.

This will require greater effort and focus in our schools, in every nation, to integrate online information into the literacy and learning curriculum, developing more critical users of information and, at the same time, engaging students in collaborative online learning experiences with students in other nations. In this way, we make it more likely that the next generation can resolve the many, seemingly intractable, problems that our planet faces today.

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Digital Citizenship and Social Media: A Curriculum Perspective

5

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Contents

Abstract

The escalating speed of technological development, particularly the pervasive accessibility of the Internet and the rise of social media in the twenty-first century, creates unprecedented opportunities for empowerment and connectedness to individuals and communities. It has also brought challenges and changes to the concept of citizenship and how it is enacted. Especially, the phenomenal growth

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of the Internet revolutionizes people's sociopolitical and civic engagement, engendering a more self-actualized form of citizenship (Bennett 2008), and directly influencing the process of democratization (Ferdinand 2000) and the processes of social and political decision-making. This chapter provides a brief overview on how the concept of "citizenship," which has traditionally been inextricably tied to the geopolitical realities of specific nation states, is changing in the twenty-first century due to the pervasive impact of technology, particularly that of globalization and ubiquitous connectedness through social media. We further discuss the implications of these changes on citizenship education, in terms of the conceptualization of digital citizenship, what constitutes a digital citizenship curriculum, and the challenges in its implementation.

Keywords
Digital citizenship · Global citizenship · Social media · Citizenship education

Technology Development, Citizenship, and Digital Citizenship

Citizenship refers to the process, right, and intellectual capacities of the members of a society to participate fully according to the prevailing standards and to share in that society's social and cultural heritage. According to T.H. Marshall's oft-cited definition (1992), citizenship consists of multiple domains, namely, the civil, political, and social rights of membership, and includes "the right to share to the full in the social heritage and to live the life of a civilized being according to the standards prevailing in the society." It can further be expressed as a sense of identity, interest, and involvement in public affairs, and the acceptance of basic social values. However, digital technologies have empowered people to participate in a broader range of societal activities through various devices and media. Therefore, contemporary definitions of citizenship need be extended to include digital entitlement and participation to truly reflect the range of activities in which the members of a society have the right to participate.

Citizenship engagement entails not only the right of access, but also the capacity (cognitive, social, and emotional) to participate, as well as the values and perspectives that underpin the motivation to participate. The latter two aspects are critically influenced by increased connectivity, extending the potential for augmented performance capacity and globalization. In fact, globalization is challenging the concept of citizenship, which has traditionally been associated with membership of geopolitical entities such as nation states. Citizenship in the twenty-first century is multileveled (personal, group, local, and global) (Kubow et al. 2000) and each of us has multiple citizenship identities, reflecting our participation in different communities: family, friends, workplace, religion, hobbies, etc. Hence, digital citizenship should also include the motivation and capacity to recognize these multiple identities and make use of digital technology to participate at these multiple levels.

Before we go into a deeper discussion of digital citizenship and its implications for education and the curriculum, it is important that we first review briefly citizenship and citizenship education to understand how digital technology and social media impacts on both these two areas.

Citizenship and Citizenship Education

Citizenship is traditionally defined by geopolitical membership, comprising responsibility, rights, and privileges (Sherrod et al. 2010). People possessing such membership are supposed to share the same set of social norms and expectations as citizens (Dalton 2008), and since the nineteenth century such membership is usually based on nationality and/or civic involvement in nation states (Flanagan and Faison 2001). As this form of citizenship is granted by the nation state one belongs to, the set of responsibility, rights, privileges, and even identity as a citizen is also defined by one's nation state membership. Duty and responsibility may include pragmatic contributions to one's nation state such as tax and insurance payment, and work (Marshall 1992). In some nation states such as the USA, where citizenship emphasizes more on shared values than race or geographical boundary, the responsibility of citizens also includes supporting the Constitution and participation in the country's democratic processes (From U.S. Citizenship and Immigration Services: https://www.uscis.gov/citizenship/learners/citizenship-rights-and-responsibilities). Concerning rights in relation to national citizenship, Marshall (1992) puts forward a multifaceted model of civic, political, and social rights, which aligns with the aspiration to achieve social equity within the framework of universal democratic values, such as giving citizens the opportunity to live at or above a basic minimum standard, to vote for their social administrators, to receive a certain level of education, to have freedom of speech, to have fair trial by jury, etc. These are fundamental human rights under Western democratic ideologies. In contrast, privilege is more associated with resources and strategies allocated to specific citizenship sectors (Kuisma 2008), such as social benefit and tax allowance for eligible citizens, which do not apply to "foreigners."

Civic or citizenship education is a mandatory component in the basic education curriculum in many countries, and is generally bound by within-nation requirements related to the rights, duties, and privileges of the respective political systems. As the meaning of citizenship is socially constructed, and differs across countries and societies, there are inherent differences in competence requirements for the individual to exercise their rights and responsibilities as a citizen (Turner 1993). The goals of civic or citizenship education in the traditional curriculum comprises two basic dimensions. The first is about the inculcation of values and norms, including national, political, cultural, and religious requirements imposed by the nation state on those vested with membership and identity as a citizen in the country (Abowitz and Harnish 2006). A major goal of this dimension of citizenship education is to ensure that all groups in the nation state share one dominant mainstream culture and value system. Schools, in serving as an agent for the delivery of citizenship education, also take on the role of promoting assimilation into the mainstream culture for building citizenship and national belonging (Banks 2007). The second dimension is on developing the competence (knowledge and skills) needed to understand the citizen roles and identity, and to exercise the associated rights and responsibilities, including participation in civic and political action. Schools are often the first institutions to introduce an elementary idea of citizenship to children, as well as to offer a societal and institutional context for understanding the concepts of rights and responsibilities (Astuto and Ruck 2010). It is thus fair to say that the role of citizenship education in the school curriculum has primarily been one of promoting homogenization in cultural norms, social values, and practices, and giving priority to national interests.

The Challenge of Globalization to Citizenship and Citizenship Education

The concept of citizenship has become less monolithic and more complex since the late twentieth century under the influence of globalization and postmodernism. Globalization can be regarded as a process that "encompasses the causes, course, and consequences of transnational and transcultural integration of human and non-human activities" (Al-Rodhan 2006), which is accompanied by changes in transnational economy, capitalism, consumption and cultural patterns, as well as political infrastructures such as global governance and authority structures (Robinson 2007). Advances in transportation and communication technologies have greatly accelerated interactions among countries, with impacts on economic cooperation and integration, policy assimilation, knowledge transmission, cultural stabilization across nations, and the redistribution of global powers. It has also led to the spread of capitalism worldwide through facilitating globally more liberal systems and free markets, as an extension of modernity and industrialization (Giddens 2013). The process of globalization is further escalated through international labor immigration and frequent economic interaction among nation states. However, economic integration across nations and changes in political ideologies may not always align, leading to political and ideological clashes at the state level. In some countries, economic liberalization stimulated changes in political ideology, demands for policy choices and reprioritization of democratization, leading to the erosion of state sovereignty by global markets (Woods 1998), and clashes with nationalism ideals.

While the globalization process challenges the concept of national and cultural citizenship, the influence of population flow, economic and social collaboration has also led to the emergence of "global citizenship" (Falk 1993) within collaborative regions, such as the transnational citizenship within member states of the European Union. In this circumstance, the rights and privilege of citizenship extend to a more macro-level, for example, the grant of freedom of movement to individuals with member states of the regional community as in the case of the European Union, and the sharing of knowledge and expertise among members of supranational organizations as in the case of sharing medical information and knowledge through WHO. Global citizens are responsible not only to their own nation states, but to the larger collaborative community.

The concept of rights is also moving beyond the confines of the nation state as a result of globalization. A two-dimensional framework of primary (or basic) rights and enabling rights has been proposed (Dahrendorf 1994). The former comprises human rights, civil rights, and democratic political corollaries, and the latter comprises social rights such as social services and welfare required to empower people with the capacity to exercise their basic rights. This originates from an ideology that strives for a world civil society and world citizenship premised upon equality not only within a society, but also across societies.

The adverse effects of globalization, such as international crimes, illegal immigration, and environmental destruction, have also generated demands on the coordination, regulation, and arbitration roles of international agencies and regulatory bodies that operate at a multilateral level, which to some extent undermine individual state sovereignty, and move citizenship from a solely national realm to a more global level. One typical example is the global "ecological imperative" to combat climate change, which requires states to abide by global ecological regulations. Citizens in the regulated nations have the responsibility to take actions for the protection of the environment, including challenging their government's decision if deemed to be against the international environmental regulations. In summary, through the process of globalization, some elements in the sovereignty of nation states is relegated upward to the regional community, international institutions, or supranational agencies, or downward to the open market economy (Delanty 2000).

Under the influence of globalizing forces, people and countries are getting irrevocably more interdependent. In addition to knowing their responsibility, rights, and privilege as citizens in their own countries, people need to understand the same as members of collaborative transnational communities, and to equip themselves with a basic level of proficiency in and acceptance of the languages and social norms of collaborating partners. Those with nontransferable skills and linear thinking styles would find it difficult to cope with the globalization process and are likely to be marginalized (Woods 1998). Hence, there is a strong move toward emphasizing transferable skills such as critical thinking, creativity, and the ability to take on multiple perspectives in recent system level curriculum reforms (Brown et al. 2001). Other emerging goals in citizenship education include the development of identity and attachment to more global communities, and the capacity to connect to people around the world, under the broad umbrella of cosmopolitanism. To function as global citizens, people have to take responsibility for actions and decisions to solve problems at the global level, which may involve giving priority to one's responsibilities as a human being to every other instead of loyalty to the local community and the state.

Social Media and the Emergence of the Netizen

Ongoing globalization processes and the development of the Internet, particularly the rapid expansion of social media, contribute to the emergence of the network society (Castells 2000). The technology underpinning social media is the read-write web, popularly referred to as Web 2.0. Technologically, Web 2.0 was not a novel leap. However, in going from a broadcast mode of communication in Web 1.0 to supporting bidirectional and interactive communications, it creates an unprecedented social novelty through supporting online communication, community-formation, collaboration, and the crowdsourcing of collective intelligence (Aghaei et al. 2012).

"Space" for public sphere and "membership" for civil engagement are the two core components constituting citizenship. Transnational cooperation brought about new concepts of citizenship through creating concrete world-regional systems of rights, civil societies, and public spaces, such that citizenship becomes definable in terms of political community, civil society, and the public sphere rather than being coterminous with the nation state, race, or culture (Habermas 2003). Similarly, social media have contributed to new forms of citizenship. The Internet provides the "space" for public sphere, and the online social networks/communities established through Web 2.0 technology provide the civil engagement contexts for "membership."

Another impact of technology on citizenship is the development of a DIY (do-it-yourself) or self-actualizing culture. This results largely from the empowerment potentials unleashed by the increasing accessibility of sophisticated technologies such as powerful search engines, 3D printers, and multimedia production software suites. DIY means taking personal charge of matters rather than leaving them to others. Engaging in DIY activities implies simultaneously becoming a producer and a consumer. DIY activities, even in the context of everyday transactions, challenge existing hierarchies of authorities and the status quo. Ratto and Boler (2014) coined the term "DIY citizens" to refer to individuals and groups who engage in politically transformative activities such as video productions, civic rituals, or political protests organized on- and offline. They also refer to large-scale networked protests such as Occupy Wall Street as a form of DIY democracy, characterized by horizontal processes of leadership and consensus, and the blatant rejection of traditional forms of government-centered democratic participation.

Public participation in politics is considered a defining feature of democratic citizenship in Western culture. Advances in digital communication platforms and social media have given rise to unprecedented levels of production and distribution of ideas, public deliberation, and network organization. Social media provide the technological infrastructure for the development of DIY organizational processes, values, and norms, and in the process extend and transform citizenship from what Bennett (2008) coined as dutiful citizenship subordinated to the government to more self-actualizing forms of citizenship. This includes the preference for more self-determined political decisions and perspectives.

The role of established civic organizations and political parties has been undermined by online communities and loose, instant networks of collective actions orchestrated through interactive technologies and social media. The burgeoning occurrence of mass civic and political movements orchestrated through digital technology and social media has brought fundamental changes to the processes of civic participation and political decision-making. These new forms of social participation and political engagement pose significant challenges to citizenship and citizenship education.

Another fundamental shift in the concept of citizenship relates to the process and authority in granting citizenship. Individuals can now form and/or select their own online "citizenship," which is very different from the citizenship granted by nation states. People can now take responsibility for defining their own identities in the "network society." Social software and digital network technology accelerate the pace of globalization, creating a parallel borderless society connected through the Internet. They also provide a network of platforms to build social and personal identities. Collaborative online networks, virtual and actual communities, together generate more fragmented, fickle but multiple identities of individuals in the digital world, where national boundary is ephemeral. The term “netizen” (members of the network society) implies a form of online citizenship that coexists with other offline citizenships.

Challenges to the Well-Being of Netizens

Digital technology has provided unprecedented empowerment and connectedness opportunities to individuals and communities, thereby extending the concept of citizenship beyond the confines of nation states and created new and innovative forms of sociopolitical participation and decision-making. Social media have played particularly significant roles in giving voice to individuals, and supported new forms of democratic participation. These changes also mean that the development of the necessary competence, particularly in the critical and socially responsible consumption and production of media, is important for ensuring the well-being of citizens. Further, there are social phenomena and behavior, both online and in real life, that are mediated or orchestrated through social media, and observed to pose new challenges to the well-being of digital citizens (or netizens). These include cyberbullying and identity thefts, as well as phenomena such as echo chambers that are setbacks to the ideals of equity in basic human rights and global citizenship. Social media have also provided opportunities for large corporates and political magnates to manipulate mass social participation through social media platforms and big data analytics of personal and behavioral data. These challenges and the implications for digital citizenship education are discussed briefly in this section.

Cyberbullying

Cyberbullying, similar to bullying, is an act of aggression with the intention to cause harm or distress to the victim, characterized by a power-imbalance (Whittaker and Kowalski 2015). In the case of bullying, the imbalance often reflects more directly observable differences such as social status or physical strength, while the imbalance in the case of cyberbullying may be differences in technological expertise. Cyberbullying occurs through digital communication technologies such as instant messages, emails, or social media, often involving sending distressing messages repeatedly and/or to hundreds of recipients for the purpose of public shaming. Social media platforms have become prominent venues for cyberbullying because of their wide and instant accessibility to the public. There are, however, important differences between traditional forms of bullying and cyberbullying. In the case of the former, the perpetrator and the victim as well as their relationship are generally identifiable, while the victim and the perpetrator may not know each other in the case of cyberbullying. Pyżalski (2012) classified cyberbullying among students into six categories: against peers, against the vulnerable, against groups who are different (such as religion or ethnicity), against celebrities, against school staff, and random cyber aggression. Whittaker and Kowalski (2015) found that reactions toward cyberbullying depend on the victims targeted, and cyber aggression targeting peers is perceived to be least acceptable. Although cyberbullying does not directly cause physical harm to the victim, it may cause serious social, emotional, and/or behavioral damages and should not be ignored.

Echo Chambers

It has been hypothesized that the Internet presents an open platform for borderless information access and expression of alternative viewpoints, fostering ideological pluralism and the creation of a more globalized and integrated society that accommodates diversity (Bimber 1998). However, it has been shown that people tend to expose themselves to information that reinforces rather than challenge their own views. Hence the abundant availability of diverse information online may simply provide more opportunities for selective attention to those that are similar to their own viewpoints, favoring the emergence of echo chambers, which may further lead to social extremism and political polarization. In a study of political homophily using Twitter data, Colleoni et al. (2014) differentiated cases when Twitter served as a social medium from when it served as a news medium, and found higher levels of homophily and echo-chamber like communication patterns in the former situation involving interpersonal networks, but not in cases when social ties are eliminated.

Influence and Manipulation of Social Participation through Social Media

The Brexit decision through referendum by UK citizens and the election of Trump as the 45th US President in 2016 not only came as unexpected political outcomes, but also stimulated a lot of debates about whether social media serve as a public sphere for democratic debates and participation or as platforms for political manipulation at an unprecedented fine level of granularity. The use of social media for political campaigning has become a reality in many countries since the turn of the millennium. Obama's 2012 election campaign has been credited as having made spectacular advances in the use of large-scale data analytics and behavioral modeling on a wide range of data beyond the general voter database, common demographic records, and commercial databases, to include data from social networks and canvassing, for the design and implementation of sophisticated micro-targeting of campaign messages (Bimber 2014). Easily accessible records of behavior on social media platforms such as Facebook likes can also be used to predict with relatively high accuracy sensitive personal attributes such as ethnicity, personality traits, and religious and political views.

Advances in data science to make accurate inferences based on digitally recorded behavior pose serious threats to privacy concerns. The lack of transparency in data collection, data processing and use by unknown actors for purposes outside of our control as data owners, and without an "opt-out" mechanism, undermines important democratic norms. Furthermore, in making use of data analytics to construct political appeals on narrow issues to appease targeted receptive electorates, campaigners are segmenting the population, thereby restricting the opportunities for wide participation in debates on important issues of public interest.

Limits to DIY Citizenship

As mentioned earlier, digital technology, especially social media, has fostered the development of a DIY culture, which is manifested as DIY democracy, such as the Arab Spring and Occupy Wall Street in the realm of civic and social participation. These mass political actions demonstrate how digital technologies can support grassroots democracy and direct action in challenging the status quo and traditional authority hierarchies, without going through the standard democratic processes of voting and advocating for policy changes (Ratto and Boler 2014). In Europe, it has been observed that this form of political participation is particularly preferred by young people, who have become increasingly disillusioned with electoral politics, and took to the streets to vent their anger and frustration with the political and economic situations.

Meta-analysis of findings from studies of social media shows that social media use is positively correlated with the three subcategories of citizen engagement: social capital, civic engagement, and political participation (Skoric et al. 2016). This indicates the tendency for political participation using digital technology to be skewed toward those who are technology savvy and well educated, particularly in countries where there are still significant gaps in digital access and use. Hence the Internet has become an instrument of inequality in political voice, which is counter to the democratic ideal of equal access to information and participation. Another challenge is that the very social media that the public depends upon for their sociopolitical participation are mostly operated by US-based corporations, with compliance to unaccountable US intelligence agencies.

Digital Citizenship Curriculum in the Literature

In the foregoing sections, we have reviewed how the concept of citizenship has been challenged and extended by the spectacular advances in connectivity and the augmentation of human performance brought about by digitally integrated technology. Given the pervasive impact of digital technology on the well-being of citizens, it is not surprising that the concept of digital citizenship started to appear in the literature related to school curricula soon after the transition into the twenty-first century. However, a careful examination reveals that the term "digital citizenship" does not carry a clearly defined meaning in the current curriculum literature.

Digital Citizenship as Digital Competence

Until now, the staunchest proponents of digital citizenship in the school curriculum have been educational professionals concerned with the development of computer literacy and information literacy in students. Among the most well-known curriculum frameworks for digital citizenship is the nine element model (Bailey and Ribble 2007; Ribble 2015) published by the International Society for Technology in Education (ISTE). This model conceptualizes digital citizenship as the behavioral norms with regard to technology use for living and learning in the twenty-first century. The nine elements are grouped into three areas:

1. Digital access, digital learning, and digital communication for *student learning and academic performance*
2. Digital rights and responsibilities, digital etiquette, and digital security as norms for *school environment and student behaviors*
3. Digital health and wellness, digital law, and digital commerce as necessary knowledge and skills for *life beyond the school environment*

Despite the popularity of Ribble's (2015) nine element model of digital citizenship within the school community, there is no common agreement on the scope of digital citizenship even within the education technology community. For example, in the third edition of the National Educational Technology Standards (NETS) for Students (ISTE 2016), digital citizenship includes the rights and responsibilities of living and learning in a networked society as well as how to act in a safe, ethical, and legal manner, which only addresses one out of the three areas of concern in Ribble's (2015) model as described above.

Digital Citizenship as an Integral Part of Information Literacy

School librarians is another educational professional sector that have been actively promoting digital citizenship education in the curriculum as an extension of the role they have been playing in students' information literacy development, focusing on helping students to use and create information responsibly, safely, and ethically (Maughan 2017). The American Library Association (ALA) plays an active role in supporting the professional development of school librarians with regard to digital citizenship education, in alignment with Ribble's nine element model.

Given the increasing complexity and sophistication of technology one encounters on a day-to-day basis, some argue that school librarians' role in digital citizenship education should include data literacy (Fontichiaro and Oehrli 2016), and critical civic literacy (Levin 2016). Data literacy focuses on developing students' statistical literacy, the ability to create and comprehend data visualization, use data in argument, participate in citizen science by contributing to big data, manage personal data, and to use data ethically. Critical civic literacy focuses on critical consumption of media, and the capacity to analyse and act on social and political issues.

Another important information literacy issue that has become more acute because of the ease of replication and transmission of information is the need to respect and protect the intellectual rights and copyrights of online materials. The Office for Harmonisation in the Internal Market (OHIM), an agency of the European Community, defines intellectual property (IP) education as "the skills and competences that young people can be expected to acquire in the classroom that enable them to become familiar with intellectual property, understand its potential to generate income and economic growth and lead them to respect intellectual property rights, whether their own or those of others" (OHIM 2015, p. 7). This report finds that a cross-curricula approach for teaching intellectual property rights, such as through the ICT, STEM, and citizenship curricula, is more feasible and effective than teaching it as a separate subject. A more in-depth understanding of IP should include more nuanced interrelationship between creative productions and their protection, especially in the case of derivative creations, and the industry structure of online digital content markets.

Digital Citizenship as Preparation for Civic and Political Participation

This digital competence focus does not address directly issues related to national belonging, cultural norms, social values/practices, and political participation, which are found in traditional citizenship education. Moyle (2014) points out that in the case of Australia, school education does not connect ICT use with the development of democratic values so as to be in alignment with the country's political system, or with civics and citizenship in the curriculum.

In an empirical study using concept analysis method on published literature related to digital citizenship in a wide range of disciplines, including political science, journalism, and communication, Choi (2016) identified four themes: ethics, multimedia and information literacy, participation and engagement (P&E), and critical resistance (CR). The first two themes are generally addressed in the school curriculum, either under the banner of digital citizenship or digital competence/information literacy as discussed earlier. However, digital modes of P&E and CR are generally not included in the school curriculum. Like Moyle (2014), Choi (2016) argued for the importance of these social/political-participation- related aspects of digital citizenship in the curriculum. He further highlighted the multidimensional nature of digital citizenship and the need for it to be connected to citizenship education.

Digital Citizenship Education Should Proactively Foster Positive Attitudes toward Diversity

Shaming is the use of defamatory language, imagery, or other media to devalue others. Shaming is often observed in social media, and is one common form of cyberbullying. Armfield et al. (2016) link shaming to the creation of a stigma, which occurs when there is a perceived discrepancy between what someone is supposed to be and what the individual actually is. Shaming thrives on the dominance of a social norm, or the construction of an "in-group" that sets the boundary to the exclusion of others, who could then become targets to be bullied. Armfield et al. (2016) further argue that social media as is normally presented fosters homogeneity and shaming behavior, as it encourages people to connect with those similar to themselves. Students will naturally socialize with those who are similar to themselves, whether online or offline. Hence, they propose that digital citizenship can be "reinforced as a way to think about others the students are not physically connected with" (ibid., p. 278). As such, teachers and schools should encourage students to make positive connections even with those who are unlike themselves as part of digital citizenship education.

Online bullying and hate speech are more severe forms of negative behavior harmful to the victims' psychological well-being, which may result in depression and other mental issues (Wang et al. 2011). Some students consider online bullying as more serious than real-life bullying because of the apparent anonymity, even though cyberbullying usually comes from within the victim's own social circle and relationships (Mishna et al. 2009). These issues need to be addressed at both school policy and curriculum levels. At the curriculum level, students need to learn how to identify and react to online bullying behavior, including reporting online bullying through appropriate channels, submitting relevant evidences, and knowing the measures to seek help.

Digital Citizenship Education in Policy and Practice

While there may be differences in emphasis or scope, the core constituent of digital citizenship is widely taken as having the digital competence and disposition for safe, responsible, and ethical use of digital technology. In the USA, Ribble's (2015) nine element framework has been integrated into the ISTE National Educational Technology Standards for students and teachers, and the information literacy framework of the American Library Association. Hence, this has been adopted in the school curriculum in many US states. It has also been incorporated in the school curriculum in some other education systems, such as in Ontario and Alberta in Canada.

UNESCO (2016) formulated a definition of digital citizenship that is somewhat narrower in scope on the basis of a wide-ranging policy review involving countries from the Asia-Pacific region: "being able to find, access, use and create information effectively; engage with other users and with content in an active, critical, sensitive and ethical manner; and navigate the online and ICT environment safely and responsibly, being aware of one's own rights" (p. 15).

Netsafe, a New Zealand-based nonprofit organization providing the community with support on online safety, put forward in a white paper (Netsafe 2016) on digital citizenship that is similarly focusing on knowledge, skills, attitudes, and values to be able to participate actively as a lifelong learner in a connected world. However, it also proposes a three-stage model of digital citizenship development. At the lowest level of development is a set of *digital literacy* skills. This should further develop into *digital fluency*, which expands the digital competence to include knowledge and understanding of digital environments and contexts and their integration with offline spaces, as well as the dispositions for positive connections and personal integrity online through the development of appropriate attitudes and values. Digital citizenship, according to this model, is a high-level outcome in being able to demonstrate digital fluency through their participation in multiple contexts. It further puts forward a *Learn-Guide-Protect* framework to support digital citizenship development, beginning with a primary focus on *protecting* children at a young age through the provision of a safe digital learning environment; to *guiding* students to develop online safety skills and engage in positive digital technology use through programs and resources; and finally to support students' *learning* to contribute as self-managing members of the community through active participation in different meaningful contexts.

Instead of focusing on the competence and behavior of the individual as is often the case in digital citizenship literature and policy documents, Cassells et al. (2016) focus on what it means to the individual to be a digital citizen. This publication is an edited volume introducing more than 30 eTwinning projects related to the theme "Digital Citizens." The authors describe three "pillars" of digital citizenship: these citizens belong to, engage in, and are protected in the networked world. More importantly, they put forward a four-level model of digital participation: through consumption and observation; through sharing information/ideas and connecting people; through creating new content, practices, and tools; and through harnessing digital technology to shape the society for a better future. This is promoting a perspective of the learner as a more active and self-directed agent, which is more aligned with the concept of the twenty-first-century learner. The projects presented in this publication demonstrate how students, with support from their teachers, take an active role in using technology to explore different forms of participation and engagement with peers in other countries.

The Future of Digital Citizenship and Digital Citizenship Curriculum

In the first part of this chapter, we traced how the concept of citizenship evolved from being closely connected to the rights, privileges, and responsibilities of the individual as a member of the nation state, through the emergence of multiple and global citizenship that goes beyond politically defined national boundaries, to the much more nuanced and complex concept of digital citizenship due to the pervasive access to the Internet, particularly the impact of social media on all aspects of our personal, social, and work lives. A fundamental difference between traditional citizenship and digital citizenship lies in the dramatic changes in participation rights, power structures, and forms of social participation and organization that have taken place because of the unprecedented ease of access to information, networks, and institutions. Cost of access is no longer a major obstacle in many countries, but the digital divide is largely one of digital competence and online social capital. The Internet and social media have influenced deeply the socioeconomic, civic, and political changes in many parts of the world. The scale and pace of such changes will only escalate in the foreseeable future, bringing deeper changes to the contexts and realities of the digital citizen.

While the concept of digital citizenship is getting increasingly fluid and dynamic, digital citizenship education is by and large staying within a competence and dispositions framework for safe, ethical, and legal participation online. As such, digital citizenship education has generally been unconnected with the social/political concerns normally addressed in citizenship education (Moyle 2014; Choi 2016). Digital technology is empowering and challenging individuals and societies in fundamental ways, and hence is also challenging long-standing concepts of citizenship. However, digital citizenship education has generally not brought these fundamental issues and changes in citizenship into the curriculum.

One important feature of contemporary citizenship concepts is the "coexistence of bipolar perspectives including universalism and particularism, heterogeneity and homogeneity" (Lee 2015, p. 94). The universal value of human rights promotes a respect for particularities and differences, and in turn diversity and heterogeneity. This echoes with Armfield et al.'s (2016) argument that digital citizenship must cultivate a respect for diversity and positive attitudes toward heterogeneity. Lee (2015) raised the question of what would be the essential features of citizenship education that can prepare students to be citizens of the future, one that focuses on becoming rather than being. The current emphasis in digital citizenship education on digital competence and disposition for safe, ethical, and legal participation provides a necessary baseline for a digital citizen of today. What would be an appropriate curriculum model for a future-oriented digital citizenship? Would Lee's (2015) model of citizenship education centering around how one relates harmoniously to oneself, to others, to nature, and to become a good citizen through self-cultivation to be a good person the appropriate direction to go?

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Students and Their Computer Literacy: Evidence and Curriculum Implications

6

John Ainley

Contents

Abstract

For a number of years, education authorities have responded to the importance of school students developing computer literacy by including it as part of the school curriculum, directly as a cross-curriculum capability, and by assessing the extent

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to which students are computer literate. Computer literacy and related concepts, such as ICT literacy, are defined so as to include both technological expertise and information literacy. Assessments of computer literacy, even though they vary, indicate that there are substantial variations in levels of computer literacy among students in the lower years of secondary school. In technologically developed countries, approximately one half of Year 8 students demonstrate proficiency, or advanced proficiency, in computer literacy, but up to 10% have very limited computer literacy. Assessments of computer literacy can also provide the basis for progression maps that could be used to inform curriculum development. Those progression maps will be more valuable if the frameworks on which they are based become more strongly integrated with each other. In addition, computer literacy appears to be influenced by student background, including familiarity with computers, as well as the emphases placed on it in classrooms and schools and the support provided by ICT in education systems. At present, there is less information about school and classroom influences on computer literacy than there is about student background influences. In the immediate future, the construct of computer literacy may need to accommodate increasingly to changes in software and hardware contexts in which it is manifested.

Keywords
Computer literacy · ICT literacy · Asessment · Curriculum

Introduction

Computer literacy has been recognized for some time as important for life in modern society (Kozma 2003), and many countries have officially recognized the importance of developing computer literacy through schools. During the first decade of the twenty-first century, policy statements from many national education authorities asserted the importance of school students developing capabilities in information and communication technology (ICT) to support learning in other domains and to provide a foundation for their productive future participation in work and society (Qualifications and Curriculum Authority 2007; E-learning Nordic 2006; Hinostroza et al. 2008; MCEETYA 2008; Sanchez and Salinas 2008; Office of Educational Technology, US Department of Education 2010).

Computer literacy also features as a focus of cross-national organizations. Interest in capabilities related to digital technologies is evident in the assertion by the European Commission that digital literacy is "increasingly becoming an essential life competence and the inability to access or use ICT has effectively become a barrier to social integration and personal development" (European Commission 2008, p. 4). The United Nations Educational, Scientific and Cultural Organization (UNESCO) has canvassed the possibility of a global measure of digital and ICT literacy skills in a paper commissioned for the 2016 Global Education Monitoring Report (ACER 2016). Projects such as the IEA International Computer and Information Literacy Study (Fraillon et al. 2014) and the Assessment and Teaching of

21st Century Skills (Griffin et al. 2012) indicate a quickened interest in defining and assessing appropriate capabilities for modern societies. An assessment of digital reading was included as an international option implemented by 19 countries in the PISA 2009 cycle (OECD 2011).

One view of student use of digital technologies was that students in the modern age were "digital natives" (Prensky 2001) who had grown up to be expert users of these technologies and who had developed "sophisticated knowledge of and skills with information technologies" and even different learning styles from older generations (Bennett et al. 2008, p. 777). Others have challenged this view pointing to wide variations among young people in their use of ICT, the lack of a clear distinction between young users and older users, and the predominance of relatively mundane usage (Helsper and Eynon 2010; Koutropoulos 2011; Selwyn 2009). Selwyn (2009) characterizes young people's Internet use as "passive consumption of knowledge rather than the active creation of content" (p. 372). For this reason, and other reasons, many school systems provide teaching of computer literacy to develop students' capabilities in that domain (Sturman and Sizmur 2011) sometimes outlining a learning progression (e.g., ACARA 2017), and the assessment of computer literacy has become a component of monitoring student achievement. In many countries, and internationally, assessment programs have been designed to determine the extent to which students are developing appropriate levels of computer or ICT literacy. This paper draws on the evidence that has been assembled by those assessment programs to address the question: To what extent are students computer literate?

Conceptualizing Computer Literacy

The terms computer literacy, ICT literacy, and digital literacy have slightly different meanings but in practice are used interchangeably (Markauskaite 2006; Siddiq et al. 2016). This chapter refers to computer literacy but recognizes that the concept overlaps with other terms. Conceptualizations of computer and ICT literacy have been greatly influenced by work of an international panel convened by the Educational Testing Service (ETS) to develop a framework for ICT literacy (ETS 2002). The panel proposed that "ICT literacy is using digital technology, communications tools, and/or networks to access, manage, integrate, evaluate, and create information in order to function in a knowledge society" (ETS 2002). Since that initial work, conceptualizations have combined aspects of technological expertise with information literacy and extended to include ways in which digital information can be transformed and used to communicate ideas (Catts and Lau 2008). The conceptualizations of computer literacy that have emerged involve both the use of digital tools and the ideas of information literacy. Studies of computer literacy assume that there is an underlying construct that can be measured in different contexts. This assumption is consistent with the view that computer literacy is more than operating hardware and software and includes the information literacy skills associated with accessing and evaluating information as well as the creative competencies of transforming and creating new digital information.

Binkley et al. (2012) synthesized the operational definitions of ICT literacy that had been developed around the knowledge, skills, and attitudes concerned with being able to access and evaluate information (e.g., search, collect, and process), use and manage information (e.g., process information accurately and creatively, manage the flow of information from various sources, understand the reliability and validity of information), and apply technology effectively (e.g., applications and devices). Similarly, the European Commission proposed a digital competence framework (DIGCOMP) based on a review of ICT literacy frameworks (European Commission 2010). It invokes five main competence areas: information management, collaboration, communication and sharing, creation of content, and problem-solving (European Commission Joint Research Center-IPTS 2013; Ferrari 2012). At a more detailed level, DIGCOMP specifies particular skills that make up these five competence areas and proficiency levels for each competence area.

ICILS adopted the definition of computer and information literacy as referring to "an individual's ability to use computers to investigate, create and communicate in order to participate effectively at home, at school, in the workplace and in society" (Fraillon et al. 2013, p. 17). It envisaged two strands. The first was a receptive strand involving collecting, managing, and processing information. It incorporated knowing about and understanding computer use (the generic characteristics and functions of computers and basic technical knowledge and skills that underpin the use of computers), accessing and evaluating information (the processes that enable a person to find, retrieve, and make judgments about the relevance, integrity, and usefulness of computer-based information), and managing information (the capacity to work with computer-based information to adopt and adapt information-classification and information-organization schemes in order to arrange and store information so that it can be used or reused efficiently). The second strand focused on producing and exchanging information and using computers as tools for thinking, creating, and communicating. This included transforming information (change how information is presented so that it is clearer for specified purposes), creating information (using computers to design and generate information products), sharing information (understanding of how to use computers to communicate and exchange information with others), and using information safely and securely (understanding legal and ethical issues of computer-based communication).

The definition of ICT literacy adopted in Australia for use in its National Assessment Program was similar to, and preceded, that used in ICILS. It was elaborated through a set of six key processes and a broad description of progress according to three strands (MCEETYA 2005). The six key processes were accessing information, managing information (organizing and storing information), evaluating and making judgments, developing new understandings (e.g., creating information and knowledge), communicating (i.e., exchanging information and creating information products), and using ICT appropriately. The three strands of progress were working with information, creating and sharing information, and using ICT responsibly.

In 2014, the US National Assessment of Educational Progress included an assessment of technology and engineering literacy (NAEP-TEL) which has ICT as one of its three areas. Information and Communication Technology was one of three content areas (the other two were Technology and Society and Design and Systems) (Institute of Education Sciences, National Center for Education Statistics 2012). Information and Communication Technology covered "computers and software learning tools, networking systems and protocols, hand-held digital devices, and other technologies for accessing, creating, and communicating information and for facilitating creative expression" (NCES 2016a, p. 8). This involved proficiency in using computers and software learning tools, networking systems and protocols, handheld digital devices, and other technologies that enable users to access, create, and communicate information and engage in creative expression. It also identified five subareas of competence: construction and exchange of ideas and solutions, information research, investigation of problems, acknowledgement of ideas and information, and selection and use of digital tools (NCES 2016b).

In Chile, the ICT Skills for Learning Test thus defines ICT literacy as "the capacity to solve problems of information, communication and knowledge in digital environments" (Claro et al. 2012, p. 1043). Claro et al. (2012) elaborate that this requires the mastery of ICT applications in order to "solve cognitive tasks in a digital environment" but that the skills are not themselves technology-driven in that they reference "information, communication and knowledge tasks in an ICT context" rather than particular software. They also incorporate higher-order thinking processes and related to continuous learning. ICT literacy is envisaged as involving using ICT with regard to information skills (sourcing for information, processing information), communication skills (effective communication, collaboration and virtual interactions), and appreciating ethical issues and social impact (evaluating responsible use and social impact) (Claro et al. 2012).

Assessing Computer Literacy

Over the past two decades, there has been a number of approaches to the assessment of computer literacy including self-reports, traditional assessments based on multiple-choice and constructed response items, and performance assessments. Each of these provides different perspectives.

Self-Reports of Computer Literacy

Siddiq et al. (2016) note that there have been numerous examples of self-reports as measures of students' ICT literacy. They caution that, although these measure self-confidence or self-efficacy, they do not provide sound measures of ICT literacy. Therefore, Siddiq et al. (2016) excluded studies based on self-reports from their review of instruments measuring ICT literacy. They noted the low correlations of self-reports with measured competence. Rohatgi et al. (2016), based on analyses of Norwegian data, note that ICT self-efficacy may not be a unidimensional construct and distinguish basic ICT self-efficacy from advanced ICT self-efficacy. Basic ICT self-efficacy was positively related to computer literacy ($r = 0.22$), whereas advanced ICT self-efficacy was negatively but minimally associated with computer literacy ($r = -0.06$) (Rohatgi et al. 2016). A similar correlation between ICT self-efficacy and measured computer literacy was reported among students in Years 6 and 10 in Australia (ACARA 2017). There is also evidence from Australia that measures of ICT self-efficacy may not be equivalent for boys and girls: Boys were more confident than girls about using ICT, but this confidence was not matched in measured computer literacy (ACARA 2017). It has been widely concluded that self-report measures do not provide a basis for inferring the extent to which students are computer literate even though these measures may be important for understanding student learning in computer-based learning environments (Moos and Azevedo 2009).

Assessments Based on Traditional Item Formats

Siddiq et al. (2016) have provided a comprehensive review of the instruments used to assess students' ICT literacy. They observe that many of the instruments are directed to lower secondary-school students, involve multiple-choice items, and measure aspects such as searching, retrieving, and evaluating information as well as technical skills. Siddiq et al. (2016, p. 63) identify four item categories in assessments of ICT literacy: multiple-choice items based on static information, multiple-choice items based on dynamic information, items that require the respondent to interact with the test material, and the performance of tasks that require responses in an authentic situation. Some assessments of computer literacy use print formats to assess computer literacy (Senkbeil et al. 2013). Critiques of approaches using standard item formats have been that they do not reflect the ways in which people use these technologies in practice and that they do not capture the range of computer literacy competencies (Siddiq et al. 2016).

Most assessments of computer literacy and related constructs have used computer-based assessments (Siddiq et al. 2016). Computer-based assessments typically take advantage of the medium to provide richer stimulus material (e.g., video and other dynamic graphic material) on which to base items and enable better targeting of item difficulty to respondent ability (e.g., assigning items based on responses to previous items). However, an essential consideration for computer-based assessments, which is not such an issue for print-based assessments, is to ensure a uniform assessment environment. Computer-based assessments delivered through software and resources loaded on devices such as laptop computers are able to achieve this, but when materials are located on demountable media such as USB devices and accessed by local computers or accessed through the Internet, uniformity is harder to achieve.

Performance Assessment

Many approaches to assessing computer literacy incorporate performance assessment in which students are required to perform tasks on a computer rather than simply answer questions about computers and computing (Aesaert et al. 2014; Ainley et al. 2016; Claro et al. 2012; NCES 2016b; Van Deursen and Van Dijk 2016). Performance assessments provide opportunities to collect different types of responses (e.g., information products) and enable interaction between the respondent and an assessment system (e.g., dialogue between a respondent and the system). Performance assessments have been used in a number of learning domains and require a demonstration of mastery by performing a task or producing an information product that is subsequently evaluated using an assessment rubric (Madaus and O'Dwyer 1999). There are also examples of recording direct observations of people completing a task (Katz 2007).

Aesaert et al. (2014) developed a performance-based direct measure of ICT competence with a focus on primary-school students' competence in digital information processing and communication. They developed and trialed 56 items around a matrix of 19 higher-order competences and 15 technical skills, and the data from the trial were examined to investigate dimensionality, fit, local item dependence, and monotonicity. The items were "simulation-based assessment tasks" which reflected "real-life information searching, processing and communication activities" (p. 171). The tasks were embedded in a narrative theme of "a journey through time" (p. 171). Twenty-seven items that required retrieving and processing digital information as well as communication with a computer were included in the final instrument.

Van Deursen and Van Dijk (2016) used a measure of Internet skills based on the performance of 21 discrete tasks in a survey of just over 1000 adults. The survey was administered as part of an online survey and also included measures of traditional literacy and Internet usage. The reliability of the measures of formal Internet skills, information Internet skills, and strategic Internet skills was high ($\alpha > 0.80$), but that of observed Internet skills was a little lower than ideal ($\alpha = 0.72$). They concluded that the level of operational skills, as well as traditional literacy, had a positive effect on formal, information, and strategic Internet skills. However, traditional literacy was not related to operational Internet skills.

ICILS employed four modules of which each student was randomly assigned two. Each module involved a number of discrete tasks and a large task (Fraillon et al. 2014, p. 18). One of the modules required students to create an advertising poster for an after-school exercise program (Available for viewing at: http://www.iea.nl/icils-past-cycles). To do this, they needed to set up an online collaborative workspace through which to share information which was then selected and adapted for the purpose. A second module required the creation of a webpage about a school band competition. Students needed to plan the webpage and use a simple website builder. The third module asked students to prepare a presentation about breathing for 8- or 9-year-old students. It involved file management and the collection and evaluation of relevant information. The fourth module required students to produce an information sheet about a school trip for their peers. They needed to use online database tools and to assemble relevant information. They could create a map using an online mapping tool. Each large task resulted in an information product that was assessed by scorers against a set of criteria (each criterion with its own unique set of scores) relating to the properties of the task. In ICILS 2013, large tasks constituted around 60% of the assessment.

In Chile, the ICT Skills for Learning Test also made use of purpose-designed software that simulated ICT applications and tasks that were embedded in realist contexts (school and work) (Claro et al. 2012). The software included commonly used applications (email, Internet browser, text processor, spreadsheet, and presentation software). In addition, there was a chat window through which a virtual conversation among three participants was simulated. Each student was assigned tasks to perform. The tasks were incorporated in a story (ecology), and in each task the student was faced with different situations, which were designed to test ICT skills. The first task required the student to participate in a campaign for the protection of species under threat of extinction. The second task required the student to prepare a working document about global warming. The third task required students to recognize risky behaviors in virtual environments and evaluate the impact of the Internet in different dimensions of life. Students were expected to use scientific evidence presented in graphs, text, and images to analyze and contextualize the evidence (Claro et al. 2012, p. 1045).

The NAEP-TEL assessment in the United States was also computer-based and included interactive, “multimedia scenario-based tasks (SBTs)” (NCES 2016b). Students were required to solve technology and engineering problems in real-world contexts that were designed to allow students to demonstrate the range of knowledge and skills detailed in the three content areas (Technology and Society, Design and Systems, and Information and Communication Technology) across three practices (Understanding Technological Principles, Developing Solutions and Achieving Goals, and Communicating and Collaborating). Some tasks related to one content area and practice, while others were concerned with more than one content area or practice. In one SBT, a local fruit juice company had offered to build a new recreation center for teenagers. Students were required to create content for a website promoting the benefits of building the recreation center (NCES 2016a). Another involved a group project examining the advantages and disadvantages of a cold medication. Students searched a relevant website and used evidence from that site to develop an evaluation. A third involved planning the building of a tree house using information from a website about tree houses and searching for information about the strength of different types of tree. The complete TEL assessment included 20 SBTs and 97 discrete questions within a rotated design so that individual students responded to only a portion of the entire assessment.

Computer Literacy of Students

In order to estimate the extent to which students are computer literate, it is necessary to focus on those studies that involve representative samples of defined student populations in one or more education systems. In practice, most of these studies focus on lower secondary schools (Years 7–10).

Perspectives from ICILS

In 2013, ICILS investigated the computer literacy of Year 8 students and established four described levels of its computer and information literacy (CIL) scale. In addition, there were a small number of items that had difficulties below Level 1 which represented the most basic skills and did not warrant description (Fraillon et al. 2014). The levels are outlined in Table 1 together with the percentages of students in the ICILS countries whose computer literacy score would place them in each of the levels.

In addition to recording the percentage distribution across levels for the 14 countries, Table 1 also shows the distribution for 12 countries with Thailand and Turkey omitted because the distributions for those 2 countries were very different from the other 12 countries. The discussion focuses on the 12-country distribution.

The ICILS scale is hierarchical in the sense that computer literacy becomes more sophisticated as student achievement progresses up the scale. Table 1 records the percentages of students "in each level" as well the percentages "up to and in each level" (in other words, the cumulative percentage). Students working below Level 1 are unlikely to be able to create digital information products.

At Level 1, students show familiarity with basic software commands enabling them to access files, complete routine text and layout editing, recognize basic software conventions, and recognize the potential for misuse of computers by unauthorized users. At Level 2 (which could be considered computer literate – see later) and beyond, students are familiar with and can use a broader range of software commands. They can format text and images in information products. At Level 3, they can edit and create information products with attention to layout and design, and at Level 4 they show an awareness of audience and purpose when formatting information products that they create including using layout and formatting features appropriately. At Level 2, students can use computers as information resources to locate information in digital sources as well as select and add content to information products. At Level 3, students independently search for information and select relevant information from digital resources being aware that information may be biased, inaccurate, or unreliable. Key factors differentiating Level 4 from Level 3 are the extent to which students can work autonomously with a critical perspective when accessing information and the precision with which they search for and locate information.

The data in Table 1 show that across the 12 countries, just over two thirds (69%) of Year 8 students recorded scores in Levels 2, 3, or 4. There was some variation across these countries with the eight middle countries in the distribution having percentages ranging from 64% to 75%. Across the 12 countries, just over one quarter (26%) of Year 8 students recorded scores that corresponded to a Level 3 or Level 4 attainment.

Links to the Australian National Assessment of ICT Literacy

ICILS 2013 was administered in Australia to a sample of 5326 students from 320 schools (de Bortoli et al. 2014). In addition to the ICILS assessment, students

Table 1 Percentages of Year 8 students at each proficiency level in ICILS 2013

Level description	Average % students (14 countries)		Average % students (12 countries)	
	In level	Up to and in level	In level	Up to and in level
Level 4:	2	2	2	2
Select the most relevant information to use for communicative purposes				
Evaluate usefulness of information based on criteria associated with need and evaluate the reliability of information based on its content and probable origin				
Create information products that demonstrate a consideration of audience and communicative purpose				
Use appropriate software features to restructure and present information in a manner that is consistent with presentation conventions, and adapt that information to suit the needs of an audience				
Demonstrate awareness of problems that can arise with respect to the use of proprietary information on the Internet				
Level 3:	21	23	24	26
Demonstrate the capacity to work independently when using computers as information-gathering and information-management tools				
Select the most appropriate information source to meet a specified purpose, retrieve information from given electronic sources to answer concrete questions, and follow instructions to use conventionally recognized software commands to edit, add content to, and reformat information products				
Recognize that the credibility of web-based information can be influenced by the identity, expertise, and motives of the creators of that information				
Level 2:	38	60	42	68
Use computers to complete basic and explicit information-gathering and information-management tasks				
Locate explicit information from within given electronic sources. These students make basic edits and add content to existing information products in response to specific instructions				
Create simple information products that show consistency of design and adherence to layout conventions				
Demonstrate awareness of mechanisms for protecting personal information				
Demonstrate awareness of some of the consequences of public access to personal information				

(*continued*)

Table 1 (continued)

Level description	Average % students (14 countries)		Average % students (12 countries)	
	In level	Up to and in level	In level	Up to and in level
Level 1:	23	83	23	91
Demonstrate a functional working knowledge of computers as tools and a basic understanding of the consequences of computers being accessed by multiple users				
Apply conventional software commands to perform basic communication tasks and add simple content to information products				
Demonstrate familiarity with the basic layout conventions of electronic documents				
Below Level 1:	17	100	9	100
Execute only the most basic skills (e.g., clicking on a hyperlink)				

Adapted from data provided in Table 3.6 in Fraillon et al. (2013, p. 98). The data refer to the 14 countries that satisfied the IEA response rate criteria: Australia, Chile, Croatia, Czech Republic, Germany, Korea, Lithuania, Norway, Poland, Russia, Slovak Republic, Slovenia, Thailand, and Turkey

also completed a module from the National Assessment Program Information and Communication Technology Literacy (NAP-ICTL) assessment (ACARA 2012). The purpose was to benchmark the NAP-ICTL scale against the international ICILS scale (ACARA 2012). It found that ICILS Level 1 was equivalent to NAP-ICTL Level 2, ICILS Level 2 was similar to NAP-ICTL Level 3, ICILS Level 3 to NAP-ICTL Level 4, and ICILS Level 4 was equivalent to NAP-ICTL Levels 5 and 6.

The NAP-ICTL surveys involved a standards-setting exercise (MCEETYA 2007). Consultations were held with panels of practicing teachers, ICT curriculum experts, and educational assessment experts. They examined test items and results from the assessments to agree on proficient standards for each year level (MCEETYA 2007, pp. 46–47). The proficient standard for Year 6 was defined as the boundary between NAP-ICT Levels 2 and 3 (ICILS Levels 1 and 2), and the proficient standard for Year 10 was defined as the boundary between NAP-ICT Levels 3 and 4 (ICILS Levels 2 and 3). Based on this standard setting, it can be concluded that across 12 developed countries, two thirds (68%) of Year 8 students had attained a standard of proficiency that would be recognized for a Year 6 as computer literate and one quarter (26%) had attained the standard of proficiency for a Year 10 student.

Perspectives from the NAEP-TEL Assessment

In the US Technological and Engineering Literacy Assessment (TEL), results were reported in terms of the percentages of Year 8 students in three performance bands and a fourth band that was lower than basic (NCS 2016b). The descriptors of these bands incorporate the related content areas of Technology and Society, Design and Systems, and Information and Communication Technology. Table 2 records the descriptors that refer to the Information and Communication Technology content area.

Perspectives from the ICT Skills for Learning Test in Chile

Results from the ICT Skills for Learning Test in Chile referred to the percentages of 15-year-old students who would be expected to successfully complete eight major tasks or levels. The analyses resulted in a set of tasks empirically ordered from most difficult to least difficult. The tasks are listed in Table 3 along with the percentages in each level and at or above each level (Claro et al. 2012).

Claro and colleagues (2012, p. 1050) concluded that approximately three quarters of Chilean students were able to search for information, half were also

Table 2 Descriptors of performance bands in the US Technological and Engineering Literacy Assessment with percentages of Year 8 students in each band: 2014

Proficiency band and descriptors	% students at level	% students up to and in level
Advanced	3	3
"Draw upon multiple tools and media to address complex problems and goals, and demonstrate their understanding of the potential impacts on society"		
"Integrate the use of multiple tools and media, evaluate and use data and information, communicate with a range of audiences, and accomplish complex tasks"		
"Explain the ethical and appropriate methods for citing use of multimedia sources and the ideas and work of others"		
Proficient	40	43
"Select and use an appropriate range of tools and media for a variety of purposes, tasks, and audiences"		
"Contribute to the work of collaborators"		
"Find, evaluate, organize, and display data and information to answer research questions"		
Basic	40	83
"Use common tools and media to achieve specified goals and identify major impacts"		
"Select common information and communications technology tools and media for specified purposes, tasks, and audiences"		
"Find and evaluate sources and organize and display data and other information to address simple research tasks"		
"Appropriately acknowledge the work of others and use feedback from colleagues"		
Below basic	17	100

Adapted from data provided in NCES (2016b)

Table 3 Percentages of 15-year-old students able to successfully complete each type of task in the ICT Skills for Learning Test in Chile: 2009

Task type or level	% students at level	% students up to and in level
Successfully perform all eight tasks including being able to "refine digital information and create a representation in a digital environment (e.g., synthesize, interpret, and represent information using worksheet tools and functions)"	17	17
Able "to develop their own ideas in a digital environment (e.g., publish a post or write an email adequate in content"	13	30
Evaluate "digital information using specific criteria related to quality (e.g., authorship, relevance, edition)" and "analyze digital information (e.g., integrate and compare information presented in a digital representation)"	10	40
"Transmit information effectively by selecting the most appropriate media (e.g., blog, social network, email, etc.) and information to communicate in a digital environment and collaborate and interact in virtual networks (e.g., solve a problem in virtual interaction with others)" as well as being able to search for, select, and organize digital information	11	51
Organize and manage digital information (e.g., search for files and arrange folders in the computer) as well as search for and select digital information	12	73
Not able to demonstrate mastery in any of the tasks	27	100

Adapted from data provided in Claro et al. (2012, p. 1050)

able to organize and manage digital information, but only one third of the students are able to develop their own ideas in a digital environment, and less than one fifth could refine digital information and create a representation in a digital environment.

Perspectives from the ICT Literacy Assessment in Korea

Kim and Lee (2013) report the results of an Internet-based test of ICT literacy that incorporated 36 multiple-choice and performance items and was administered to a representative sample of 15,558 middle-school students in Korea in 2011. A set of performance levels was defined through a standard-setting exercise with expert judges. According to Kim and Lee (2013, p. 85), "excellent" represented an ability "to use or create information using existing ICT most effectively for solving problems"; "average" indicated "an understanding of the operating principles of computer and IT equipment" as well as "essential concepts and principles of computer science" and being able to use ICT for solving problems somewhat effectively; and "basic" signifies the ability to use IT skills "without having an understanding of the principles behind the skills." The percentage distribution of student scores for Grade 3 was categorized as excellent (8%), average (34%), basic (53%), and below basic (4%).

Factors Associated with Computer Literacy

From a number of studies, it is evident that student computer literacy varies across countries, across schools within countries, and across students within schools. To begin with the variation across countries, average computer literacy varies greatly across countries and is positively associated with the *ICT Development Index* and negatively associated with the average ratio of students to computers in schools (Fraillon et al. 2014). Aesaert et al. (2015) point out that national ICT policies influence school and classroom practice through the curriculum, professional development for teachers, and the provision of resources. In terms of variation within countries, Aesaert et al. (2015) proposed a multilevel model based on factors from the student, classroom, and school level to explain differences in computer literacy within countries.

Individual Influences

Student-level influences on the development of computer literacy can be considered in terms of attitudinal or dispositional characteristics, familiarity with ICT, and background characteristics. In terms of attitudinal factors, Hatlevik et al. (2015) report that higher levels of mastery orientation and self-efficacy were associated with the development of digital competence in Year 7 students in Norway. ACARA (2015) reports that ICT literacy and ICT self-efficacy were both associated with interest and enjoyment in using computer technology. Greater interest in and enjoyment of ICT use were associated with higher CIL scores in 9 of the 14 countries that met the ICILS sampling requirements (Fraillon et al. 2014). The direction of the relationship between ICT or computer literacy and ICT self-efficacy is not clear from these studies and may involve reciprocal links. It also appears that measured computer literacy is positively associated with basic ICT self-efficacy but not with advanced ICT self-efficacy (Fraillon et al. 2014; Rohatgi et al. 2016). This is consistent with measures of computer literacy being focused on information and communication rather than advanced computer skills such as programming or database management.

Familiarity with computer technology is taken to include frequency of use and experience of using the technology. These factors appear to be consistently associated with computer literacy and self-efficacy in many countries (ACARA 2015; Fraillon et al. 2014; Kim et al. 2014; Rohatgi et al. 2016). Interestingly, it appears that ICT use for recreation may be a stronger predictor of computer literacy than ICT use for study or school purposes (Rohatgi et al. 2016). Among background characteristics, greater access to ICT resources (e.g., access to a home Internet connection and the number of computers at home) and higher socioeconomic status in general (e.g., as measured by parental occupation and educational attainment, the number of books in the home, or access to subsidized meals) are consistently associated with higher levels of computer literacy (ACARA 2015; Fraillon et al. 2014; Claro et al. 2012; Kim et al. 2014; Hatlevik et al. 2015). Aesaert et al. (2015) argue that, in addition to the socioeconomic characteristics of homes, consideration needs to be given to parental attitudes to, and practices with, information technology.

A number of studies report that girls have higher levels of computer literacy than boys (ACARA 2015; Fraillon et al. 2014; Kim et al. 2014) but this is not universally the case with some studies reporting the reverse and others finding no difference (Rohatgi et al. 2016). It seems possible that an explanation for this mixed pattern could lie in the nature of the assessments with those assessments that emphasize information literacy favoring girls and those that emphasize technical aspects favoring boys.

There is also evidence that computer literacy is higher for students in more advanced school years than those in earlier school years. The Australian National Assessment of ICT Literacy used a linked scale covering Year 6 and Year 10 so that it was possible to compare the performance of students 4 years apart (ACARA 2015). It found that students in Year 10 exhibited higher levels of computer literacy than students in Year 6. The differences were between one and one and a half standard deviations but becoming smaller over time from 2005 to 2014. Kim and Lee (2013, p. 87) also report higher levels of computer literacy among students in the third year of secondary school than among students in the first year of secondary school.

Classroom and Teacher Influences

The model proposed by Aesaert et al. (2015) includes among potential classroom- and teacher-level influences teachers' ICT competence, attitudes to ICT, professional development, logistic appropriateness, ICT use, and ICT experience. However, there are few reported studies that relate teacher attributes and classroom practices using ICT to the development of student computer literacy. There is evidence that the emphasis on developing computer literacy is related to teachers' ICT self-efficacy and positive views of ICT in education (Fraillon et al. p. 218). It also appears that the emphasis placed on developing computer literacy varies across learning areas being much higher in computer studies than in other learning areas and relatively higher in science and human sciences or humanities than in mathematics (Fraillon et al. 2014, p. 220). Kim et al. (2014) suggest that satisfaction level of students in classes using ICT was related to students' ICT literacy levels. Again, the direction of causality is not clear.

School Influences

There are several studies that explore school-level influences on student computer literacy. It does generally appear, across most countries, that the average level of socioeconomic background of the students attending a school is associated with student computer literacy (Fraillon et al. 2014). Hatlevik et al. (2015) found that commitment among teachers in a school toward professional development was associated with students' computer literacy. Dexter (2008) argued that managing teachers' professional development in the use of ICT for teaching and learning was an important school-level influence on the use of ICT in schools. Fraillon et al. (2014) found that collaboration among teachers about the use of ICT was positively associated with the emphasis placed on developing computer literacy. ICILS also reported that in several countries student reports of having learned about ICT at school were associated with higher levels of computer literacy (after controlling for other measured influences).

Emerging Issues

The Challenge of Change

Changes in hardware and software technologies have meant that the contexts in which computer literacy can be demonstrated have also changed. An important question is whether the nature of the computer literacy construct has remained consistent even though advances in hardware and software technologies have meant that the contexts in which computer or ICT literacy can be demonstrated have changed. Studies that have attempted to measure changes in computer literacy over time have used anchor tasks between adjacent cycles and new tasks to accommodate new developments in software and hardware contexts (ACARA 2015). It is important to establish that the construct has remained the same if the proportions of students who are computer literate are to be compared.

Computer Science and Computational Thinking

There has emerged a challenge to the idea that computer literacy as currently conceptualized is an adequate element of understanding computing and computers. This challenge proposes that learning to use and apply computer technology is not an adequate representation of computer literacy and that understanding some principles of computing has educational benefits (Peyton Jones 2011). In other words, this view sees the sort of thinking used when programming a computer as being part of computer literacy (Grover and Pea 2013; Lye and Koh 2014). Computational thinking includes activities such as formulating, representing, analyzing, and executing a solution. This can involve developing or implementing an algorithm with computer code. The principles of teaching computational thinking resonate with work from five decades ago using "logo" and "turtle graphics" (McDougall et al. 2014). A number of countries have school computer science courses that contain computational thinking. The take-up of the ideas of computational thinking represents a challenge to the ways in which computer literacy has been envisaged since 2002. There remains a debate as to whether this provides a basis for general education (Barr et al. 2011) and how computational thinking relates empirically to computer literacy as currently conceptualized.

Conclusion

Since 2002, computer literacy has been accepted as referring to being capable of accessing, evaluating, using, managing, processing, and communicating information with digital technology. On the basis of international and national studies of computer literacy, it appears that there are substantial variations in levels of computer literacy among students in the lower and middle grades of secondary school. Therefore, there is no simple unambiguous answer to the question are students computer literate? In most countries, there is a group of students whose computer literacy is very limited. In most technologically developed countries, this appears to be fewer than 10% of students, but it is more than that in many countries. In general, approximately one half of lower secondary students demonstrate proficiency, or advanced proficiency, in computer literacy, and approximately one quarter demonstrate advanced proficiency in computer literacy. However, the field could benefit from investigations of how the various measures of computer literacy relate to each other from standards-setting exercises that could inform judgments about the scores on these scales that represent computer literacy.

Computer literacy is higher in countries with higher levels of ICT development and within countries is higher among students whose families are socioeconomically advantaged, who are more familiar and experienced with computer technology, and who have greater confidence in using computer technology. Girls tend to have slightly higher levels of computer literacy than boys. It is sometimes assumed that young people who have grown up with computers as a ubiquitous part of their lives will have high levels of computer literacy. However, there remain wide variations in computer literacy, and there is a challenge to ensure all young people are capable of productively using a range of digital technologies. Part of that challenge is to build a larger base of empirical studies of school and classroom influences on the development of computer literacy. Longitudinal studies of these influences on changes in computer literacy would be especially informative.

If we are to ensure that the widest possible range of young people becomes computer literate, greater attention needs to be given to the inclusion of education about computer technologies in the school curriculum. Designated courses about computer technology currently appear to provide the greatest emphasis on developing computer literacy, and the prospect for developing computational thinking, but what happens in other subjects is also important. Computer literacy is best seen as a cross-curricular capability and needs to be underpinned by progression maps (such as those reviewed in this chapter) that are linked to curricula in other learning areas. A progression map could provide a focus for collaboration among teachers and for professional learning activities for teachers.

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Computer Science and Computational Thinking in the Curriculum: Research and Practice

7

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Contents

Abstract

Computer science education, including computational thinking, has received considerable attention over the last few years as more and more countries are expanding or starting efforts in the primary and secondary schools. In this chapter, we provide examples of computer science efforts in a number of countries, including the United States, and discuss how these efforts to increase the role of computing in schools gives us a unique opportunity to expand computing education research, which

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has significantly lagged the rapid growth of computer science. We have laid out directions for future research under two broad areas of teaching training and student learning. Specifically, we discuss potential research areas around knowledge teachers need to teach computing ideas and factors that influence students learning to program.

"The child programs the computer and, in doing so, both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building" – Seymour Papert

Keywords
Computer science education · Computational thinking · Teacher development · Student learning

Introduction

The above quote by Papert in *Mindstorms* highlights the power of computing to enhance how students think and learn by changing mental processes even when they are removed from the physical presence of a computer (Papert 1993). This is even more true today as computing has significantly changed how we interact with our world. From how we consume information to simulating scientific processes, the pervasiveness of computing technologies touches all aspects of our lives. Furthermore, computing tools and ideas provide individuals with opportunities to extend their creative expression to solve problems, create computational artifacts, and even develop new knowledge (Yadav and Cooper 2017). Computing promotes innovation by allowing individuals to explore and create digital artifacts and "extend traditional forms of human expression and experience" (College Board, p. 8). For example, Mishra and Yadav (2013) highlighted two examples of how individual creative expression in partnership with the power of computing can lead to new forms of artifacts. One of the examples included David Cope, a noted musician, who used programming as an extension of his brain to compose music (with the computer program as a co-composer). The deep knowledge of music and an understanding of computer programming allowed David to combine the power to develop creative insights into composing music. This example highlights the ever-increasing use of computation across multiple fields, which makes it imperative to prepare students for their future studies and careers.

At the same time, demand for professionals with computing experience, the interest of undergraduates in computer science (CS) as a major, and the overall drive to expand computer science course offerings in K-12 have increased considerably in the last few years (Strickland 2014; Taylor and Miller 2015). Hence, there is a push for students across the elementary, secondary, and postsecondary education spectrum to understand computing ideas and how they influence our lives. Computational thinking has been suggested as one way to introduce students to concepts fundamental to computer science and expose students to a "range of mental tools that reflect the breadth of computer science" (Wing 2006).

In this chapter, we discuss computational thinking, its applicability across the curriculum, and how it could instantiate across the primary and secondary classrooms. Next, we provide an overview of computer science education initiatives across the globe, including the United States, United Kingdom, the Netherlands, Australia, and Mexico. Finally, we argue that these initiatives provide computer science education researchers with opportunities to develop an empirical base on factors that influence how students learn computing ideas, how to train teachers in computing, and how to support diverse learners in computing.

Computational Thinking: A Problem Solving Approach for Digital Age

Computational Thinking (CT) has been defined as a set of mental skills that were historically developed though the study and practice of computer science, yet can be found and used across multiple contexts (Barr and Stephenson 2011; Wing 2008). Wing (2006) stated that CT involved "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (p. 33). Denning (2017) argued that computational thinking came into wide using during the 1980s when it was referred to as computational science. During this era, scientists started using computational science as the term for emerging branches of science that used computation as their primary method of inquiry. Physicist Kenneth Wilson, who developed "computational models that produced startling new discoveries about phase changes in materials," was instrumental in lending credence to the field. Denning also suggested that some of the scientists "used the term computational thinking for the thought processes in doing computational science – designing, testing, and using computational models." He went on to define computational thinking as "the mental skills that facilitate the design of automated processes" and asserted that CT became popular after 2006 when educators started using computation as a part of STEM education in order to draw more young learners to science. While there have been a number of CT definitions, Wing (2006, 2008) identified three A's of computational thinking as being central to the practice of computer science and as being the most critical skills for students to develop – abstraction, algorithms, and automation.

Abstraction

Wing (2008) described abstraction as "the essence of computational thinking" in which "deciding what details we need to highlight and what details we can ignore – underlies computational thinking" (pp. 3717–3718). Abstraction allows us to deal with complexity by focusing on the essence of an object/problem and ignoring unimportant details. Using abstraction, individuals must choose "the right detail to hide so that the problem becomes easier, without losing anything that is important" (Csizmadia et al. 2015, p. 7). Throughout the process of enacting possible solutions to problems, individuals must repeatedly revisit their previous abstractions to refine them, test them, and refine again. Abstraction is used to craft algorithms, decide upon test cases, identify needs of the stakeholders, and a myriad of other tasks related to problem-solving.

Algorithms

Algorithms in their most basic form are a series of step-by-step instructions for how to complete a task. Wing (2008) stated that algorithm is an "abstraction of a step-by-step procedure for taking input and producing some desired output" (p. 3718). As algorithms become more complex they allow for decision points, request data from other sources, and may branch into simultaneous processes. The development, refinement, and repeated use of these algorithms is another central component of computational thinking (Wing 2006, 2008; Barr and Stephenson 2011; Yadav et al. 2016b). Within the context of computer science, algorithms are represented through lines of code, whereas within the noncomputing environment algorithms could be employed via flowcharts and similar planning tools to ensure that tasks are completed in a complete and timely manner. We use algorithms daily in our lives to accomplish simplistic tasks, such as brushing our teeth, to solving more complex problems, such as the traveling salesman problem. For students, refining the skill of developing algorithms allows them to employ their existing abstractions to develop solutions to problems. The visual or textual representations of those algorithms provide a guide to their planned steps, which they can refer to when interpreting unexpected results.

Automation

Wing (2008) argued that while abstraction is the mental tool of computing, computing itself is the automation of our abstractions. Automation, the act of mechanizing an algorithm, gets to the heart of what makes computation so powerful in multiple fields. In its most common form, automation is enacted through the use of computing hardware and software. However, Wing also argued that this could also be done within the human "hardware," as there are tasks that humans still execute more efficiently than computers, such as visual interpretation of objects. For students, this is not simply learning how to translate instructions into code, or a set of steps for their classmates to enact. For automation to be powerful, students must consider the strengths and weaknesses that their "hardware" provides. Crafting an algorithm with these characteristics in mind will results in a more effective and efficient solution.

CT in Primary and Secondary Education

Building on Wing's work, researchers have expanded on these central computational thinking concepts to allow educators to embed them in elementary and secondary classrooms. For example, Barr and Stephenson (2011) envisioned computational thinking in the classroom through a collection of nine CT concepts and capabilities. Specifically, they suggested that data collection, data analysis, data representation, problem decomposition, abstraction, algorithms/procedures, automation, parallelization, and simulation have applicability across multiple subject areas in elementary and secondary classrooms contexts. Grover and Pea (2013) also offered elements of computational thinking that could form the basis of curricula, including pattern generalizations, processing of information, problem decomposition, and conditional logic. While programming is one of the key tools for supporting the development of computational thinking, researchers have also suggested that unplugged activities (i.e., not using a computer) are equally valuable in introducing computing ideas and the nature of computer science to students (Grover and Pea 2013; Yadav et al. 2014, 2017).

To introduce CT concepts to a primary and secondary audience, it is critical to keep in mind that these skills are already being used to some degree in the classroom (Weintrop et al. 2016). What computational thinking provides is a framework for naming, organizing, and developing these abilities into a complementary skillset (Voogt et al. 2015). Students use abstraction when deciding what belongs on a chart of plant growth, categorizing numbers in a mathematics lesson, or writing a report on their summer vacation. Algorithms are developed and employed in science experiments, developing strategy in sports in gym, and developing daily study habits. Automation can be found in simulations and models that are enacted with software in the classroom, such as viewing animations of the effects of global warming models on coastlines, how altering the shape of a catapulted object affects its velocity and flight path, or how different preferences may affect how students arrange themselves on a school bus.

We believe that computational thinking provides a framework for educators and students to become familiar with how computing ideas influenc and transform other disciplines. This has multiple benefits as students develop an understanding of computational thinking. First, it opens pathways for students into computing fields and even prepares students for a future in computer science. Those entering a programming course for the first time will be aided by the familiar terminology such as algorithms, data, and logic. Second, it allows students to understand how computation shapes their lives in an increasingly digital and computerized world. A knowledge of CT concepts and practices provides students with opportunities to see its applicability and use to solve complex problems in other domains. For example, a scientist may be able to use CT skills to automate lab tests and analyze results; an artist could use it to design computational artifacts; and a historian could discover patterns in documents and maps as a result of having an understanding of CT.

Another argument for embedding CT ideas in primary and secondary schooling is to prepare students to become critical consumers of information in a digital age. The knowledge of computing would give students a skillset to be critical of how and why they receive particular news stories and know how advertisers target their needs. Gretter and Yadav (2016) argued that computational thinking is complementary to media and information literacy to provide students with not only useful tools for their further studies and careers but also a critical lens through which to approach their personal and professional lives. Majority of the efforts to expose students to CT has been lead under the umbrella of computer science education efforts. In the following section, we discuss how these efforts are shaping up across the globe.

Curriculum for Computer Science Education: A Global Perspective

Across the globe, a number of governments and organizations have ramped up efforts to expand access to computer science in primary and secondary classrooms. For example, in the United States, the CS for All consortium is a culmination of years of hard work of computer science education community to expand computing education in K-12 schools in the United States. Similar efforts are underway in other countries, such as Computing at School in the United Kingdom (Peyton-Jones et al. 2013) and Digital Literacy in the Netherlands (Voogt and ten Brummelhuis 2014). The common thread across all of these initiatives is the need to prepare students for the jobs of the future in a twenty-first-century digital economy. The jobs argument is valid and strong as computing jobs are one of the highest job growth areas over the next decade (Bureau of Labor Statistics 2016). However, just using the jobs as the reasoning for computing education sells short the power of computer science to influence students' thinking and creativity. A stronger argument could be made regarding how computing allows an expression of creative ideas and develop students' problem-solving abilities (Yadav and Cooper 2017). The emphasis on creativity in computing has appeared in many places in newly developed curriculum, including its appearance as one of the seven big ideas in the new Advanced Placement Computer Science Principles Course.

Current State of Affairs: The United States

The current push towards increased access to computer science in American elementary and secondary schools has been based on a number of efforts over the last decade led by National Science Foundation (NSF) and Computer Science Teachers Association (CSTA). With support from NSF, the College Board launched a new course entitled Advanced Placement Computer Science Principles (CSP) in 2016–2017 to help increase student participation in computing. The CSP course, which focuses on a selected subset of seven big ideas in computer science (Abstraction, Algorithms, Creativity, Data and Information, the Internet, Global Impact, and Programming), covers concepts from a broader perspective than traditional programming-centered courses (College Board 2016). One of the chief aims of this course is to attract a more diverse set of learners given the large gender and racial imbalance in computer science courses.

Both the CSP course and increase in computer science education advocacy led by NSF, CSTA, and Code.org has driven a significant increase in demand of computer science courses in US schools. For example, the number of overall students taking the AP CS A exam increased by 17.3% in 2016 (Ericson 2016). While this growth has been significant in terms of overall participation, the number of women and underrepresented minority student participation is still far below the expected rates. Additionally, pass rates for students of color remain abysmal. Given the focus of CS principles on big ideas of computing, it is hoped that it would open pathways for all students to pursue computing and reduce the disparities in numbers of minority students in computer science.

While there is an increase in enthusiasm and enrollment of students into computer science, there are several barriers that exist that could derail these efforts. One of the biggest challenges to meet the critical needs in computing education in the United States is the training of new teachers (CSTA 2013). A report on teacher certification in the United States stated that "teachers, administrators, and policymakers must work together to create requirements that are grounded in the discipline of Computer Science and these requirements must be supported by teacher preparation programs for pre-service teachers and professional development for current teachers that enable all teachers to become exemplary teachers" (CSTA, p. 26). With various entities pushing for every student to have access to computing education in the curriculum, the need for qualified educators is the major bottleneck for reaching equity and accessibility goals. While a number of efforts have focused on providing professional development and training for inservice teachers, there is an urgent need to develop pathways at the teacher preparation level to provide certification for pre-service teachers to teach computer science (Flatland et al. 2015). Once the issue of how to recruit, train, and retain computer science educators has been addressed, future steps to examine best teaching practices will move to the forefront in CS teacher preparation.

Current State of Affairs: United Kingdom

Similar to the efforts in the United States, Computing at School (CAS) effort in the United Kingdom has spearheaded computer science in elementary and secondary classrooms. The working group for CAS had its inception at Microsoft Research Cambridge in 2008, and blossomed as part of a partnership with the British Computer Society (Peyton-Jones et al. 2013). The collaboration between these groups was the start of the development of a full computing program for primary and secondary schools in schools in Scotland, Wales, Northern Ireland, and England. In 2012, following the publication of the report "Shutdown or Restart" from the Royal Society, the government made the necessary legislative changes to include computing in the curriculum (Furber 2012). To change the computing opportunities for learners in the United Kingdom, a General Certificate of Secondary Education for Computer Science was henceforth offered to students at age 16. This was the replacement to an existing curriculum for an Information and Computing Technology course which allowed students to focus on computer science concepts in their program of study. Additionally, computer science was added to the English Baccalaureate science section. This effort has seen a rise in the number of students participating in the General certificate of Secondary Education (GCSE) for computer science to 62,945 students in 2015–2016 (from 15,557 in 2013–2014), with 12,700 of those students being female (from 2300 in 2013–2014) (United Kingdom Department for Education 2016).

In order to meet the growing need for CS teachers in the United Kingdom, the government has primarily focused on recruiting new educators in computer science with the launch of a program to provide scholarships of £20,000 for computer scientists that intend to train to become teachers. To support beginning teachers, CAS has also led the effort to provide professional development of computer science teachers through local communities of practice. Sentance et al. (2014) discussed the CAS professional development model, which uses master teachers to support beginning computer science teachers in a community of practice. Master teachers are experienced computer science teachers with "excellent subject pedagogy and outstanding classroom practice" (p. 81), but also have "experience in mentoring colleagues, running training sessions, and credibility in their communities" (p. 82). Other parts of the United Kingdom have experienced different challenges in their CS education efforts, mostly around issues of teacher preparation. A report by CAS Scotland found that there is a greater outflow of retiring teachers as compared to influx of new CS teachers, which has led to a 25% drop in CS teachers (CAS Scotland 2016).

Current State of Affairs: Examples from Other Countries

A number of other nations have focused their attention on CS education at the primary and secondary levels. Of particular interest are regions and nations that have seen investment from advocacy groups, and the curriculum changes that seek to engage all students in the conversation about computing.

In Netherlands, a dramatic shift towards computer science education happened in 2013 with the publication of a report on digital literacies by the Royal Netherlands Academy of Arts and Sciences (See Lenstra et al. 2012). The report forced Dutch educators to assess the role of computational thinking in their preexisting digital literacy courses (Voogt and ten Brummelhuis 2014) and how it fits "as part of the digital literacy skills along with critical thinking skills when using Information and Communication Technologies (ICT), and applying (ethical) rules when using ICT, including notions of privacy and security" (Yadav et al. 2017, p. 1055). In addition to the computing specific change, Netherlands has also embraced a larger national movement known as "Onderwijs 2032," with a goal to create a dialogue on skills needed by students that will graduate in 2032.

Australia made a commitment to invest $12 million to revamp the national curriculum, aiming to replace components of history and geography at the primary level with coding (Sarabia 2015). As a part of this effort, the Victorian Certificate of Education (VCE) includes a new study on algorithmic thinking to provide students with the foundation to study computer science and software engineering. In New Zealand, there are digital technology guidelines now in place for schools based on a listing of "Technological Context Knowledge and Skills," including a segment focused solely on computer science (Bell et al. 2010). This includes higher level questions regarding tractability, coding complexity, and implementation of the software development lifecycle.

Israel has a long history of attention to computer science education dating back to influential changes in the mid-1990s. In the early 2010s, a renewed emphasis was placed on the sciences, which included a revamp of the computer science curriculum in secondary schools. In addition, students in Israel may take an entire computer science track in high school, which involves five additional units including topics such as, cybersecurity, graphics, and mobile development (Gal-Ezer and Stephenson 2014). Other supporting elements in Israel include the Machshava, which is the Israel National Center for Computer Science Teachers. The center focuses the work of Israeli CS educators through conferences, courses, meetings, publications, and learning material development.

Finally, in Mexico we have an example of a nation that is taking some preliminary steps towards engaging the population with computing curriculum. Student enrollment is up overall (94% of 6–14-year-olds in 2010), but the nation still deals with high dropout rates. A majority of schools do not have computers at all, and only 18% have access to the Internet. In conjunction with CS Ed Week 2014, Mexico adopted the Scalable Game Design approach, and implemented CS Ed Week activities in a small number of schools focused on this curriculum (Escherle et al. 2016). The impact of this approach has yet to be measured fully, and there is much work to do to provide opportunities to explore computing across the curriculum.

Research Agenda for Computing Education

The growing demand to increase the role of computing in schools also provides a unique opportunity to expand computing education research, which has significantly lagged the rapid growth of computer science. We have decided to use computing education research rather than computer science education intentionally because we do not want this productive research area to be limited to just learning to program. Instead, we view computing education research broadly, which includes questions like how to embed computational thinking concepts and practices in other subject areas; how do computing activities influence learners creative thinking; what knowledge teachers need to effectively teach computing concepts; how to train CS teachers through professional development and teacher preparation programs; how to assess student learning and understanding of computing ideas; and how to engage a diverse group of learners in computing. Computing Community Consortium recently released a white paper (Cooper et al. 2016) on the importance of computing education research and called the field to answer some fundamental research questions in the field:

- “How should we teach computer science, from programming to advanced principles, to a broader and more diverse audience?
- How can we ensure that we retain this more diverse audience through inclusive pedagogy and generally more effective teaching?
- How can teaching approaches and their assessment (regarding student learning) scale effectively?

- What training should K-12 teachers receive? What methods have been shown to be effective?
- How can computer science teaching adapt to how different people learn and build on age-related learning progressions?
- How should computing be taught and integrated into other disciplines?" (p. 1–2)

These broad questions serve as a good starting point for computing education researchers to expand the empirical basis for what works. However, in order to answer these questions, computer education research needs to move beyond experimental design as the standard for methodological rigor and value other theoretical perspectives and approaches. While there are a number of research studies that could be developed under these questions, we focus remainder of the chapter on a discussion around computer science teacher development and factors that influence student learning in computer science.

Research on Teacher Training and Development

As discussed previously, training and development of teachers remains one of the biggest obstacles to meet the growing demand of computing courses. The challenge is not only to train new teachers to teach computer science but also prepare teachers to embed computational thinking within core subject areas. The challenge of recruiting, training, and retaining CS teachers becomes even more problematic given that we know little about what knowledge teachers need to effectively teach computing concepts and how to support CS teachers given that they are typically the lone teacher in schools (Yadav et al. 2016). A recent study by Yadav and colleagues (2016) found that CS teachers report a number of challenges related to teaching computer science, including limited content and pedagogical knowledge related to computer science. Specifically, the study found that teaching computer science presents a unique set of challenges outlined below.

- *Isolation*. There are few computer science teachers (often at most one per school), and they typically work independently from one another. They rely on email lists and online discussion groups to stay in touch, rather than informal collaborations and opportunities to team teach.
- *Professional Development*. With the combined difficulties of a rapidly changing computing field, lack of training opportunities, and busy workday schedules, teachers are finding it increasingly difficult to stay current in the field.
- *Lack of Support*. Teachers face a lack of support for and interest in computer science from administrators and IT staff.

Other researchers have also reported similar barriers teachers face in the classroom and types of support they need to be successful (Sentance and Csizmadia 2016). Prior research on teacher retention has suggested that 40–50% of teachers leave the profession in the first 5 years as a result of a number of factors, including isolation (Fantilli and McDougall 2009). Within the STEM disciplines, teacher retention is even more dire as teachers in these fields are twice as likely to leave the profession than any other subject area (Ingersoll 2001). Furthermore, teacher turnover in urban areas is significantly greater than suburban areas as highlighted by Guarino et al. (2006) who found that “28% of teachers in the New York City region were still in the same school 5 years later, as compared with 46% in suburban schools” (p. 189). Given that the recent efforts to expand computer science have mainly involved large urban school districts in the United States, such as New York City and Chicago, so it is important for computer science educators to examine potential pitfalls in teacher retention and develop mechanisms to support beginning CS teachers.

While there is considerable work being done to provide professional development to teachers, we know little about the impact of this training with regard to addressing the following questions for the CS education community. How can we train and showcase effective instructional practices to inservice teachers, where they can learn to use the knowledge in the context of classroom practice? How do teachers acquire knowledge, including the knowledge of subject matter, pedagogy, and pedagogical content knowledge? The number of inservice teacher professional development providers, such as Project Lead the Way and Exploring Computer Science, provides an opportunity for researchers to better understand how different professional development models (face-to-face vs. online, short intensive summer programs vs. longer academic year programs, etc.) can support computer science teachers and develop their knowledge to teach computer science to all students.

In order to examine the effectiveness of the professional development efforts to train computer science teachers, researchers need to develop measures that examine teachers’ knowledge to teach computing (i.e., pedagogical content knowledge). Shulman (1986) argued that in addition to the knowledge of subject matter and knowledge about methods of teaching, ability to teach also requires pedagogical content knowledge (PCK), which includes “the ways of representing and formulating the subject that makes it comprehensible to others” (p. 9). We know very little about what computer science pedagogical content knowledge (CS-PCK) looks like and how teachers come to develop CS-PCK. In an analysis of teaching vignettes designed to measure CS-PCK, Yadav and colleagues (2016) found that computer science teachers are able to address observable issues of teaching; however, they struggle to see students’ thinking during teaching. Other researchers have also argued that measuring CS-PCK should include teachers’ ability to recognize and address student thinking (Margaritis et al. 2015). While there is some research beginning to emerge on CS-PCK, we need to measures that transfer across teacher training efforts to assess what models are successful in developing knowledge teachers need to effectively teaching computer science.

The computer science education community also needs to address teacher pipeline issues in order to ensure that there will be enough teachers to meet the increased demand of computing courses. A natural place to address this issue is at the pre-service teacher preparation level through colleges of education. Yadav and colleagues (2016) argued that the dearth of CS teacher preparation programs in conjunction with teacher attrition rates should cause alarms for CS education stakeholders, including policy-makers. A CSTA (2013) report highlighted that teacher certification in the United States is deeply flawed as there are few pathways for undergraduates to become certified to teach computer science. A Computing at School report in Scotland also called attention to similar challenge of recruiting high quality applicants to teacher education program in computer science (CAS 2016). So how do we prepare next generation of teachers to not only be able to teach computer science but also become computationally literate teachers. An initial starting point might be for teacher education programs to embed computational thinking ideas in the core courses for pre-service teachers. This could start with educational technology courses forming the core, and then incorporating CT ideas into content area methods courses (Yadav et al. 2017).

Yadav et al. (2017) provided a framework to prepare preservice teachers to teach computational thinking and provide recommendations on approaches to do so within the constraints of teacher education curricula. Prior research has suggested that once preservice teachers are exposed to computing ideas, they are more confident in their ability to integrate those ideas in their own practice (Yadav et al. 2011, 2014). We also believe that once teacher education students are exposed to these ideas, they are more likely to pursue computer science teaching licensure programs. Future research needs to examine these pathways for preservice teachers and how they come to understand computing ideas. For example, research need to understand how varying levels of exposure to computational thinking from small modules to integration in the teacher education curricula influences preservice teachers' knowledge of CT as well as confidence in pursuing computing courses.

Research on Student Learning in Computer Science

Research on student factors that play a role in learning has been one of the most productive areas within computer science education. A number of studies have examined how cognitive (e.g., Barker and Unger 1983), noncognitive (e.g., Wiedenbeck 2005), and background (e.g., Wilson and Shrock 2001) variables influence students' academic outcomes in computer science. Cognitive factors have mainly involved mental ability constructs, generally surrounding problem solving, critical thinking, analytical reasoning, and mathematical ability. Non-cognitive factors, on the other hand, have included motivational constructs, self-efficacy, and metacognitive strategies. Researchers have also examined how students' prior programming experience (e.g., Hagan and Markham 2000), anxiety and comfort level (e.g., Bergin and Reilly 2005; Wilson and Shrock 2001) influence their performance.

Prior research has examined a number of different cognitive factors (such as, problem solving and abstract reasoning) in relation to student outcomes in computer science, focusing primarily on programming courses (e.g., Barker and Unger 1983). Various skills related to problem solving are also related to student success in programming, including the ability to translate a problem statement into abstract formal notation, the ability to choose the correct sequence of steps needed to solve a problem (Hostetler 1983), and the ability to predict the outcome of a procedure stated in plain language (Mayer 1985). Furthermore, training in problem solving strategies may contribute to success in programming courses (Evans 1988). Other cognitive variable that predict students' performance in programming include abstract reasoning development (Barker and Unger 1983a) and mathematical ability (Wilson and Shrock 2001; Bergin and Reilly 2005).

A number of studies have also examined how noncognitive variables, such as motivation and self-efficacy, relate to student outcomes in computer science. For example, Wiedenbeck (2005) found that self-efficacy is positively associated with overall course grades and students debugging abilities. Similarly, Ramalingam et al. (2004) found that CS1 (introductory programming course) students' self-efficacy increased over time and was positively associated with course grades and previous programming experience. Goal orientation is another noncognitive variable that influences success in CS. Intrinsic goal orientations have been found to be associated with higher exam scores in a CS1 course (Bergin and Reilly 2005). The use of metacognitive strategies is associated with higher course grades in CS1 (Bergin et al. 2005).

In order to ascertain a fine-grained picture of how motivation and learning strategies affect student performance, Lishinski et al. (2016) used the Motivated Strategies for Learning Questionnaire (MSLQ) to measure students' self-efficacy, metacognitive self-regulation, intrinsic goal orientation, and extrinsic goal orientation. Through multiple measures of self-efficacy, programming projects, and two multiple exams throughout the semester, the authors were able to develop the most comprehensive picture to date on the role of noncognitive variable on student programming performance. Results suggested that self-efficacy was significantly related to students' multiple different types of programming course outcomes, including both multiple choice exams and programming projects. However, one of the most important findings was that "metacognitive strategies and goal orientation impact self-efficacy, which impacts performance, and then performance impacts self-efficacy, which then impacts performance again" (Lishinski et al. 2016, p. 218). The authors also found that male and female students modified their self-efficacy beliefs differently with females responding to performance feedback and revising their self-efficacy beliefs earlier than males.

Another noncognitive factor that appears to be important for success in programming is learner's comfort level. Comfort level refers to the general levels of feelings of ease and confidence that students experience in class and while doing course assignments. This factor has a strong impact on student success in programming courses (Wilson and Shrock 2001; Bergin and Reilly 2005). Not surprisingly, prior work has suggested that previous programming experience contributes to student success in programming courses with even one programming language increasing success in introductory programming courses (Hagan and Markham 2000). However, formal programming course experience may have more of an impact on student success than independent study of programming (Wilson and Shrock 2001). Previous programming experience may also have an indirect effect on students' programming course outcomes by virtue of having a positive effect on self-efficacy (Wiedenbeck et al. 2004).

Although many individual student factors have been examined in the literature on learning to program, there are many aspects of how and why students succeed or fail at programming that we do not yet know. The broadest issue with the existing literature on student factors in learning programming is that the majority of the research has only examined simple correlations between single and small groups of factors with the easiest to measure course outcomes, such as exam scores or overall grades. Despite the fact that researchers have created detailed models for the developmental process involved in learning to program (e.g. Robins 2010), researchers have by and large not investigated student success factors in the context of an ongoing learning process. Future research should examine how students respond to feedback as they learn to program, as it would allow CS education researchers to redesign instructional practices that are inclusive for all learners. Future research should also examine a number of other factors that have not yet been studied, such as the way students' affective states during programming influence their learning; how cognitive and affective factors interact to predict student success; and how dispositional characteristics during the process of learn to program differ across various student demographics.

Future research also needs to understand how these factors play a role in success for all students at the elementary and secondary level. Specifically, we need to examine the influence of computer science efforts (e.g., Computing at School, CSforAll, etc.) on students' understanding of computer science. Research needs to focus not only on how K-12 students learn programming but also how they come to understand computational thinking ideas (e.g., conditionals, data, etc.) and use computational thinking practices (e.g., problem-decomposition, abstraction, etc.). We also need to study how problem-solving skills developed as a result of engaging in computing activities transfer to other academic disciplines. Calao et al. (2015) found that students' understanding of mathematical processes increased significantly after embedding computational thinking ideas in sixth grade mathematics lessons. Future research needs to also study processes students engage with during computational thinking activities using qualitative methods, such as think-aloud interviews.

Valentine (2004) argued that computing education research needs to move beyond what he called "Marco Polo" research where a researcher describes "how their institution has tried a new curriculum, adopted a new language or put up a new course" and conclusions are drawn simply based on anecdotal evidence. Such research does not contribute to developing an empirical basis for what works in computing education. Computer science education researchers, however, should also be cautious as they try to study what works in computing education based on prior work in other social science fields, including education and psychology. The contextual nature of educational research means that findings do not transfer from one situation to another, which led Berliner to call education "the hardest science of them all." This is highlighted by Morrison (2015), who found that even rigorous experimental research studies from educational psychology do not replicate well in computing education. It is quite possible that the uniqueness of computing education makes it difficult to translate results from other educational domains.

Conclusion

This chapter focused on current computer science efforts across the globe to develop elementary and secondary students' abilities to think computationally, including how computation can help solve problems across disciplines. We believe that while computational thinking provides students with opportunities to engage in practices central to computer science, it also shows them how those ideas are applicable to other disciplines. However, as we have argued above, computer science education research is still in its infancy and there is considerable work that needs to be done in order to develop an empirical basis for what works in computing education. We have laid out directions for future research under two broad areas of teaching training and student learning. We understand a lot more about factors that influence student learning than how to develop computer science teacher knowledge. Given that the success of computing education efforts described in this chapter largely depends on training thousands of teachers, there is an urgent need to examine mechanisms to support teachers to effectively teach CS both at the preservice and the inservice teacher level. At the same time, we need to develop a more complete picture of how various cognitive and noncognitive factors interact to influence students' success in computing. While our discussion on directions for future research in computing is not exhaustive, we hope that it provides computer science education researchers a starting point to begin to address some of the research questions raised above.

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Dissolving the Digital Divide: Creating Coherence in Young People's Social Ecologies of Learning and Identity Building

8

Kristiina Kumpulainen, Anna Mikkola, and Antti Rajala

Contents

Abstract

This chapter discusses current research on educational efforts to connect school learning with young people's digital practices in- and out-of-school. Instead of focusing on divides between in-school and out-of-school learning or between the "digital generation" and other age groups, in this chapter we discuss what recent research says about the ways in which school can become a space in which young people's digital practices can transformatively converge with schooling, and how this convergence is related to their learning and identity building. We begin our narrative reflection of current research by focusing on the myth of digital natives. Next, we will conceptualize recent efforts to researching and understanding young

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people's engagement, learning and identity building across sites and contexts. We will then turn to illuminating some key rationales of current educational research on creating convergence in young people's social ecologies via the use of digital technologies and media. We conclude our reflections by pointing out that although there are some promising findings on how digital technologies and media can create convergence in young people's engagement and learning across sites and contexts, less research attention is given to young people's personal sense-making and self-making mediated by their digital practices, and how formal education could build on those practices for academic, vocational and/or civic ends.

Keywords
Young people · Digital Learning · Identity building · Social ecologies · In-school learning · Out-of-school learning

Introduction

Today's children increasingly grow up in media-rich homes and are in daily contact with a wide range of digital tools (e.g., Chaudron 2015). Digital practices and contents are becoming an important source of many young people's "cultural curriculum" not necessarily in the sense of preferable but in the sense of pervasive (Wineburg et al. 2007). At the same time, recent educational efforts motivated by the need to make the school curriculum more relevant for young people and to support their readiness for the twenty-first century including digital literacy have begun to explore the ways in which to meaningfully bridge the informal digital practices of contemporary youth with formal schooling (Hung et al. 2012; Ito et al. 2013). These developments stem from an accumulating body of research that points to a need to create coherence between formal and informal learning (Rajala et al. 2016; Bronkhorst and Akkerman 2016, see also ► Chap. 14, "Bridging Formal and Informal Learning Through Technology in the Twenty-First Century: Issues and Challenges" by Lewin and Charania). For example, emerging research suggests that disengaged students could become more engaged at school if sociodigital technologies they use in their informal lives were also made available to them at school (e.g., Salmela-Aro et al. 2016). There are also concerns for social equity and inclusion; for some students constructing coherence between school and other spheres of their lives is much easier than for others, with serious consequences for their success in school (Ito et al. 2013; Phelan et al. 1991). Furthermore, creating coherence between school instruction and students' everyday reasoning and cultural practices can support robust conceptual learning and engagement in authentic disciplinary practices in studies of different school subjects (e.g., Rosebery et al. 2010; Wong et al. 2010).

Curriculum reforms and pedagogies enriched by the use of digital technologies and media are being developed to connect with young people's everyday lives aligned with their experiential worlds and personal aspirations, including informal digital practices (Loveless and Williamson 2013). For instance, in Finland the new national core curriculum calls for learning environments and pedagogies that draw upon students' life worlds in and out of school (FNBE 2014). The rationale for this approach is to relate with, critically examine, and further extend young people's learning experiences in- and out-of-school, and in general to make learning at school more interesting and relevant to students encouraging their lifewide and lifelong learning (Kumpulainen and Sefton-Green 2014). Furthermore, as young people's informal lives and peer cultures are widely reported to be strongly related to their academic engagement and learning (e.g., Bempechat and Shernoff 2012; Berndt and Murphy 2002), attention in education is increasingly directed to the social ecologies of young people's learning, defined as a set of interacting sites in young people's lives that mediate their engagement, learning, and identity building (Barron 2006).

In this chapter, we will direct our attention to the rationales of recent research on educational efforts to connect school learning with young people's digital practices in- and out-of-school. By drawing on recent research studies in the field, we will reflect on the conditions and implications of such efforts and what is currently known about how these mediate and position young people's learning and identity building. Instead of directing our attention to divides between in-school and out-of-school learning or between the "digital generation" and other age groups, in this chapter we discuss what recent research says about the ways in which school can become a space in which young people's digital practices can transformatively converge with schooling, and how this convergence is related to their learning and identity building.

We begin our narrative reflection of current research by focusing on the myth of digital natives. In doing so, we demonstrate the important role of educational institutions in fostering every young people's technological fluency, digital literacy, and other twenty-first-century knowledge and competencies. Next, we will conceptualize recent efforts to researching and understanding young people's engagement, learning, and identity building across sites and contexts. We will then turn to illuminating some key rationales of current educational research on creating convergence in young people's social ecologies via the use of digital technologies and media. We conclude our reflections by pointing out that although there are some promising findings on how digital technologies and media can create convergence across sites and contexts of young people's engagement and learning, too often young people are positioned authoritatively to standardized expectations of the school. Less research attention is given to young people's personal sense-making and self-making mediated by their use of digital technologies and media across contexts, and how formal education could build on these practices for academic, vocational, and/or civic ends.

"Digital Natives": A Problematic Category

For the last two decades or so, young people have oftentimes been characterized by notions such as "digital natives" (e.g., Prensky 2001), "digital generation" (e.g., Tapscott 1998), or in terms of other portrayals of expert technology users. Proponents of such categorizations have argued for the highly active, engaged, and resourceful kinds of learning young people are gaining, for example, with digital games and online activities (Ito et al. 2013). However, there is very little research evidence to support the claims that all young people are digitally savvy and that they have radically different patterns of knowledge creation and sharing in comparison with older generations. In fact, the level of digital competencies among children in Finland and throughout Europe is found inadequate (European Commission 2013). Young people are reported to be adept in using technologies for operational purposes but they generally lack more advanced competencies, such as critical literacy (Ala-Mutka 2011). Overall, research indicates that mere exposure to technology does not equate with the development of more advanced digital competencies. The picture of young people as being information-savvy digital natives is more of a myth than an evidence-based claim (Kirschner and De Bruyckere 2017).

Also labeling youth under a unified label of “digital natives” or alike category based solely on generational differences is argued to be flawed and misleading (Bennett et al. 2008). Not all young people have equal opportunities to use digital technologies fully due to various social and cultural factors, lack of interest and confidence, or social support (Ala-Mutka 2011). Altogether, the digital native paradigm discounts technical skill disparities that result from developmental, socio-economic, gender, and cultural differences, effectively erasing the educational needs of the individual and privileging the technically adept (Bennett et al. 2008).

Although physical access to digital media is becoming less of an issue, there are stark differences among young people in access to learning opportunities that will help position them to use media in ways that can promote their own development and career paths (Barron 2006). It is generally educationally privileged youth with productive learning supports at home who are able to take full advantage of the new learning opportunities that the online world has to offer and to translate these opportunities to their academic and/or career success (Li et al. 2017; Ito et al. 2009). Hence, the role of educational institutions in supporting every young people’s learning and identity building in and for the digital age deserves attention.

Learning in School and out: From Dichotomies to Convergence

The uptake of digital technologies and media in various spheres of life has changed the ways in which young people can access information; create and consume, use, and produce meaning and knowledge; how they can interact with others; how they can engage in learning; and how they see themselves and their futures (e.g., Li et al. 2017). The growing diversity and fragmentation of today’s media ecology means that young people have a greater range and choices in their participation, learning, and identity building (e.g., Erstad and Sefton-Green 2013). It is evident that the sites and contexts of learning of many young people, at least in the Western world, have expanded and transformed from the time when Lauren L. Resnick (1987) wrote her seminal paper on the discrepancies of in-school and out-of-school learning. For her, school learning is typically based on individual performance, symbolic thought, and general skills and knowledge. Out-of-school learning, on the other hand, is mostly socially shared, tool-aided, and embedded in mediating objects, resources, and situations, resulting in contextualized competencies, skills, and knowledge practices (Resnick 1987).

While contrasts between the dominant features of learning in-school and out are valuable in extending our understanding of the contextuality of learning, this limited view of in-school and out-of-school learning easily leads to oversimplifications on the nature of young people’s engagement, learning, and identity building in the digital age. Most importantly, this kind of conceptualization is unable to explain the convergences and inter-relationships between various sites and contexts in young people’s social ecologies. For example, to date we have little knowledge how young people’s informal digital literacy practice mediate their engagement and learning at school. We also know little how learning at school travels to and impacts young people’s informal lives. Yet, the questions of how, when, and why young people learn are particularly salient now, as there has been a rapid increase in access to information and to novel kinds of technologically mediated learning environments. Understanding how engagement, learning, and identity are distributed among multiple settings and resources is hence an increasingly important goal.

Today, educational researchers are increasingly directing their attention to researching young people’s learning and identity building across sites and contexts (e.g., Erstad and Sefton-Green 2013). For the most part, these studies have been guided by sociocultural theorization on human learning and development (e.g., Cole 1996) where learning is conceived as ontological and ideological as much as it is epistemological. This intertwined and holistic understanding allows researchers to approach young people as actors who participate not only in school but other contexts which dynamically interact with one another and contribute to their meaning-making (i.e. learning) and self-making (i.e., identity building) (McLay et al. 2017).

The sociocultural framing defines learning as a social construct that emerges in interaction, while people participate in and contribute to various activities mediated by different communities, participants, rules, instruments, and artifacts. Here, learning is understood as a holistic experience of participation situated across multiple sociocultural contexts, not as something that takes place exclusively in one setting, such as in formal education (Ludvigsen et al. 2010). Hence, rather than seeing technology use in schools merely in terms of “digital divides” or inequalities of access, many of these studies have turned their attention to the broader social contexts and symbolic resources that structure diverse educational uses of new media that lead to certain forms of engagement, learning, and identity formation among young people.

Creating Convergence in Young People’s Social Ecologies

We can identify a variety of rationales for the use of digital technologies and media in education to promote young people’s learning and identity building across sites and contexts, also captured in the notions of “seamless” or “anywhere anytime” learning (Wong 2013). As McLay et al. (2017) point out, many of these approaches direct their attention to mobilizing young people's learning across physical and social space (Kearney et al. 2012), interest (or "conceptual mobility"), and time (Kumpulainen et al. 2013). In a recent review of research literature, Rajala et al. (2016) further explicated efforts to these approaches by identifying three, often overlapping, rationales that have guided educational efforts to build convergence in young people's learning across sites and contexts. These rationales are dealing with efforts to promote: (a) equity and educational inclusiveness, (b) learning requirements and competences of the twenty-first century, and (c) learner agency and identity. Our narrative review of empirical research in the field has been inspired by this distinction in rationales, and we use these rationales as heuristics to guide our work. However, in the context of our work, we have adjusted these rationales in order to better address the role and meaning of digital media and technologies in mediating young people's learning and identity building across sites and contexts.

Opening up and Valuing Diverse Opportunities for Educational Engagement

The rationale of educational inclusiveness stems from efforts for opening up diverse opportunities for young people's educational engagement in which they can harness various cultural resources stemming from their social ecologies to make meaning of their learning and becoming. An example of such an effort is a study by De Lange (2011) on vocational media studies course in a Norwegian upper secondary school. In this study inclusiveness was tied with efforts to promote young people's twenty-first-century competencies as the students were invited to address curricular goals on the basis of their informal media experiences. In the course, media teachers and their students worked together to collaboratively plan, execute, and evaluate classroom-based media projects. The findings of the study showed that the participative procedure of the course created a transactive space for students to bring in their informally developed expertise in using digital tools and to challenge the structuring of the classroom work. However, the author cautions that the students' experiences in using digital tools did not guarantee a reflective or knowledgeable perspective on their own digital practice. Instead for developing productive strategies of digital production, it was found essential that the teachers also confronted and challenged the students' perspectives.

Some other studies have also documented the creation of online learning spaces that resembled those that young people are commonly known to use in their leisure time in order to support young people's educational engagement (Lantz-Andersson et al. 2013; Kumpulainen and Mikkola 2014; Vigmo and Lantz-Andersson, 2014). The aim has been to let the students take these digital spaces as theirs and to enable them to use the advanced and creative media practices they have developed in their leisure time for academic learning. The digital spaces have included commercially available digital tools such as blogging (Vigmo and Lantz-Andersson 2014), Facebook groups (Lantz-Andersson et al. 2013), and various online collaborative learning spaces (Kumpulainen and Mikkola 2014).

Building Competencies for Active Participation in the Twenty-First-Century Society

The educational rationale of twenty-first-century learning requirements addresses young people's competences for active participation in the academic, working, and/or civic life. Such rationales are evidenced, for example, by studies that document young people's creative competencies across school and out-of-school sites, and which have positioned young people in the role of active producers instead of mere consumers of digital technologies and media (see e.g., de Lange 2011). In these studies, the expertises that students developed outside of school, such as in digital production, were not seen as self-sufficient but complementary to what they developed in school.

Other studies addressing the promotion of young people's twenty-first-century competencies, including civic engagement and citizenship have examined educational activities that deal with complex problems with social significance (Rajala et al. 2013). For example, Fauville et al. (2016) studied how a digital tool for calculating carbon footprint was used by high school students around the world. The carbon footprint calculator measures the quantity of a person's carbon dioxide emissions associated with their lifestyle and visualizes this otherwise invisible aspect of the person's environmental impact. The students used the calculator to determine how different activities of their everyday life contributed to their carbon footprint and compared the results to the local and global averages. Students were also prompted to reflect on how to reduce their carbon footprint. The averages of each of the participating classes worldwide were then displayed on a digital map and the students took part in international online discussions about the topics of climate change and its mitigation. Finally, students completed a questionnaire regarding the pedagogical activity. The study showed that involvement in the activity triggered emotionally and morally charged reactions, such as pride and guilt, among the students. The pedagogical activity also allowed the students to shift their focus between local and global perspectives in ways that challenged and expanded their views about the topic. The focus on a local perspective was found important because reflections at this level enabled students to feel responsible for the environment and take action. Yet, the possibility to shift to a global perspective fostered the students' awareness of the issues at a general level enabled them to make sense of their local life styles in the global context.

In some other educational efforts, the focus has been on young people's "abilities to self-direct" learning while engaging in learning activities across contexts. Here, self-directed learning has been considered as a valued learning outcome in itself. This argument is visible in the so-called seamless learning approach (Wong 2013). Wong (2013) presented two design experiments in Singapore in which seamless learning was fostered by giving primary school students smart phones that featured a digital camera and a mobile learning environment software. The smart phones functioned as "learning hubs" that the students carried with them all the time enabling them to manage their seamless learning across contexts and activities. The pedagogical design involved a cyclical model consisting of four types of activities: learning engagement, personalized learning, online social learning, and in-class consolidation. Some of these activities took place in formal and some in informal settings. The first design experiment involved learning of idioms in Chinese, and the second one involved a series of inquiry-based science learning projects. Among other things, in both of the projects the students made observations and took photos in their daily encounters outside of school and associated these photos with the knowledge learned in the class. The students' photos and other learning products that they created were then discussed in virtual learning environment among peers and in class facilitated by the teacher.

While in both of the projects the seamless learning design contributed to the conceptual learning of the students, indications of the emergence of limited but growing self-directed seamless learning were documented. In the first design experiment, the students started to take photos illustrating given idioms in their homes and in other locations of their everyday life on their own initiative. Thus, the formal artifact creation activities "spilled into" the students' informal settings. In the second design experiment, the students started to sustain informal inquiries on topics of their own interest with the aid of the smart phones. The researchers interpreted these as indications of their success in "planting a seed of seamless learning in the children."

Identity Building across Sites and Contexts

Educational rationales addressing young people's identities across sites and contexts focus on young people's identity negotiations in relation to others, digital technologies and media, and the contexts of their activities (Erstad and Sefton-Green 2013). For instance, in their research, McLay et al. (2017) explored the fluid shifts and transformations of learner identities in response to the mediating influence of the iPad taken up in an Australian high school to enable students to move fluidly between in-school and out-of-school contexts. Following Bakhtinian perspectives, these researchers attempted to illuminate young people's identity building by making visible the ways the students negotiated their identities in relation to social resources and material resources, sometimes taking up and at other times resisting and rejecting various possible selves.

Altogether, a review of existing research reveals that there is fairly little documented research on young people's identity building processes in relation to educational efforts that aimed at building coherence in young people's learning across sites and context via the use of digital technologies and media. Furthermore, many of the reported educational activities have been framed authoritatively with expected ways of working, learning, and being with little attention to young people's self-making processes. These reported educational activities have positioned young people with somewhat predefined identities to which they are assumed to aspire and which are to promote particular kinds of desired futures for the youth. Such forms of identities often entail being active, creative, connected, autonomous, and self-responsible (Loveless and Williamson 2013).

Efforts that recognize and build on young people's own aspirations and motives are typically situated in other contexts than schools, such as, in after-school clubs, libraries, science centers, and other cultural communities (e.g. Ito et al. 2013). Here, young people are supported to pursue their personal interests with the support of peers and adults with the goal of linking these initial interests to academic achievement, career success, and/or civic engagement. In doing so, such connected learning efforts aim to harness "digital technologies and media to more easily link home, school, community and peer contexts of learning; support peer and intergenerational connections based on shared interests; and create more connections with non-dominant youth, drawing from capacities of diverse communities" (Ito et al. 2013, p. 4). It remains to be seen how such "connected learning" efforts will travel to schools and how they manage to embody the values of students' equity, social belonging, and participation, as advocated by such approaches.

Conditions and Challenges

While there are some promising findings how digital technologies and media can mediate convergence across sites and contexts in young people's digital engagement, learning, and identity building, existing research has also pointed out challenges and critical conditions that are worthy of attention to guide future research and educational practice.

Extending Official Classroom Space to Incorporate Students' Everyday Ways of Being

The study by Lantz-Andersson et al. (2013) which focused on the pedagogical use of a Facebook group in English-learning classes, with 60 students aged between 13 and 16 from Colombia, Finland, Sweden, and Taiwan, showed that the ways in which these spaces were framed in formal instruction created tensions with those of the students' peer culture and everyday interactions. The study showed that the conventional educational activity was resistant to being extended to incorporate nonschool language use and that the conventional framing of the activity was sustained both by the teacher and the students. However, an expansion of the activity took place through students' playful, everyday interactions that challenged the formal language use in the group. A posting by one of the students that made fun of the assignment generated a lively interactional exchange of comments that diverged from a formal language use at school and resembled young people's everyday interactions in social media. The results of the study highlight that extending the official classroom space to incorporate students' everyday ways of engaging in digital media was not trivial. Despite the seemingly unproductive nature of these exchanges, at times, they were found to mark a shift in the interaction pattern after which the students more frequently commented on each other's postings. Also Kumpulainen and Mikkola (2014) in their study of primary school students' chat interaction during collaborative writing of a school musical script both inside and outside school found out that seemingly "useless" everyday interactions of the students played an important role in building trust and social relationships. The study also reports that boundary crossing in the students' chat interactions gave rise to hybrid spaces where the discourses of schooling and everyday life intersected.

As these studies show, the values and identities young people themselves wish to pursue can sometimes be at odds with what is considered appropriate in a school setting or teachers could find it risky to allow students to bring some aspects of their lives to school. Nevertheless, attending to more difficult aspects of students' lives can connect instruction to vital personal meanings in the students' lives and foster deep engagement in school learning (Zipin 2009; Thomson and Hall 2008). Conversely, the avoidance of topics that are of central importance in some of the students' lives may alienate these students from instruction. It is also important that the "cultural curriculum" of students' informal lives is brought under joint reflection, critical analysis, and elaboration in the schools, as to guide students' learning and identity building towards enriched directions promoting their academic, vocational and civic engagement, and learning.

Altogether, existing research points out how it is important to acknowledge that educational efforts that aim at building coherence across young people's digital learning lives across school and out can lead to meaningful and transformative engagement, learning and identity building can only emerge through sustained collective efforts. Without an appropriate curriculum and pedagogical working culture that transform traditional learning practices, digital media and the knowledge funds of contemporary youth are initially likely to represent a mere additional layer to schooling with a likelihood of even counter-productive consequences. Furthermore, while creating education extends across young people's social ecologies, it is thus not just a matter of implementing and putting into use alternative pedagogical ideas and technologies, but in many cases, it is also a matter of transforming simultaneously existing social practices. Co-evolution of the social and technological infrastructures of education should be the starting point for expanded and hybrid learning opportunities (Kumpulainen et al. 2013).

Authentic, Current, and Complex Real-Life Problems

Facilitating learning across sites and contexts also demands educational activities that are authentic, current, and complex real-life problems (Hakkarainen 2010). These learning activities can have the potential to transform the forms of students' engagement by expanding the requirements for engagement and bringing in new audiences with whom students pose questions; share and discuss their observations, opinions, reflections; as well as co-develop new knowledge and understanding. In these situations, students are likely to see the meaningfulness and applicability of their learning within and beyond the school. When doing so, new audiences respond, thus providing students with feedback about the feasibility of their ideas and work. In essence, the culture of learning mediated by hybrid approach leaves room for creativity, renegotiations, and surprises. Addressing authentic problems and tasks requires the teacher and students to work with open, flexible, and tentative plans and goals that might not be clear from the outset and need reconfiguring also along the way (Rajala et al. 2013).

Enacting educational opportunities that stretch across sites and contexts also require transformative actions on the part of the teachers (Lipponen and Kumpulainen 2011). In particular, pursuing a transformative stance to traditional pedagogical practice that is typically limited in space and time and dominated by narrow and authoritative stance can result in conflicts and contradictions (Brown and Renshaw 2000). However, questioning current practices and seeing alternative futures are pivotal prerequisites in transforming social practices (Engeström and Sannino 2010). Also, in order to connect learning and teaching to expert communities outside school, teachers and schools need to build partnerships and networks. Building networks and partnerships also requires new competences from teachers, such as being able to engage in multiprofessional collaboration (Kumpulainen et al. 2010). In sum, to build education that is responsive to young people's learning and identity building across sites and contexts requires transformation at many levels that create the systemic whole.

Conclusions

Existing research among youth has revealed that in contrast with the view of dissatisfied "Net Generation" people who do not value school, there is evidence that are a number of young people who regard school as a valuable learning environment (Bennett et al. 2008). Yet, it is the object and nature of learning that makes schoolwork easily irrelevant and meaningless. It is unwise to assume that the interest, motivation, or affinity of all young people will be automatically enhanced by the simple inclusion of digital media technologies in educational contexts. In fact, without a meaningful pedagogical agenda, students can react negatively to the use of technologies and media in formal education, what they may perceive as teachers' attempts to colonize their free-time domains (Sharples 2006). Indeed, a number of researchers warn against attempts to motivate and engage students simply through the introduction of consciously trendy forms of media technology into educational processes. Young people are unlikely to be automatically enthused and motivated by the use of digital technologies, social media, and gaming for educational purpose, if these technologies are not meaningfully integrated into learning practices and pedagogies that support their authentic and transformative engagement (Kumpulainen et al. 2013).

Education that is responsive to young people's social ecologies is part of a long-standing tradition in progressive education that has stressed the importance of civic engagement, connecting schools with the wider world, and the value of hands-on and social learning (Dewey 1916). Today's digital technologies and media offer us the ability to pursue these progressive goals in new ways through purposeful integration of tools for social connection, knowledge co-creation, and linking the classroom, community, and home. From this perspective, the role and position of the school in the digital age needs to be seen not in opposition to youth cultures nor as "digital enrichment" of traditional schooling but rather conceptualizing school as an important element of all young people's social ecologies for engagement, learning, and identity building in and for the digital age.

Education that stretches across sites and contexts has implications for schools, including curriculum, pedagogies, and the design of learning environments. Conceiving the school as a meeting place for different identities, interests, and discourses reveals the potential of formal education to become a site where no cultural ways of being and acting are secondary but important focuses of joint attention, analysis, and reflection (Gutiérrez et al. 2011). At best, it can provide teachers with a more holistic way of thinking about their students, directing attention to epistemic and ontological dimensions of young people's learning and becoming. Yet, as our narrative review reveals, little attention has been paid into educational activities that position children as active, creative, and critical investigators of and with digital technologies. Moreover, at present there is a dearth of knowledge for creating learning opportunities for digital competencies that are inclusive for diverse learners with different capabilities and interests, and that are able to accommodate their different personal situations and objectives and combine, for example, formal and informal learning (Kumpulainen and Mikkola 2014). In sum, these realities point out the urgent need for research and development of innovative pedagogies as to ensure meaningful learning experiences that enhance every child's digital competencies already early on.

It is clear that further research is necessary in order to better understand young people's learning and identity building in education that aims to build convergence in young people's social ecologies via the mediating influence of digital technologies and media. In specific, there is a need for research studies that look into the dynamics of young people's learning (sense-making) and becoming (self-making) at the intersection of multiple sites and contexts mediated by digital technologies and media. This seems as a serious deficiency that should be overcome as to gain a better understanding about the values and learning identities young people themselves wish to pursue in the moment and in their futures.

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Section III

The Learner and the Learning Process

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Section Introduction: The Learner and the Learning Process

9

Kwok-Wing Lai and Keryn Pratt

Abstract

This introduction provides an overview of the main focus of the chapters in Section III "The Learner and the Learning Process", in the *Second Handbook of Information Technology in Primary and Secondary Education*.

Keywords

Technology-enhanced learning · Informal learning · Learning theories · Computer-supported collaborative learning · Inquiry learning · Social media

The landscape of technology-enhanced learning (TEL) in primary and secondary education has changed tremendously in the last decade due, at least in part, to the proliferation of mobile technologies and social networking applications as well as the availability of learning resources such as MOOCs and OERs. This change has led to a reconceptualization of how learning should be conducted and where, when, and how it should take place. The chapters included in this *Handbook* section have reviewed the most significant new developments of TEL in primary and secondary education and, in particular, discussed the pertinent learning issues and challenges related to technology use in education in the twenty-first century, with a key focus on the learner and the learning process. Since one of the objectives of this *Handbook* is to review the relationship between research and educational practice, the chapters in this section have paid close attention to pedagogical designs and highlighted exemplar practices in a variety of technology-supported learning environments, both in formal and informal contexts.

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The first chapter of this section, (▶ Chap. 10, "The Learner and the Learning Process: Research and Practice in Technology-Enhanced Learning" by Lai), is an overview chapter, which reviews a range of promising and effective ICT tools used in the learning process focusing on their pedagogical design. New developments in neuroscience research and innovative pedagogical practices, such as flipped learning, one-to-one computing, and online learning, are also reviewed in this chapter. The author argues that while in the last 10 years there has been an increasing focus on the learner rather than on the technology, mainstream research is still primarily looking for technological impacts or effects on learning outcomes and adopts a rather deterministic view on the use of digital technologies in education.

In ▶ Chap. 11, "Information and Communication Technologies, and Learning Theories: Putting Pedagogy into Practice," Dennen et al. discuss how learning theories, including behaviorism, cognitivist, and constructivism, underpin the use of digital technologies in the K-12 classroom. An emerging theory, connectivism, is also explored. The authors argue in this chapter that learning theories are important in guiding the development of pedagogical knowledge and instructional strategies, but there are challenges and implications of using them to successfully integrate information and communication technologies to the learning process to facilitate effective student learning experiences.

In ▶ Chap. 12, "Developing Scientific Inquiry in Technology-Enhanced Learning Environments," Chan and Yang adopt a learning sciences framework to examine some key theoretical issues affecting the design of learning environments in supporting inquiry-based learning. Four technology-enhanced learning environments designed to support inquiry-based learning are reviewed. The learner and the learning process, nature of collaboration, pedagogical design, and assessment of these inquiry-based learning environments are compared to highlight the theoretical and educational implications of designing technology-enhanced inquiry-based learning environments.

Kimmons and Belikov argue, in ▶ Chap. 13, "Cultural and Social Issues in Using Social Media to Support Learning," that while social media certainly have benefits to the learners, there are also cultural and social challenges related to their use in the learning process that practitioners need to understand. The authors of this chapter tease out these issues under four themes, namely, literacy, privacy, civility, and identity. Under each of these themes, they discuss the key problems in the use of social media and recommend how teachers can effectively tackle these problems.

In ▶ Chap. 14, "Bridging Formal and Informal Learning Through Technology in the Twenty-First Century: Issues and Challenges," Lewin and Charania review how formal and informal learning are defined and how they can be connected by using technologies to support pedagogical practices. The authors argue for the importance of changing the school culture to support the shifting from transmissive to collaborative pedagogical strategies in order to enhance the learner's agency and collaboration and provide opportunities for authentic learning.

Information and communication technology affords new learning opportunities for learners to learn together. The sixth and final chapter in this part, ▶ Chap. 15, "Computer-Supported Collaborative Learning: Mediated and Co-Present Forms of Learning Together," by Schmitt and Weinberger, reviews the potentials and problems of different forms of computer-supported collaborative learning (CSCL) and discusses how current pedagogical approaches deal with these problems and afford the sharing of knowledge and co-creating solutions.

These six chapters in this section present a coherent theme, that is, we should not lose sight of the centrality of the learner when designing technology-enhanced learning environments. It is pertinent that when harnessing technology affordances, we focus on how well technology can afford the development of learner agency, in both personalized and collaborative learning and in formal and informal environments. This presents a challenge for practitioners and researchers to consider as we move forward in the twenty-first century.

The Learner and the Learning Process: Research and Practice in Technology-Enhanced Learning

10

Kwok-Wing Lai

Contents

Abstract

This overview chapter surveys the most significant developments of technology-enhanced learning (TEL) in primary and secondary education in the last 10 years to highlight some significant learning issues and challenges related to technology use in the twenty-first century, and also their implications to the learner and how these changes affect the learning process. New developments such as advances in neuroscience research, innovative pedagogical practices such as flipped learning, one-to-one computing, and online learning are discussed. While in the last 10 years there

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has been increasing focus on the learner rather than on the technology, mainstream research is still looking for technological impacts or effects on learning outcomes, and many adopt a rather deterministic view on the use of digital technologies in education. It is also noted that how innovative technology-supported learning environments can be scaled up and sustained is a major issue. Also, more attention needed be put on the psychological and emotional effects of TEL, as well as health and safety issues of digital technology use on the young learners.

Keywords
Technology-enhanced learning · Learning process and characteristics · ICT in education

Introduction

Since the publication of the overview chapter on the learner and the learning process in the first edition of this *Handbook* (Lai 2008) some 10 years ago, new digital technologies and applications have emerged and some of them (e.g., *Facebook and Twitter*) have become extremely popular with students. Children and young people now spend a significant amount of time using digital and mobile devices to access the Internet and the Web to engage in cognitive as well as social tasks. A survey undertaken by the Pew Research Center in 2015 reported that over 92% of the teenagers (aged 13–17) in the USA accessed the Internet on a daily basis, and close to a quarter of them (24%) used the Internet almost constantly, with 91% of them accessing the Internet at least occasionally using a mobile device (Lenhart 2015). Findings from PISA (Programme for International Student Assessment) also showed that students in the OECD (Organization for Economic Cooperation and Development) countries on average spent over 2 hours online during school days in 2012 (OECD 2015). Taking advantages of the new affordances of digital and mobile technologies, innovative pedagogical designs and models of technology-enhanced learning (TEL) have also emerged in the last decade. With the prevalence of digital and mobile devices and social media which undoubtedly has affected how children and young people communicate and learn, we note that in the last decade this increasing accessibility and connectivity of digital technologies have not only provided new learning opportunities but also created new issues and challenges.

With technologies being increasingly ubiquitous, it is pertinent for policy makers, practitioners, and researchers to understand their implications to learning, and in particular, how new digital technologies can help support the development of the twenty-first-century skills. In the last decade we have amassed a large number of case studies investigating technology use in different curriculum areas and levels. Review studies (e.g., Clark et al. 2016; Lawless 2016; Warschauer and Matuchniak 2010) have also been undertaken to synthesize research conducted in the field. We find that increasingly TEL research has attended to the contextual factors of learning, such as student learning characteristics and styles, demographic and socioeconomic contexts, subject content, school and class cultures, and a wider context at the system level when investigating the relationship between technology and learning. Also, a realist perspective (Pawson et al. 2005) has often been adopted to understand the digital technology phenomenon. Instead of seeking a blanket answer to the question of what works, the question of what works for whom and under what conditions is now being asked and investigated by many TEL researchers.

The purpose of this overview chapter is not to add another review to the literature, but to screen the most significant developments of TEL in primary and secondary education in the last 10 years to highlight some significant learning issues and challenges related to digital technology use in the twenty-first century. This chapter thus surveys the landscape of how the field of technology-enhanced learning has advanced in the last 10 years, and also discusses its implications to the learner and how it affects the learning process.

In the other five chapters in this section of the *Handbook*, issues and challenges of the key pedagogical strategies related to TEL will be reviewed and discussed in more detail. These chapters will review and discuss several key technology-enhanced learning environments, including inquiry-based learning, computer-supported collaborative learning (CSCL), learning supported by social media, and learning facilitated in informal contexts. Key learning theories underpinning the use of technologies in the learning process will also be reviewed in one of the chapters.

We begin this chapter by focusing on the learner, and reviewing how digital technologies have influenced the learning behaviors based on research findings from cognitive science and educational neuroscience. Then we will discuss the relationship between technologies and twenty-first-century skills. In the subsequent section we will discuss some new technology-enhanced learning models and strategies, and finally key issues and challenges in TEL will be reviewed in the last section.

The Digital Learner

The Myth of the Digital Native

With the prevalence of digital and mobile technologies, a pertinent question is whether and how students would learn differently. Some researchers argue that since students increasingly spend a large amount of time immersing in technologies both in and out of school, the current generation of learners has developed a set of learning characteristics and styles which are fundamentally different from previous generations (e.g., refer Prensky 2001; Rosen 2010). The term digital natives has often been used to describe the young digital learners who prefer images than text, multitask, are constantly connected with their peers, have needs for immediacy, and prefer experiential learning (Bullen et al. 2011). Due to these new learner characteristics, the digital natives advocates further argue that new pedagogical strategies should be designed to meet their "more technology-driven, spontaneous, and multisensory" learning needs (Prensky 2001). While the concept digital natives is intuitively appealing, it is noted that very little empirical research has been conducted at the primary or secondary levels to show that there is in fact a distinctive set of digital learning styles characterizing children and adolescents of the digital age. On the contrary, research conducted in higher education (e.g., Bullen et al. 2011; Lai and Hong 2014) suggests that the way younger tertiary students (who would be considered as digital natives) use digital technologies does not fundamentally differ from older students (who would be considered as digital immigrants) and it will be an oversimplification to use terms such as digital natives to categorize young learners as a homogeneous group. However, while the validity of the digital natives concept is questionable, with the widespread use of digital technologies, undoubtedly children and young people have now developed certain expectations of how technologies should be used in formal and informal learning settings. These expectations have created pressure for teachers to change their pedagogical practices and policy makers to invest in digital technologies as well as develop guidelines for their use.

Advances in Neuroscience Research

There is a high expectation that recent advances in neuroscience research using technologies such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) to identify changes in neural activities can increase our understanding of how the brain works and how neural activities affect the learner in the learning process. A new discipline called educational neuroscience has been rapidly developing in the past decade focusing on how cognitive neuroscience research can inform educational practice. It is expected that a better understanding of the biology of learning will provide guidelines to classroom practice and specifically for TEL (Howard-Jones et al. 2015). For example, neuroscience research findings relating to the plasticity of the brain have already led to the conjecture that frequent interaction with digital technologies may reorganize and restructure the brain (Prensky 2009). This conjecture has resulted in the flourishing of computer-based brain training software aiming to improve the working memory for retention and transfer of skills, arithmetic and reading performance, as well as literacy skills (Howard-Jones 2014). However, it is not yet clear what and how these computer-based training programs can help achieve. A review of 20 computer-based math intervention programs by Kroeger et al. (2012) concluded that "[A]lthough much has been learned about how the brain develops and functions, and program development has begun to be influenced by neuroscience, claims that bear a direct impact on individual student learning may be immature" (pp. 52–53). Researchers have also begun to apply neuroscientific principles to technology-enhanced learning. For example, Howard-Jones et al. (2015) have investigated the relationship between digital gaming and the brain's reward system to seek explanations as to why game-based learning is effective. However, it is acknowledged that at present the connection between educational neuroscience research and technology-enhanced teaching practice is not straightforward and it is difficult to translate educational neuroscience research findings into technology-enhanced practices. As observed by

Howard-Jones et al. (2015), “what we do know about the learning brain must be combined with educational research and expertise, and also some common sense, if we are to develop pedagogy that draws on authentic science and is educationally valuable” (p. 133). Research on educational neuroscience so far has not been able to provide concrete guidelines to improve the design of technology-enhanced learning environments.

Twenty-First-Century Skills and Technologies

With the emergence of globalization and the knowledge economy in the late twentieth century, it is now recognized that knowledge is the primary driver of growth and development in the twenty-first century, and thus learners need to develop new skills and competencies to adapt to technological innovations and become knowledge-based workers in order to tackle many unprecedented complex socio-economic-political problems. There is a call to equip young learners with new knowledge and twenty-first-century skills to enhance “problem solving, critical thinking, communication, collaboration, and self-management” (Pellegrino and Hilton 2012, p. 14) and to increase their innovative and knowledge creating capability (Scardamalia 2001). Many pedagogical guidelines (e.g., Partnership for 21st Century Skills 2007) have been developed nationally and internationally to support this development. After an extensive review of the literature, Pellegrino and Hilton (2012) suggest that these so-called twenty-first-century skills can be categorized under three domains: “the cognitive domain, including competencies such as critical thinking, information literacy, reasoning and argumentation, and innovation; . . . the intrapersonal domain, including competencies such as flexibility, initiative, appreciation for diversity, and metacognition; . . . [and] the interpersonal domain, including competencies such as communication, collaboration, responsibility, and conflict resolution” (p. Sum-3). As pointed out by Warschauer and Matuchniak (2010), many of these so-called twenty-first-century skills or competencies are technology-related. In fact, the use of technology to enhance thinking skills has a long history. For example, in the early 1980s, Papert (1980) has developed the Logo programming language to support the development of problem solving and metacognitive skills of young learners. More recently, advances in computational thinking research (Grover and Pea 2013) suggest the need to include computational thinking as a required domain in the school curriculum. However, we are reminded by Scardamalia (2001) that in supporting students to develop twenty-first-century skills, educators should not start by focusing on the technology, but instead need to first ask what kind of education and learning experience children and young people should acquire in a knowledge-based society, and then consider in what way can technology be used to enhance such a process and experience. Scardamalia (2001) suggests that we should encourage students to use digital technology to enhance pursue of deep understanding, develop knowledge creating capability and epistemic agency, rather than simply acquiring technological skills for its own sake.

Technology-Enhanced Learning

In evaluating the use of new digital technologies in learning, we thus must be mindful of how they can add value to the learning process. While digital technologies can certainly help increase the efficiency of learning, for example, they can be used to support students to access and present information, facilitate word processing, manage spreadsheets and databases, and enhance communication and collaboration, Wellington (2004) points out that there may be a trade-off in using technologies to perform these tasks since some important cognitive skills may be lost in the process because students are no longer required to practice them. We are reminded to distinguish between the inauthentic experience from using digital technologies, which is only labor saving, and the authentic learning experience which can lead to further learning (Wellington 2004). A unique contribution of digital technologies, which adds value to the learning process, is their affordances in supporting the development of innovative and creative skills. In the following subsections some recent advances of pedagogical models of technology-enhanced learning which may add value to the learning process are briefly discussed.

Flipped Learning

The flipped learning model has become a popular pedagogical model in the last decade. As defined by the Flipped Learning Network (FLN) (2014):

> Flipped learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter.

The flipped learning model has become popular in primary and secondary education in the economically more advanced countries in the last decade. For example, in the Speak Up survey (Project Tomorrow 2015) on flipped learning conducted across the USA in 2014, almost half (48%) of the school technology leaders reported that flipped learning had positive results in their schools. In a flipped classroom, students are given more control of the learning process since they are asked to be an active learner in charge of what, when, and how they study the subject content. As a learner-centered approach, the flipped learning model can help develop learner agency, which is essential for lifelong learning. The use of digital technologies is integral to this model to facilitate students to take part in whole class and small group online discussions, access content from the Internet in and out of class time, and also for teachers to create learning materials. Flipped classrooms are benefited from cloud computing. For example, by using the freely available Google Apps for Education such as *Gmail*, *Docs*, and *Calendar*, collaborative learning and group projects can be supported where students can share and develop their ideas. The *Google plus community* can be used to support asynchronous text-based discussion and *Google Hangouts* can support synchronous video conferencing for students to collaborate in formal and informal settings. Technology has always been closely associated with social constructivism, and flipped learning is yet another example of how technology can be used to support a pedagogy which is underpinned by constructivist principles such as active, self-regulated, and collaborative learning.

Informal Learning Augmenting Formal Learning

Increasingly, it is now being recognized that technologies have huge potential to augment formal learning with informal learning since students are now no longer constrained by a lack of access to information. The affordances of mobile devices such as smartphones and tablets, which are distinctive from previous technologies in terms of portability and connectivity, can provide anywhere, anytime, on-demand, on-the-fly learning opportunities for students (So et al. 2009). Since children and young people use mobile devices primarily in out-of-school settings, they are able to gain knowledge and skills as well as computing experience in these informal settings. For example, there is evidence that informal learning in computer classes in community centers help young people develop twenty-first-century learning skills and lifelong learning skills (Warschauer and Matuchniak 2010). It is well documented that the way young people use technologies in informal settings is often different from how they use them in formal school settings (Khaddage et al. 2015), and this is challenging for teachers since they need to develop pedagogical practices to bridge in and out-of-school learning in order to harness what students have learned informally to support what they learn in the school. The key issue is for teachers to reconceptualize learning as a continuum and understand that there should be no distinction between formal and informal learning in terms of its value to the learners. In fact, students spend more time engaging in informal rather than formal learning but their efforts are seldom recognized in formal education since assessments are primarily focused on formal course content (Khaddage et al. 2015). It should be noted that while it is pertinent to study the relationship between formal and informal learning, there are pedagogical (e.g., instructional strategies, assessment), policy (e.g., Bring Your Own Device, BYOD), technical (e.g., infrastructural support and connectivity), and research (e.g., evaluation) challenges that researchers, policy makers, and practitioners need to tackle if digital technologies and in particular mobile devices are to be successfully employed to support school learning and augment it with informal learning (Khaddage et al. 2015). For a more detailed discussion of the connection between formal and informal learning using digital technologies refer Lewin and Charania, ▶ Chap. 14, "Bridging Formal and Informal Learning Through Technology in the Twenty-First Century: Issues and Challenges" in this *Handbook*.

Gaming

There has always been huge interest for children and young people to engage in computer games (Lenhart et al. 2008). With the rapid increase in Internet connectivity and accessibility of mobile devices, interest in digital video games has greatly increased in the last 10 years and playing multiplayer digital games has become one of the most popular leisure activities of teenagers (Young et al. 2012). According to Lenhart et al. (2008), about 97% of the teenagers in the USA already regularly played some form of video games about a decade ago. Research on gaming is primarily conducted as case studies to document the use of digital games in different learning settings. Reviews surveying the field have also been undertaken. For example, in a recent media comparison review, Clark et al. (2016) have identified 69 media studies conducted between 2000 and 2012 and concluded that digital games could significantly enhance student learning as compared to nongame conditions. However, as will be discussed later in this chapter, there are issues in using media comparison studies to support the efficacy of TEL. More detailed discussion of games and simulation-based learning can also be found in Section X "Game and Simulation-Based Learning and Teaching" of this *Handbook.*

One-to-One Computing

The improved access to computing hardware and software by primary and secondary students in the last decade has greatly facilitated one-to-one computing. For example, in the USA, it is estimated that one-third of the middle and high school students use school-owned mobile devices (Nagel 2014). Mobile technologies also provide new learning opportunities in the economically less advanced countries and Africa countries in particular are the fastest growing countries in the world in terms of mobile phone penetration, with an increase from 200 million connected mobile devices in 2006 to 735 million in 2012 (UNESCO 2012). While in the economically less advanced countries mobile devices are primarily used to provide informal learning opportunities, in the economically more advanced countries it is now commonly expected that students in schools will work in a one-to-one computing environment. In these countries, students are either provided with a laptop or tablet computer by the school, or they are required to provide their own mobile devices. In a one-to-one computing environment, there are funding issues for schools to provide fast Internet connectivity and software access. There are also issues of technical support, Internet privacy, and protection of intellectual property that schools need to tackle (Alberta Education 2012). If students are required to provide their own digital devices (i.e., BYOD) for school learning, there is an equity issue of justifying the shift of provision of learning tools from the school to the parents. The limited research available on one-to-one computing does provide some evidence to show that it is beneficial to teaching and learning, with teachers and students using technologies more often in the class, and there is also an improvement in student engagement, research skills, achievement, and collaboration (Bebell and Kay 2010; New South Wales Department of Education and Training 2009).

Social Media and Formal Learning

It is quite clear that in the last 10 years social media have become the most popular digital applications for young people (Lawless 2016), and social media apps have drastically changed how young people communicate and learn. The use of social media can have huge implications on formal learning. However, the majority of research on social media has been conducted in informal settings and so far very little is known about how social media can be used to support learning in formal settings (Khaddage et al. 2015). While there is some positive evidence on the use of social media in schools (e.g., refer review by Gao et al. 2012 on *Twitter*), there are questions of how they can be used productively in class without causing distraction to other students, and issues such as privacy and identity have also been raised (Crook 2012). In this *Handbook*, Kimmon and Belikov, ▶ Chap. 13, "Cultural and Social Issues in Using Social Media to Support Learning" have reviewed the cultural and social issues of using social media in supporting learning.

Online Learning

Online learning in primary and secondary education is growing and in particular, in the USA where virtual schools have become increasingly common and high school students can now complete their diploma totally online. According to one estimate (Wicks 2010), over 1.5 million US K-12 students enrolled in online learning in 2010. In the UK, one source reported that there were over 300 virtual schools with over 200,000 students enrolled in 2014 (UK Department for Education 2014). Online learning can facilitate personalized learning as it provides additional choices to the student. It also reduces inequity since students who previously had no access to face-to-face education can now have the opportunity to complete schooling without having to attend a brick-and-mortar school. Online learning is now supported by the proliferation of open education resources (OER) available on the Internet, and there are also open educational courses that students can enroll. Massive open online courses (MOOCs) have become popular at the tertiary level in recent years, and now there are MOOCs specifically designed for primary and secondary students. For example, in 2014, 5% of the 3 million students enrolled in MOOCs developed by the edX platform were high school students (Atkeson 2014). In the UK, the Department of Education (2014) has listed 24 MOOCs specifically designed for students. There are MOOCs on specialized or supplementary courses that are not normally available in formal education, and they give students choice and facilitate personalized learning. However, the effectiveness of MOOCs is not known since so far there is a paucity of research on learning outcomes of MOOCs in primary or secondary education. A more detailed discussion of MOOCs and open learning can be found in Dron and Ardito, ▶ Chap. 50, "Open Education Resources, Massive Open Online Courses, and Online Platforms for Distance and Flexible Learning" in this *Handbook*.

"Effects" of Using Technologies in the Learning Process

In the last 10 years, governments globally have continued to invest heavily on ICT equipment and software, and also to fund professional learning and development of teachers of how to use digital technologies in their classrooms. For example, in the USA, in 2014, K-12 schools have reportedly spent nearly US$10 billion on learning technologies (Lawless 2016). Similarly, in the UK, schools spent around £880 million on ICT in 2008/9 (Livingstone 2012). Digital literacy has also been included as a required component in the national curriculum in many countries. For example, in Norway, in its national curriculum, digital competence has been listed as a basic skill (Erstad 2009). Advocates have continued to expect that digital technologies can be used effectively to transform teaching and learning. However, even though numerous studies have been conducted in the last 30 years to investigate the relationship between digital technology and learning, there is little conclusive evidence to justify what Kozma (2008) has called the "strategic educational ICT policy rationales" (p. 1085) for its use, and there is little evidence to confirm that the use of ICT in education has supported economic growth, promoted social development, advanced educational reform, or enhanced education management. In terms of learning outcomes, as pointed out by Lawless (2016) in a recent review, "taken as a whole, research on the effectiveness of general contemporary technologies does not yield enough decisive evidence to support conclusive proof of their effectiveness in improving educational outcomes" (p.5). The most recent large-scale review was published by OECD (2015), titled *Students, computers, and learning: Making the connection*, based on data from two PISA studies (2009 and 2012). This report concludes that "the connections among students, computers and learning are neither simple nor hard-wired; and the real contributions ICT can make to teaching and learning have yet to be fully realised and exploited" (p. 4). The OECD (2015) report verifies the mixed results of the effects of ICT on student performances frequently reported in previous reviews, with a conclusion that there is a lack of evidence to show "appreciable improvements in student achievement in reading, mathematics or science in the countries that had invested heavily in ICT for education" (p. 15).

Various reasons have been suggested to explain why the use of digital technologies in schools has not resulted in measureable positive effects. For example, when reviewing the benefits of games, Young et al. (2012) argue that the wrong question may have been asked because there is no such thing as "the effects of technology," and their advice is to "stop seeking simple answers that address the wrong question" (p. 84), as there are both methodological and substantive issues which make measuring technology effects or impacts very difficult if impossible. The "media effects debate" back in the 1980s and 1990s has highlighted the controversy of measuring the impact of digital technology on learning. In this debate R. E. Clark (1983) argued that since the instructional medium (i.e., a technology) could not be teased out from the instructional design (i.e., a pedagogy), trying to measure the effect of the medium was a futile exercise. Taking an opposing stance, Kozma (1994) stressed that a technology might have certain attributes, which would provide specific affordances without which the instructional strategy could not be carried out. Thus research could focus on these affordances. Commenting on this debate using digital gaming as an example, Clark et al. (2016) response was that while technological applications/software provided new affordances, it was how they were used, and how the learning environment was designed which "leverage those affordances" (p. 116). This debate highlights the problem of using media comparison data to support technology use in the classroom. (Media comparison studies compare the outcomes of using a technology (medium) in a class with another class not using the technology or using another medium of instruction.) The media comparison approach has been criticized (e.g., Selwyn 2011) for not able to measure the true effect of technology use. Salomon (2002) also criticizes the media comparison approach by arguing that while technology rich learning environments can change education in a profound way, for example, in supporting the development of knowledge and skills needed for the twenty-first century, it may not necessarily enhance achievement, and thus it is pointless to measure it in media comparison research.

As a cultural tool, digital technology is not a "disembedded tool" (Wellington 2004) since it cannot be used in a vacuum, but to be embedded in and influenced by a complex sociopolitical and cultural system with each of its constituent components interacting with one another simultaneously. Thus, trying to achieve any "degree of confidence or certainty over a discernible 'case-and-effect' relationship between technology and learning is nigh on impossible" (Selwyn 2011, p. 84). To better understand the design and implementation of TEL, as well as its benefits, some researchers argue that design-based research is a more fruitful methodology to employ because it is classroom-based, it involves a partnership between the researcher and practitioner, is more holistic in approach, and it generates knowledge in both theory and practice (Amiel and Reeves 2008).

While there is little generalizable evidence to document how technology can support learning (but a wealth of case study findings), some researchers argue that there are "soft" effects that technologies bring to the learning process (Livingstone 2012). One of the most cited "soft" effects is the motivational effect to engage students to learn. Indeed, there is evidence that positive motivational effects are found in technology-enhanced classes (e.g., Passey et al. 2014). However, we should be cautioned about these effects. Are they simply the novelty effects of digital technologies which help create the short-term interest in the learning tasks? Hidi and Renninger (2006) distinguish two forms of interest: situational and mature or deeper interest. As argued by Philip and Garcia (2013), the motivational effects of digital technologies are by and large situational. Using technologies in class may provide situational interest, but it may not lead to sustained interest, which will be required to engage students in deep learning. It is the contexts of learning and in particular the pedagogy employed in a learning context which will be crucial for supporting students to sustain their interest, rather than simply by using technologies (which are often used as a reward system).

Furthermore, it seems that the negative effects of using digital technologies in learning are seldom reported in the literature (Selwyn 2011). We should be mindful that there are cognitive as well as social costs in using digital technology. Taking multitasking as an example, multitasking has been widely endorsed by digital technology advocates as a positive learning outcome of technology use, and a skill that students should acquire, to the extent that teachers in some countries, e.g., Germany, are required to teach their students the skill of how to multitask (Spitzer 2014). However, as pointed out by Lee et al. (2012), multitasking as a learning strategy contradicts with what we have learned from cognitive science (the cognitive load theory) and neuroscience research, which suggests that undivided attention is needed in intentional learning. Multitasking may not be an effective learning strategy in academic learning and thus should not be encouraged. Also, how intense and frequent should students use digital technologies are contestable. For example, Fuchs and Woessmann (2004) argue that while some students may benefit from using digital technologies in class, their frequent use at home may "distract students from effective learning" (p. 1). As pointed out by Philip and Garcia (2013), seeing technology as a quick fix for educational issues is at best problematic and at worst dangerous. Taking a techno-centric view in evaluating the use of ICT in learning and education may create a biased view of what is actually happening in the classroom. Thus, in reviewing the literature, it is important to differentiate what are the expected or potential benefits of digital technologies, as proposed by digital technology advocates, from their actual benefits as classroom practices as documented in empirical research studies (Selwyn 2011).

We should also note that while there has been significant increase in technology-related activities in schools in the last 10 years, for example, technology hardware such as interactive whiteboards and tablets are now more widely used in schools, there is a digital divide in technology access, and digital technologies are frequently used only by a minority of students, and in certain school subjects. (A more detailed discussion of equity issues can be found in Section XI "Issues and Challenges Related to Digital Equity" of this *Handbook*.) For example, the recent OECD (2015) report showed that even in countries such as China and South Korea where the computer and mobile device penetration rates topped the world, only 42% and 38% of the students in these countries, respectively, used computers in schools in 2011. It seems what Cuban (1986) has argued some 30 years ago about the cycles of technology use in education still holds today. Cuban (1986) maintains that there is a cycle of technology use whenever a new technology is introduced to the education sector. At first there is great expectation for its benefits; then it is supported by some initial research confirming its effectiveness; subsequently policy makers will invest on it; but at the end of this cycle there is limited use in the classroom and no conclusive outcome is reported. Then it comes the next cycle when a new technology is advocated.

Issues and Challenges for Researchers and Practitioners

With the increasing ubiquity of digital and mobile technologies, it is a challenging time to be a technology-using teacher or a TEL researcher. For practitioners, they now face even greater institutional pressure than a decade ago to use digital technologies in their teaching, even though they may not be conversant with the pedagogies associated with TEL and their educational benefits. Almost 15 years ago

Maddux (2003) used the term Everest syndrome to describe how policy makers and teachers viewed the use of technology in learning, and his observation is still valid today. The Everest syndrome refers to a general conception that “computers should be brought into educational settings simply because they are there” (p. 5). As a quick add-on to the classroom, the use of digital technologies is often driven by a technology-centered approach where technological innovations are adopted in the classroom to drive pedagogy without adequate research validation (Maddux 2003). This techno-centric ethos still largely dominates the thinking of many educators, even though they may not be aware of it. It is hoped that through professional learning and development this techno-centric mindset can be erased or at least minimized. As for researchers, with the proliferation of TEL journals and conferences, and increased work pressure in a knowledge-driven society, there is a temptation to publish speedily from small exploratory case studies. As pointed out by Selwyn (2011), the challenge for researchers is to spend sufficient amount of time in the classroom with students and teachers so as to understand what is actually going on when digital technology is used to support teaching and learning, since TEL research is not just about the technology, or for that matter even just about learning, but how and why learning happens within a complex sociopolitical system, with technology being only one of the components of the system. While in the last 10 years there has been increasing focus on the learner rather than on the technology, mainstream research is still looking for technological impacts or effects on learning outcomes, and many researchers and policy adopt a rather deterministic view on the use of digital technologies in education. A more ecological view should be encouraged in the future, and the learner should be seen as organically interacting with technologies embedded in a sociocultural environment.

While digital technologies have primarily been seen as cognitive tools, increasingly practitioners, researchers, and policy makers have become aware of their psychological and emotional effects on the young learners. Attention is drawn to the health and safety issues related to digital technology use. With the ease of creating anonymity and identity on the Internet, cyber bullying is on the rise (Navarro et al. 2016). Easy accessibility and fast connectivity to the Internet also mean a higher risk of students being exposed to inappropriate materials, and the possibility of developing addictive behaviors. While the issue of Internet privacy has always been a concern, with the increasingly use of analytics tools by schools, there is an urgent need to develop policy guidelines to protect the access and use of personal data and to prevent unnecessary intrusions of personal learning space (Livingstone et al. 2012). Using a more holistic view in examining the use of technologies in the learning process, researchers, policy makers, and practitioners should be mindful of how to protect the learners and look after their overall well-being. This concern should not exclusively be cognitive, but also emotional, as well as the general health and safety of the children and young people.

How practitioners use technologies to support the learning process is a big challenge. Teachers should not underestimate their key influences on how technologies are used by their students in formal settings, as well as in informal settings outside the school context. If students are to be encouraged to use digital technologies to support deep learning, develop twenty-first-century skills, and be innovative in creating knowledge (Scardamalia 2001), the roles of the teachers and their professional identities have to be changed. Teachers have to model the attitudes and dispositions of being a lifelong learner and knowledge creator in order to support their students to develop these attributes. The goal is to harness technology's affordances to support learner agency in a holistic way.

Conclusion

This chapter has provided a general overview of how digital technologies have been used to support the learner and the learning process. It should be noted that while in the last 10 years there has been an increase in the use of digital technologies in the learning process, on the whole their use has not been as widespread as expected. There is also a major difference between the anticipated use of digital technology, as advocated by some technology enthusiasts, and its actual use. While there are pockets of innovative designs of TEL, how these technology-supported learning environments can be scaled up and sustained is a major issue. Also, after more than 30 years of using digital technologies in the school system, and a wealth of research has been amassed on TEL, we need to admit that we do not know very much about what actually happens to the learner during the learning process when digital technologies are used to support such a process. The effects of digital technology use are inconclusive, since it is not clear whether and how they can be measured. We are reminded by Cuban (1986) that since digital technologies are advancing so rapidly, it is easy to fall into the trap of the endless "pursuit of the new" and keep reinventing ourselves without truly understanding the promises and benefits of technology-enhanced learning.

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11 Information and Communication Technologies, and Learning Theories: Putting Pedagogy into Practice

Vanessa P. Dennen, Kerry J. Burner, and Michelle L. Cates

Contents

Abstract

This chapter explores how learning theory relates to the use of information and communication technologies (ICT) in the K-12 classroom. Teachers need both pedagogical knowledge and technological knowledge, along with content knowledge, in order to support effective learning experiences for their students. Learning theories guide this pedagogical knowledge, providing support for which instructional strategies teachers might use. The three historically dominant learning theories – behaviorism, cognitivist, and constructivism – are briefly presented

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through vignettes that explore student and teacher ICT use. Basic tenets of each theory are briefly discussed along with examples of instructional strategies that reflect each theoretical approach to ICT use. A fourth theory, connectivism, which has yet to be fully accepted or embraced as a major learning theory but nonetheless represents a theoretical approach to learning via ICT-based networks, also is explored. With these theories in mind, this chapter notes that ICT are not always used in a manner that reflects sound or thoughtful pedagogical decisions; a teacher's pedagogical choices may also be system-driven or technology-driven. As the chapter concludes, we share implications both for using ICT in a manner that is consistent with and fully supports learner development and for supporting teacher development of knowledge about learning theory along with the intersection of pedagogy and technology.

Keywords
Behaviorism · Cognitivisim · Constructivism · Connectivism · Learning theory · Pedagogy · ICT

Information and communication technologies (ICT) can be integrated in K-12 education in myriad ways, reflecting diverse approaches to learning, communication, and behavior management among teachers and institutions as well as differences in disciplinary areas. Some ICT have been developed with specific learning theories and related instructional strategies in mind. Additionally, instructors may choose specific ICT for classroom use and develop learning activities that reflect and support a specific epistemological perspective. Regardless of the approach taken, the greater point is that ICT are not theory-neutral technologies. Instead, their design and classroom integration both reflect specific orientations toward knowing and learning.

In this chapter, we explore how theoretical perspectives – particularly pedagogical theories – shape how ICT are used in K-12 settings. We start with brief discussions of how teacher pedagogical beliefs and knowledge influence the ways learning theory is used to support K-12 ICT adoption and integration. Next, we summarize theoretical approaches, focusing primarily on how the three dominant learning theories – behaviorism, cognitivism, and constructivism – and a newer theory (connectivism) provide instructional implications for ICT use. As we conclude, we discuss specific challenges and implications related to taking a theory-oriented approach to ICT use in K-12 learning contexts.

ICT Integration and Teacher Pedagogical Orientation

Learning and related ICT use cannot easily be disambiguated from the context in which it occurs. To that end, technology integration is a systemic endeavor that integrates technology, pedagogy, and content in the service of achieving learning goals. The Technological Pedagogical Content Knowledge (TPACK) Framework explores how these three constructs relate to each other and overlap in the service of technology integration (Mishra and Koehler 2006). One dimension of TPACK is Technological Pedagogical Knowledge (TPK), or knowledge of how to use technologies in support of learning. Teachers with strong TPK can effectively use technology in ways that enhance learning and make decisions about technology integration that are responsive to different types of teaching activities and learning outcomes (Schmidt et al. 2009). With the addition of content knowledge, teachers can make these technology integration decisions in a manner that is discipline-appropriate.

Pedagogical beliefs have great influence over if and how teachers choose to integrate technologies into their classrooms. Teachers tend to choose technologies that both support their beliefs and their prior experiences (Tondeur et al. 2016). They can be supported in their technology integration endeavors by the provision of examples, support, and professional development that are aligned with their existing beliefs (Ertmer and Ottenbreit-Leftwich 2010). In the classroom, pedagogical knowledge is closely intertwined with both technological and content knowledge (Archambault and Barnett 2010). It is difficult to clearly specify the boundaries between each of these constructs, but doing so is necessary to help better guide practitioners on technology integration issues (Graham 2011). By isolating pedagogical beliefs, it is possible both to challenge teachers to try new technologies and to support teachers in finding technologies and technology integration strategies that are likely to succeed in their classrooms.

Theoretical Approaches

Various means have been suggested for examining theoretical – especially pedagogical – approaches to ICT use in education. Taylor (1980) classified approaches to computer-supported learning in terms of how the learner interacts with the ICT, whether as a tutor, a tool, or a tutee. Koschmann and colleagues later explored these classifications in the context of ICT research, seeking a way to understand how newer technologies were being used to support interpersonal collaboration (Koschmann 2001; Koschmann et al. 1996). This initial work demonstrated how ICT use and research paradigms aligned with learning theories, with the most recent paradigm – computer-supported collaborative learning (CSCL) – having a social constructivist foundation (Koschmann et al. 1996). Others have also drawn direct parallels between ICT use and learning theories. Bottino (2004) described three models of ICT-based learning, a transmission model, a learner-centered model, and a participative model; these models parallel the dominant three learning theories. Naismith et al. (2004) similarly remain close to learning theories when describing approaches to mobile learning use. They classified mobile learning activities in six ways. The first three activity classifications directly reflect the learning theories that are embodied in the design and use of the technology (behaviorist, constructivist, situated), whereas the last three reflect the purpose and conditions of use (collaborative, informal and lifelong, and learning and teaching support). What all these approaches to ICT classification share is a focus on the underlying epistemological beliefs and their corresponding learning theories.

This section discusses ICT use within the context of behaviorist, cognitivist, and constructivist learning theories. Each theory is introduced with a vignette that introduces classroom scenarios in which ICT are used in accordance with that theory. Then the core tenets of the theories are presented along with an overview of ICT use related to that theoretical approach. It is only possible to scratch the surface of these theories and related ICT use in a single chapter, but the key ideas and cited literature pave a path for deeper inquiry in these areas.

Behaviorism

Julia picks up an iPad from the cart in the corner of her third grade classroom and returns to her desk. Swiping the device on, she opens an app called Multiplication Circus. After logging in, Julia is given a series of multiplication problems to solve. Each time she solves a problem correctly, the clown in the corner of the screen gets an extra ball to juggle. Each time she solves one incorrectly, the clown drops the balls. When the next question is answered correctly, the clown begins to juggle again. Every time she solves five consecutive problems correctly, she is rewarded with an animation of acrobats. While Julia is engrossed in the app, her teacher takes note. Using her iPad, the teacher opens Class Dojo and marks down that Julia is "on task." That evening, her parents will be able to log on to the system and see that Julia had good behavior in school today and how far she progressed with her multiplication practice. Julia is motivated – if she gets all good reports on her behavior and class progress this week – she will be able to have her best friend sleep over on Saturday.

Across town, in a high school classroom, Julia's older brother Jacob is using a student response system, or clicker, in his chemistry class. His instructor is doing a quick review of the material from the previous unit and the review is punctuated with slides that have multiple choice questions. When a question screen pops up, Jacob and his classmates select a response. The teacher then shows the answers, allowing the students to see whether they were right or wrong. Later, the teacher will review the students' responses to determine the areas where more practice is needed. Additionally, students who answer all the practice questions correctly will not be required to turn in homework the next day.

That afternoon, in Julia's music class, the iPads are being used again. This time the students are using simulated keyboards and learning how to play a simple song within a one octave range. Each time the student repeats a measure from the song satisfactorily three times, the student is prompted to practice the entire song as learned thus far, and moves on to learning the next measure. Students are moving at their own pace, and the teacher circulates the room to see if anyone needs additional help.

Major Tenets of Behaviorism. Behaviorism is a theory focused on learning as a persistent change in observable behavior. In other words, in the behaviorist approach we know that someone has learned something when they are able to perform a new behavior visibly and consistently. Behaviors can be strengthened or weakened by using a reinforcing stimulus (Skinner 1958). This stimulus may be satisfying or aversive, and it may be presented to the learner or removed (see Driscoll 2005, for a fuller description of the principles of behavior management). It is not limited to physical actions but also includes verbal behavior (Skinner 1957).

Behaviorism and ICT. The roots of behaviorism and technology use date back to Skinner's work in the 1950s with programmed instruction and teaching machines. Skinner (1958) proposed that individual students could engage in self-paced mastery learning, responding to prompts, checking answers, and only advancing when the correct answer is supplied. Skinner suggested that this practice and feedback was a form of shaping the correct behavior as the learner received incremental feedback with each bit of learning progress. Skinner and his early colleagues were technological determinists, believing that the technology, along with its precisely designed learning materials, was the key to the promoting efficient instruction. Programmed instruction saw its decline as a primary means of education as researchers identified other elements (e.g., teacher attitude, student motivation) that were critical to learning success and as the rigidity of the intervention led to limited and oversimplified learning interactions (McDonald et al. 2005). Still, behaviorism lives on in current uses of ICT, although in many instances they are developed with more flexibility in mind. For example, student response systems (SRS) can be used to foster the same type of interactions, with students responding individually to a question and receiving immediate feedback on their response (Edens 2008). Today's SRS differ from programmed instruction, however, in that they are typically used in a group situation, with questions asked of an entire class. Although SRS may be used in support of other learning theories, their use is frequently embedded in lectures for the purposes of attendance and individual formative learning assessment, and students may receive points for their participation (Liu et al. 2016). Additionally, the teacher plays an integral role in both determining the questions and setting the overall pace of the instruction based on the responses of the whole group (Scott 2014).

Behaviorism also remains alive and well in the classroom through the many applications designed to promote drill-and-practice style interactions, allowing students to answer practice questions focused on simple skills and concepts (see Kuiper and de Pater-Sneep 2014 for an example), as well as classroom management tools. Behaviorist practice activities may be embedded in a game-like context to help engage the learner (Kebritchi and Hirumi 2008). This form of ICT-based learning became popular in the 1990s as CD-ROM technology rose to prominence and has again found a strong user base through mobile applications and learning systems. Today, most mobile learning activities for PK-12 children are designed from a behaviorist perspective (Crompton et al. 2017). Computer-based learning systems that address mathematics and reading skills, often purchased from educational publishers, typically support objective-style practice activities and generate learner performance analytics that can later be used to monitor learner progress and to guide subsequent learning activities. Typically aligned with standardized tests, use of this software may be associated with increased test performance (Martindale et al. 2005).

Finally, teachers are adopting technology-based behavior management systems that allow them to keep digital records of student behaviors, reward students for their behaviors, and share student behavior information with parents. Through digital token economies, these systems may support behavioral goal setting and, ultimately, change (Krach and McCreery 2015). Although not yet heavily researched, early indicators suggest that these behavioral ICT interventions help improve student behavior when used for positive reinforcement (MacLean-Blevins 2013).

In the above vignette, Julia's teacher is using Class Dojo as a behavior management tool. Reporting Julia's on task performance to her parents is a reward, a form of positive reinforcement. The multiplication game that she plays similarly provides positive reinforcement when she answers questions correctly (e.g., the clown juggles an extra ball, or an animation appears) and punishment for incorrect answers (e.g., the clown drops the balls). Her brother Jacob is similarly answering questions and receiving feedback about the correctness of his answer. His teacher is using negative reinforcement (e.g., removing homework) to encourage students to perform well on the practice activities. Finally, Julia's music teacher has students learning via an app that teaches the complex behavior of playing an entire song via chaining, or connecting smaller behaviors.

Cognitivism

Malcolm's seventh grade civics class is visiting the computer lab today. Once seated, Malcolm opens *Webspiration* and begins concept mapping roles of the US government. His task requires him to synthesize information from his teacher's lectures, his textbook, and cursory web searches. Malcolm chooses the three branches of federal government as his top organization categories and then includes key responsibilities which further branch into landmark decisions. Next to him, Chloe has chosen to make governmental roles as the main categories and then branches into the various levels of government that fulfill these roles. When complete, Malcolm and Chloe share their concept maps with their teacher, who will provide feedback through comments directly in the web-based program.

In a classroom across campus, eighth grader Anna pulls a laptop from a cart and opens her digital textbook. Class begins with a short lecture during which the teacher projects a Venn Diagram on the screen. The teacher proceeds to compare viruses, today's topic, to bacteria, which students studied last week. Anna then reads the assigned portion of her textbook on the laptop, the content of which is chunked into three sections. Each page utilizes bold headings and vocabulary words so Anna is focused on the key concepts. The concepts are summarized and elaborated in frequent tables and diagrams. When Anna completes each section, she checks her comprehension in an embedded three-question multiple choice quiz. To her delight, Anna is directed to pull out her smart phones and slip it into a Google Cardboard. Anna is now immersed in a 3-D virtual reality scene showing a virus attacking a cell and spreading throughout the body. Finally, she works with two students to demonstrate their new learning in a digital worksheet accessed through the online textbook software.

In the nearby elementary school, first-grader Aidan is choosing a research topic for his contribution to an ocean unit. He opens *Pebble Go*, a K-2 research database, and is greeted by a picture-based browsing window. Aidan browses through the following categories in increasing specificity: animals, mammals, whales and other water mammals, killer whales. Having chosen the topic "killer whales," Aidan's task is to print the two activity sheets included in the software, and then to use those sheets for recording information. One sheet is a color diagram of a killer whale on which Aidan will identify body parts from a word bank. The other sheet is a notetaking page on which he will record facts about the killer whale's body, habitat, food, and life cycle. Aidan now has a purpose for reading. The *Pebble Go* information is divided into five tabs aligned with the activity sheets. Each tab has three sentences and a picture. Since Aidan is a beginning reader, he clicks the speaker icon so the text is read aloud to him in a natural voice, highlighting each word as it is read. He then chooses the media icons to see video of killer whales in the wild, hear their songs, and see a range map of their habitat. Finally, Aidan returns to the tabs that align with his activity sheet and reads independently for information to complete the research questions.

Major Tenets of Cognitivism. Malcolm, Anna, and Aidan are learning through ICT activities entrenched in cognitivist learning theory. This theory emerged around the mid-twentieth century as an outgrowth of behaviorism. Like behaviorism, cognitivists believe in an objective reality that can be known and taught. Unlike behaviorists, cognitivists focus on the internal processes within the brain through which new information is stored in long-term memory and then retrieved for use in the short-term memory.

Cognitivists support a three-component memory system akin to a computer: sensory memory → short-term memory ↔ long-term memory. Students are surrounded by environmental stimuli, some of which is attended to by their sensory memory. From there, the information then moves to the short-term memory (STM). It is in the STM that active thinking occurs. If students rehearse the information in their STM, it may be encoded and stored in the long-term memory (LTM). When students need that information again, they retrieve it from the LTM and transfer it to the STM. Cognitive scientists focus on ways of helping students attend to, encode, and retrieve information so it may effectively transition between the three memories. Frequent and diverse practice coupled with elaborative feedback is the means by which learning occurs in the memory system.

Cognitivism and ICT. Cognitive theorists have proposed many approaches to supporting student learning that are now familiar in classrooms. These well-established approaches are often utilized in ICT to help students effectively learn and remember information. Below are a few fundamental approaches that were apparent in the above vignette. This list is representative rather than exhaustive.

Advance Organizers. Advance organizers structure learning material for use prior to mastering the content. Anna's teacher uses the Venn diagram to connect new knowledge to previous learning. Aidan printed his activity sheet prior to learning so that he knew where to focus his reading. ICT often include an overview and objectives as advance organizers. Advance organizers alert students to the important concepts or elicit prior knowledge, preparing students to organize new information into existing mental structures (Ausubel 1978).

Chunking. Chunking occurs when pieces of content are grouped together, or chunked, to assist short-term memory. Short-term memory is finite; it is thought to hold seven bits of information, plus or minus two, for 15–30 sec (Miller 1956). When many discrete facts are chunked into topics, the STM can utilize the chunks of facts as needed, rather than attempting to recall discrete bits of information at once. In the vignette, Anna's text was divided into sections followed by short quizzes and Aidan's killer whale text was presented in topical tabs. These design decisions increased STM capacity through chunking.

Cognitive Load and Encoding. Cognitive load is the amount of effort expended by the STM to complete a task. Heavy cognitive load may impede learning. Sweller (2010) states that the intrinsic cognitive load of information can only be minimized by instructional design, not by changing the nature of the information itself. ICT-based learning environments make use of multiple channels of information (e.g., text, visual, audio); depending on their design, they may reduce or increase cognitive load. Sweller's research shows that dual-encoding, using both visual and verbal inputs, reduces cognitive load and thereby increases STM capacity. Similarly, Mayer's (2009) theory of multimedia learning provides guidance for designing multimedia-based ICT that will reduce cognitive load and support effective encoding. In the vignette, Aidan used the narration feature in *Pebble Go* to manage his cognitive load, ensuring that reading struggles did not impede his comprehension, while Anna used typographic and graphic supports for semantic encoding when reading her digital textbooks.

Practice, Feedback, and Schema Development. To encode information, students need to practice or rehearse it. The simplest encoding strategy would be tireless repetition for rote facts such as multiplication tables. Here, cognitivism is like behaviorism, using drill-and-practice coupled with feedback. However, where behaviorism relied on reinforcement as feedback, cognitivism supports specific and elaborative feedback to shape encoding, breaking misconceptions, and building better relationships. But cognitivism expands knowledge beyond rote learning to include conceptual learning, the relationship of information to other information. Gagné (1985) claims learning through relationships rather than simple reinforcement is a defining improvement of cognitivism over behaviorism. These relationships, called schema, are a hallmark of cognitivism; information is organized into hierarchical models in the brain, interrelated though examples and nonexamples, categories, and attributes (Anderson 1984).

Malcolm explored and solidified his schema of the US government through his concept mapping, a common cognitivist strategy wherein students explore information relationships in a manner that is logical to their existing schema. Anna and Aidan's content was preorganized into relationships for them, which is less effective for meaningful encoding and therefore less able to be retrieved unless coupled with other types of practice. In terms of feedback, Malcolm only shared his project with this teacher, but he could have used ICT to share a copy with classmates, too. Anna will also receive feedback on her team effort synthesizing the reading with the tables, charts, and simulation; however, this feedback will be supplied by the online textbook. What differentiates Anna's feedback from behavioral feedback is elaboration on why responses were right or wrong.

Constructivism

As the web-conference started, Demetria noticed Margarit was sitting low, with her shoulders drooping. As the two began to talk, Demetria learned that her mentee was having difficulty differentiating instruction in her ESOL immersion class. Margarit was concerned that her students were not learning as effectively as they could. Her students in this class were a mixed grade, mixed proficiency group of nonnative speakers, most quite new to the country. Excluding English, five languages were represented in her classroom. She explained that she was having classroom management problems, possible due to the challenge of keeping everyone engaged in the same lesson.

Demetria asked how the hands-on project-based learning unit was going. Margarit explained to Demetria that she had believed the building block robotics project would be a way to bring the students together in a hands-on task that did not depend on common language or having demonstrated proficiency at a state standard. The students had access to the Internet to search for resources in their own languages and could translate material for them by the tool loaded onto the four computers in her classroom. She had hoped that as the students interacted and shared the success of building their project, they would all be motivated to communicate and write in their classroom translation journals, which they used for their weekly oral updates, so they could share in English their excitement about the project. Instead, the students were angry and nonparticipative. They did not stop to use the computers; they argued, and one afternoon a part was broken.

Demetria pointed out that the project contained an unfamiliar set of objects requiring specialized knowledge and handling. The students did not know how to do the project or how to research then translate the information they needed. Demetria suggested this project was evoking the opposite of Margarit's intentions. Demetria challenged Magarit to keep the idea of collaborative problem-based learning but to pick an enterprise already common or at least familiar to all or most of the children and build on what they knew. She asked Margarit to think of an experience that would be familiar to all the students in her class and one for which she would be able to provide learner support for each of her students. Then she asked Margarit to describe what worked best about the buddy-reading program that paired lower grade students with upper-grade students at the elementary school three times a week to read to each other. Margarit shared that her ESOL students especially benefited because they were usually paired with the other ESOL students and then it hit her. She sat straight up and looked at Demetria with a smile and shared her idea.

Magarit explained that she was going to develop a seed-to-table bake-a-birthday cake unit in collaboration with the local middle school ESOL teacher. She continued that she had an established relationship and that her class had previously interacted with the local middle school ESOL pull-out class using the school's learning management system's conferencing tool for a version of the buddy-reading program. The two groups of students worked hard to communicate in English. She had gotten special permission to let her students use their phones or mobile devices, if they had one, to translate as they all typically had a preferred tool already loaded and the one provided by the school was limited in scope of languages and unfamiliar to all of them. Margarit wondered if she could get that permission for mobile use all the time. She also hoped that by working with the middle school teacher, his students would be working a week ahead of hers, making the weekly conference calls an opportunity for the older kids to practice their new English skills by sharing their expertise on the content. The more she talked about it, the more excited she was. Demetria recalled the slump-shouldered first-year teacher she saw on her screen an hour ago and made sure to point out to Margarit how she turned what she thought was a failure into an opportunity. Both women logged off their mentoring meeting satisfied and were looking forward to the next one.

Major Tenets of Constructivism. Constructivism holds that people create their own unique meaning based on their sensory-based experiences and the subsequent integration of and reflection on those experiences. As a pedagogical framework, constructivism in the classroom requires reinforcing the individual's independent involvement in what is commonly found in K12: a structured group setting. Differentiating instruction requires that teachers have a sense of their students' ranges. In addition to the formal assessment of learning outcomes that is a standard feature in K12 settings, constructivist approaches require constant assessment during the learning process, which is, according to Green and Gredler (2002), consistent with the types of problem-solving approaches educational psychologists believe are most efficacious for learning. Teaching from a constructivist perspective does not mean that there are not attainable, common learning outcomes, but it does mean that our larger, inner knowledge bases are different because of our own unique historical trajectories and of our resulting standpoints. Constructivism relies on the constituted nature of human experience: the context in which we learn and the context that has shaped our at-this-moment selves is integral to the nature of constructivism. There are various forms of constructivism, the most common being social and cognitive constructivism. Both support the key tenet that meaning is constructed through human experiences, but the locus of knowledge construction differs.

Social Constructivism. Social constructivism centers around the notion that people create individual meaning by way of social interaction. Berger and Luckmann (1967) introduced the idea of socially constructed reality at the level of the individual, arguing that individuals use language and experiences to uniquely interpret then internalize these interpretations as their reality. Vygotsky (1978) also considered the role of social interaction, culture, and language in the meaning making of children, identifying the zone of proximal development (ZPD), "the distance between the actual developmental level as determined by the independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). Learning experiences should be scaffolded by the provision of support that is just enough to help the learner accomplish new tasks within the ZPD.

Cognitive Constructivism. Cognitive constructivism focuses on the internal processes of an individual's learning more than on the context, culture, or social setting in which that learning happens. Cognitive constructivism relies heavily on schema theory as well; learners are constructing knowledge by adding it to the old in an ongoing process of refining individual knowledge. Bartlett (1932) first introduced the term schema to refer to an individual's internal understanding and perspective on a given topic. It is to this internal schema, all newly learned information is added, according to educational psychologists and learning theorists. The activation of that knowledge is key to the process of adding to it. From a cognitive constructivist teaching perspective, the onus is on the instructor to stimulate and build upon what the learner already knows and do so in a developmentally appropriate way (Piaget 1960; Bruner 1964).

Constructivism and ICT. In the mentoring example above, ICT were used both by the teachers and students. The ability to mentor a teacher via web conferencing is an example of Demetria using a common ICT in a socially constructivist way. Modeling this manner of connecting at a distance for the sake of learning demonstrates both social cognitivism and cognitive constructivism. The cognitive apprenticeship between Demetria and Margarit centers around their co-construction of meaning in relation to Margarit's first-year teaching experiences. Cognitive constructivists would argue that the mental model of connecting at a distance with a more experienced peer influenced the eventual lesson design Margarit settled: connecting her Grade 4/5 students with middle school ones via web conferencing is using an ICT in support of promoting learning in her students' zones of proximal development. Teaching from a constructivist perspective in a classroom with speakers of many languages adds a level of complication as constructivist theories and language are entwined. The first iteration of her lesson failed because she was relying on novelty to outweigh the need for extant knowledge on which to build. Her students had limited schema in place for building block robotics projects; coupled with the lack of common language, this created a frustrating not fruitful learning experience for her students. By tapping into something they all likely have some experience with, and learning what the level of experience is by assessing their current mental models, Margarit has developed a lesson from a constructivist perspective that incorporates ICT in a way consistent with that perspective.

The collaboration evidenced in the vignette is a type of computer supported collaborative learning (CSCL). CSCL involves fostering collaboration among students with a computer as a key partner in that interaction and should not be confused with e-learning efforts that emphasize computer-based dissemination of learning materials (Stahl et al. 2006). CSCL theory has been the focus of robust research and development during the twenty-first century, as researchers seek ways to best support learning collaborations and enculturate learners in the practice of shared knowledge activities (Roschelle 2013). Metacognition, social factors, guiding scripts, and scaffolded interactions all play important roles in this theory (Kirschner and Erkens 2013).

Beyond Behaviorism, Cognitivism, and Constructivism: Connectivism

Lou is fascinated by hurricanes and is interested in being a meteorologist someday. Her interests have led her to explore the topic online. When she first started researching hurricanes on the Internet, she immediately came across several great resources. They ranged from the websites of official meteorology organizations to regular citizens who shared her interests and who also wanted to learn more about meteorology in general and hurricanes more specifically. Lou reached out and made connections with these people; she followed them on Twitter, joined listservs and discussion forums, and even began to host her own blog where she documented her personal learning journey about hurricanes, including her experiences as a child growing up in Florida, where hurricanes are an annual threat. When Hurricane Harvey bore down on the United States, Lou was very active online. With her online network, she was sharing and discussing the latest hurricane tracking data. She in turn blogged a twice-daily hurricane update, which was read by both people in her social networks (e.g., family and friends, her fellow hurricane followers) and others who stumbled upon her blog. People asked her questions in the comments, which she answered to the best of her ability. She helped connect her blog followers to other online hurricane resources, as well, because she knew the value of her network for learning about hurricanes.

Major Tenets of Connectivism

One criticism of the major three learning theories has been that they reflect learning in a different era (Siemens 2005). All three theories – behaviorism, cognitivism, and constructivism – have their roots and major development situated firmly in the nineteenth century, a time when learning involved either face-to-face interaction or interaction with static learning materials. Siemens (2005) suggests that we need a new way of looking at learning, one that reflects current technologies and trends such as informal learning, lifelong learning, a rising need for information access skills, and a growing dependence on technology to handle formerly memory-intensive tasks. Siemens (2005) asserts that "technology is altering (rewiring) our brains. The tools we use define and shape our thinking" (para. 4). Not everyone will agree with technological determinism as an approach to learning theory, but technological determinism nonetheless has been a common theme of distance learning scholars and ideally technology and pedagogy work in a symbiotic manner to foster effective learning (Anderson and Dron 2011). Based on this idea that contemporary life is shaped by technology, connectivism has been recommended by Siemens (2005) as a fourth theoretical approach to learning, one that is inextricably interwoven with ICT and focuses on networked learning. Although connectivism's status as a theory has been questioned (Kop and Hill 2008), even its critics believe it is at a minimum complementary to existing learning theories (Bell 2011), and the technological shift that has prompted researchers and theorists to renew the discussion of the adequacy of existing learning theories has been termed "seismic" in its effect on how people think and learn in their everyday lives (Dede 2008).

Connectivism and K-12 Education

The connectivist approach supposes that learners can act autonomously within their networks to set and achieve their goals, which may not be realistic for all learners and in all contexts (Anderson and Dron 2011). Within the K-12 curriculum, the idea of preparing students to engage in lifelong and informal learning via connectivist means fits well with the current efforts to support ICT literacy skills, although engaging elementary students in this form of learning may be a bit of a stretch developmentally. As can be seen in Lou's vignette, the connectivist approach puts the learner in the position of building and interacting in a personal online learning network, which requires not only sufficient literacy skills but also a degree of maturity.

Learner development is not the only challenge facing connectivist learning in K-12 settings; even at the high school level, there are few examples of connectivism in practice. Schools are rife with structure and rely on teachers to lead and assess learning activities. Connectivism – which leaves no clear role for a teacher other than that of network member (Anderson and Dron 2011) – is somewhat at odds with formal educational systems. A shift in the teacher's role has been suggested, blending instructivism and constructivism in the service of developing connections (Siemens 2008). For example, perhaps Lou could have been guided by a science teacher to explore meteorology online, and her classmates might have been encouraged to explore their own relevant science interests in online networks. However, we currently lack guidelines and examples to work this approach into existing K-12 educational systems.

Additionally, Internet use policies in K-12 schools may prohibit or restrict learners' freedom to form meaningful online networks and connect to the full range of people and information that may be useful to support their learning goals. These limiting actions are done in the name of student safety but may mean that true connectivist approaches to K-12 learning are not feasible. It is possible that via a social constructivist approach to ICT-based learning – or perhaps a modified connectivist approach (e.g., mixing restricted networks and limited autonomy with flexible, learner-driven goals, and decision-making processes in a resource-dense online environment) – K-12 students could develop the information and networking skills that will allow them to engage effectively in connectivist learning outside of the school setting and throughout their lives.

Challenges

System-Driven Pedagogy

One challenge that limits learning theory-driven ICT integration within K-12 settings is the competing forces at play in educational systems. For example, the growing accountability culture in the United States (Rice 2014) has resulted in the increased use of software designed to prepare students for standardized tests, which themselves have increasingly been administered via computer. These tests, as currently designed, are focused primarily on assessing preset content and convergent thinking (Schoen and

Fusarelli 2008). At the same time, competing messages about the aims of education and ICT use are being sent at the national level. A content analysis of US Department of Education (USDOE) reports focused on elucidating the key components of contemporary ICT movements in K-12 education showed a heavy interest in technology use to support twenty-first century skills such as critical thinking and problem solving (Roberts-Mahoney et al. 2016). However, until student-centered instruction becomes the norm in classrooms and assessments and accountability measures that focus on the complexity and creativity underlying these skills are developed and adopted (Rotherham and Willingham 2010), efforts in this area are likely to be diffuse.

Additionally, ICT literacy skills are among the fuller list of twenty-first century skills supported by organizations such as Partnership for twenty-first Century Learning and the International Society for Technology in Education (refs). However, in terms of concrete ICT-based classroom activities, the USDOE mostly discusses student use of contemporary personal learning systems to practice and receive feedback in a manner reminiscent of Skinner's learning machines that leads to the standardized assessment of preset content discussed by Schoen and Fusarelli (2008). These learning systems continuously generate learning analytics data that are used for formative assessment in preparation for high-stakes testing. As Swan (2016) notes, this use of learning analytics influences epistemology, "privileg[ing] knowledge that can be quantified and tested" (p. 6). Theoretically, this approach to ICT-based learning represents an objectivist epistemology with largely behavioral and cognitivist undertones. Social learning is not heavily represented in this vision of K-12 ICT use (Roberts-Mahoney et al. 2016) even though social learning activities are consistent with addressing the complexities of twenty-first century skills (Rotherham and Willingham 2010). Although this example is from the United States, the larger point could apply anywhere: forces within the system such as legislation and policy may hinder a pedagogy-first approach.

Technology-Driven Pedagogy

Pedagogical choices may be led by technology adoption in some instances, rather than vice versa. Teachers may feel pressured to make use of technologies that the school has purchased, and these purchases may reflect a desire to follow trends or appease a group of stakeholders rather than a thoughtful choice about supporting a particular pedagogical strategy. ICT use also may be driven by an individual teacher's desire to be innovative and try something new in the classroom, and the novelty factor may encourage a tool-first approach in which technology adoption overshadows pedagogical concerns and strategies.

Further complicating matters, in many instances technologies are developed for other purposes and then co-opted by education, and technology-based learning materials may be developed by people whose programming expertise is stronger than their pedagogical knowledge. This means that the pedagogy is not necessarily designed into the ICT, but rather that the ICT are in search of a pedagogically sound use. While these atheoretical approaches may have their successes, ideally ICT will be designed and used in a manner that is pedagogically grounded.

Implications

Implications for Developing Learners

Each learning theory brings with it different implications for learners. Many of these are discussed above, but it also is worth considering the intersection of ICT, learning theory, and cognitive development. As children develop, they attain new psychomotor and cognitive skills. During grades K-2, many children are new readers and they benefit from graphical and auditory-based ICT interfaces. They may not yet read or understand text, and they are still learning the interface conventions that guide many programs. As they develop, these learners will engage in several cognitive transitions through which they will acquire increasingly complex cognitive abilities, such as those involved in abstract and hypothetical thought (Flavell 1992; Piaget 1960). Different ICT will be developmentally appropriate for different groups of learners. This does not mean that most learners will outgrow some ICT, but rather that some learners will need to grow into those ICT.

Bruner's (1964) work on modes of knowledge representation also has implications for how ICT literacy skills are developed. Novice learners likely need direct, manipulative experiences with both hardware and software. Learners with limited experience will still benefit from these action-based forms of instruction but may also be able to learn new ICT skills by watching someone else or watching a video. Advanced learners are the ones who are most likely to succeed when this instruction is delivered solely through written or spoken words.

Implications for Teacher Preparation and Professional Development

Teachers need theory to help them select the appropriate ICT integrated learning activities to achieve their instructional goals. For example, if the instructional objective is remembering and understanding, then ICT activities based in behaviorism are appropriate. Students receive information, practice repeatedly and at increasing levels of complexity, and then can demonstrate their learning. If applying and analyzing are the objectives, then cognitivist ICT activities, in which learning is based on connections, may be used. If critical thinking is the objective, then constructivist ICT activities in which students collaboratively address ill-structured problems are well suited. Teacher preparation and professional development programs can support teachers in developing this dual-view of ICT in which learning objectives and theoretical influence are intertwined.

What teachers do in their classrooms can reveal their epistemological beliefs, which may be tied to a single theory or more likely a pragmatic combination of behaviorism, cognitivism, constructivism, and connectivism. At the same time, teachers may be unaware of the nuanced theory underpinning their decisions and instead articulate their ICT-related choices as a reflection on what will be effective or has been successful in the past. Alternately, they may not know how to effectively match ICT use to their beliefs about learning and may limit classroom ICT experiences to academic software that presents knowledge and provides practice, either through drills, tutorials, or multimedia information sources. Teacher preparation and professional development programs can help develop and improve teachers' TPK, helping them better understand how to select and apply theoretically-based learning strategies in conjunction with ICT.

Conclusion

Learning theory plays a critical role in the success of K-12 ICT integration. As can be seen in this general overview of learning theories and their manifestation in ICT design and use, learning theory, although very important, is not the only factor that influences how ICT are used in schools. ICT integration occurs within a larger system; Fu's (2013) conclusion, that ICT integration takes effort from students, teachers, and administration, is one that we echo. We would add that teacher preparation and professional development that focuses on technical knowledge and pedagogical knowledge in addition to content knowledge is necessary to help teachers select appropriate ICT and make effective use of those already at hand.

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Developing Scientific Inquiry in Technology-Enhanced Learning Environments

12

Carol K. K. Chan and Yuqin Yang

Contents

Abstract

This chapter discusses theory, pedagogy, and design of technology-enhanced learning environments in promoting inquiry in science classrooms. Inquiry refers to both the diverse ways in which scientists study the natural world and the means of engaging students actively in developing an understanding about science

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content, science process, and how science develops. Supported by technology, students can be scaffolded to engage in inquiry practices, like those used by scientists, to help them deepen their understanding of science and to develop twenty-first-century educational competencies.

This chapter employs the Learning Sciences research paradigm that emphasizes social-constructivist frameworks and design-based research methodology. We first outline changing theories and frameworks of learning, pedagogy, and assessment, and discuss how they influence the design of technology-based learning environments. We then examine several major research programs, including Knowledge Integration, Project-Based Science, Virtual Environments, and Knowledge Building, all of which focus on the alignment of technology, theory, and pedagogy, and emphasize iterative implementation and design principles. Analysis and comparison of these different programs help illuminate theoretical issues and educational implications and identify challenges to designing technology-enhanced inquiry-based environments. We conclude that theory, pedagogy, and technology need to be integrated, and design-based research can illuminate and support learner processes synergizing theory and practice in real-world classrooms.

Keywords

Technology-enhanced learning environments · Inquiry · Collaboration · Knowledge creation · Design-based research

Introduction

Information and network technology-enhanced learning environments (TELEs) are receiving increasing attention for their potential to support new educational goals, including collaborative inquiry, problem solving, and knowledge creation (Edelson et al. 1999; Jeong and Hmelo-Silver 2016). The changing needs of knowledge-based societies have spawned new educational demands and opportunities; in particular, students need to develop new capacities as inquiry learners, collaborative problem solvers, and knowledge workers. The possibilities and challenges of technology-enhanced inquiry environments in scaffolding inquiry and transforming classroom practices are important questions for education and school improvement.

Helping students to engage in inquiry is a major educational goal in the knowledge era, and inquiry is of particular importance in science education – major policy documents and science curricula have specified the goal of teaching students scientific inquiry (e.g., National Research Council 1996; 2007). Inquiry has diverse meanings and we follow the framework adopted by the National Science Council documents – Inquiry refers to *both* the diverse ways in which scientists study the natural world and the means of engaging students actively in developing an understanding about science content, science process, and how science develops. Scientific inquiry in classroom, similar to how scientists study the world, involves several interrelated processes: (a) core inquiry processes, such as initiating and generating questions, inquiring into problems, using data, testing hypotheses, constructing explanation, and manipulating and coordinating scientific representations in problem solving; (b) process management and regulation, such as deciding what to do next, and planning, reflecting on, and regulating inquiry processes deploying metacognition; and (c) synthesizing, such as communicating and articulating how knowledge has been developed, and sustaining inquiry for knowledge creation (Edelson et al. 1999; Eslinger et al. 2008; Quintana and Zhang 2004). When engaging in inquiry learning, students have the opportunities to behave like what scientists do and inquiry is the main way of how knowledge is generated.

Inquiry plays a crucial role in science education: Participation in inquiry-based learning contributes to students' development of scientific practice such as posing and refining questions, planning and managing investigations, analyzing and communicating results, and also developing understanding of scientific principles. Inquiry can also help develop key twenty-first-century competencies and higher order thinking including problem solving, metacognition, and collaboration. Different from traditional approaches, inquiry learning is open-ended and entails cognitively complex tasks. In pursuing inquiry, students become problem solvers, and since inquiry is often implemented in social situations where discussion, argumentation, and negotiation are involved, students must interact and collaborate with others. Specifically, inquiry learning requires and provides opportunities to promote students' metacognitive skills, as they must engage in planning, monitoring, and regulating complex processes, and work collaboratively to solve complex problems; collaboration is now considered key to knowledge advance and creation (Scardamalia and Bereiter 2014).

Inquiry learning has many benefits, but it is also a complex process in which technology can support. Research has shown that technology-enhanced inquiry-based learning promotes such high-order thinking skills as questioning and explanation, problem-solving, critical thinking, reflection, self-directness, collaboration, and knowledge creation (Ketelhut et al. 2010; Geier et al. 2008; White and Frederiksen 1998; Yang et al. 2016), and develops students' high-level epistemic agency (Damşa 2014; Scardamalia and Bereiter 2014). Technological affordances can support inquiry-based learning by promoting student motivation and interests, making information and digital libraries accessible, helping students manipulate real-world modeling processes, visualizing and investigating scientific process, enabling and tracking records, and supporting reflection and discourse (Jeong and Hmelo-Silver 2016).

Despite the enthusiasm surrounding technology, its educational benefits are unconvincing (Kim and Hannafin 2011). Integrating technology with classroom practices requires substantial pedagogical changes and sociocultural support (Jeong and Hmelo-Silver 2016). Rather than using short-term experimental approaches or applied classroom research, we propose the use of design-based research commonly used in Learning Sciences for research-practice synergy.

In this chapter, we adopt a *Learning Sciences* paradigm that focuses on the alignment of theory, pedagogy, and technology, and emphasizes design, iteration, and design principles. Design-based research (DBR) addresses the dialectical relationships between theory and practice, supporting researchers and teachers to design productive learning environments while allowing researchers to study such phenomena as learner processes. Design-based research that consists of iterations of classroom implementation and evaluation is an important methodology for studying the interaction between technology, contexts, and learning theories (Collins et al. 2004); one that often involves teacher-researcher and multidisciplinary teams as codesigners.

This chapter examines theory, pedagogy, tools as integrated designs of technology-enhanced learning environments (TELEs) in scaffolding learning and inquiry in science classrooms. We first outline changes in theories of learning, pedagogy, and assessment (section "Contemporary Theories of Learning Underlying Design of Learning Environments"), and then review several major research programs of technology-enhanced inquiry-based learning environments (section "Technology-Enhanced Classroom Innovations on Inquiry-Based Learning"), followed by a comparative analysis of these programs and discussion of theoretical and pedagogical issues and implications for future research (section "Implications and Further Issues").

Contemporary Theories of Learning Underlying Design of Learning Environments

This section introduces contemporary themes in learning, pedagogy, and assessment to provide theoretical perspectives for examining technology-enhanced inquiry-based learning.

From Behavioral Learning to Knowledge Construction to Knowledge Creation

Traditionally, learning has been considered from a behaviorist perspective and situated in school settings emphasizing information transmission and students' acquisition of well-established content knowledge and skills. Early computer-assisted learning reflects and amplifies this approach through drill, practice, reinforcement, and rewards designed to make students' acquisition of predefined knowledge and skills more efficient and effective.

Since the early 1980s, learning has been reconceptualized from a constructivist perspective. Bransford et al. (1999), in their seminal book, *How People Learn*, maintained that learners adopt a constructive role in the learning process – relating new information to prior knowledge to restructure the latter, and use metacognitive strategies to reflect on their learning. In the 1990s, cognitive constructivism evolved into social constructivism, which conceptualized knowledge as coconstructed via interaction and sociocultural processes, and viewed learning as situated cognition, acculturation of practice, and participation via interaction and discourse. Since the 2000s, metaphors of learning have been expanded beyond "knowledge acquisition" and "acculturation," and researchers conceptualize learning as "knowledge creation," examining the emergence of new ideas and knowledge mediated by artifacts (Paavola et al. 2004; Scardamalia and Bereiter 2014). Aligned with these theoretical shifts, technologies have been designed to elicit and support students' learning and inquiry, including constructive processing and knowledge integration (Linn et al. 2004); metacognitive inquiry and regulation (Azevedo 2005); interaction and group cognition (Stahl 2006); and collaborative knowledge-building (Scardamalia and Bereiter 2014).

From Individual Learning to Group Learning to Knowledge Communities

Early learning theories and psychological studies predominately focused on *individual* learning and emphasized *individual* performance; thus, technology was developed to support individual learning. Recent approaches, however, depict learning as a social process. Related to learning theories emphasizing situated cognition (Lave and Wenger 1991), distributed cognition (Salomon 1993), activity theory (Greeno 2006), and collective cognitive responsibility (Scardamalia and Bereiter 2014), the unit of analysis has shifted toward group cognition and collective accomplishment; learning is distributed within group and emerges collectively in group and community contexts.

Such shifts underpin the development of new computer technologies that support students' collaborative, rather than individual, problem-solving, and inquiry. Specifically, computer-supported collaborative learning (CSCL) has emerged as a field focusing on examining the analysis of collaborative processes and how learning emerges through small group inquiry and interaction. The unit of analysis has changed from individuals to groups and communities, extending to students' interactions with agents (Leelawong and Biswas 2008), collaborative inquiry among community members (Zhang et al. 2009), and technology-supported mass collaboration (Halatchliyski et al. 2014).

From Instructionism to Guided Instruction to Emergent Design

Sawyer (2014) critiqued traditional schooling's emphasis on instructionism, a transmission teaching approach in which students receive information from the teacher, process it superficially, without constructing their own knowledge. Learning science designs highlight the importance of pedagogy that fosters deep learning and understanding; research has indicated students learn and retain materials better, and can better generalize it to other contexts, when they solve problems and act as professionals do in the field. *Authentic* problems and practices are thus key in pedagogical design. Accordingly, computer-supported environments must support deep learning and understanding (Sawyer 2014). Classroom implementation and design of technology learning environments must enable learners to manipulate and revise their developing knowledge by working with different scientific models and representations and engaging in inquiry-based activities for deep learning, much as scientists ask driving questions, propose hypotheses, and find evidence to support their conclusions (Linn et al. 2004; Krajcik and Shin 2014; Scardamalia and Bereiter 2014).

In learning sciences research, technologies are designed to guide and scaffold different kinds of learner and inquiry processes integrating with different pedagogy. For example, when structured inquiry is used to help students develop conceptual understanding of difficult science concepts, web-based libraries are developed; different tools are designed in alignment with different instructional patterns to support the knowledge integration processes (Linn et al. 2004; Slotta and Linn 2009). Knowledge building emphasizes emergent inquiry and advocates principle-based pedagogy not scripted activities; Knowledge Forum® is designed in ways to realize these principles and facilitate the development of knowledge-creation processes (Scardamalia and Bereiter 2014). Primarily, changing and emerging pedagogy influences the design of technology-enhanced environments in supporting learner processes.

From Assessment of Learning to Assessment as Learning and Collective Assessment

A fourth theme pertains to changing *assessment* theories and practices. Traditionally, assessment has focused on the objective measurement of such constructs as intelligence and ability (Shepard 2000); constructivism has shown knowledge domains to be more complex, and has informed a progression from evaluating student performance (*assessment of learning*), to using assessment to promote learning (*assessment for learning*), to students taking agency to monitor and reflect on and improve their learning progress (*assessment as learning*) (Shepard 2000; Black and Wiliam 1998). Researchers have urged better alignment among theory, practice, and assessment, spawning additional research on formative assessment (Carless 2010).

Changing assessment theories and practices have influenced technology design for computer-supported learning and peer assessment. Researchers in the recently emerged learning analytics field have used data stored in digital learning environments to examine and evaluate interaction patterns contributing to learning (Shum and Ferguson 2012), and use this data to facilitate *formative assessment* – that is, providing feedback to improve ongoing teaching and learning processes (Black and Wiliam 1998; Evans 2013). Assessment approaches also emphasize *reflective assessment* (learners reflecting on assessment data to improve their scientific inquiry) (White and Frederiksen 1998) and concurrent and transformative assessment (Scardamalia and Bereiter 2014). Most current learning analytics assess predefined learning objectives and learners' acquisition of static-state knowledge and skills (Schwartz and Arena 2013), rather than higher order thinking skills essential for innovation (Chen and Zhang 2016). Aligning assessment with pedagogy, and learning for promoting students' inquiry in technology-enhanced learning environments, are important research areas.

Technology-Enhanced Classroom Innovations on Inquiry-Based Learning

This section discusses four major research traditions of technology-enhanced learning environments, spanning over two decades, that support student inquiry, and make problem-solving, metacognition, and collaboration more prominent in classrooms. All these programs employ design-based research, involving iterative classroom implementation and evaluation for improving designs, and integrate theory, pedagogy, and technology in classrooms.

Knowledge Integration and the Web-Based Inquiry Science Environment (WISE)

The knowledge integration framework and WISE (http://wise.berkeley.edu) support science learning through technology-enhanced and web-based inquiry in the science classroom. Building on such earlier projects as the Computer as Learning Partner Project (1980s) and the Knowledge-Integration Environment (1990s), WISE is a free, open-source curriculum platform that provides inquiry-based units on a wide range of science topics for middle- and high-school students; it also provides authoring tools for creating new inquiry units. The goal is to bridge the science taught in schools with students' everyday life (Linn et al. 2004), engage students in inquiry, and help them improve their scientific understanding in becoming lifelong learners (Linn and Eylon 2011).

WISE was designed based on the Knowledge Integration (KI) framework, which is "a dynamic process where students connect their conceptual ideas, link ideas to explain phenomena, add more experiences from the world to their mix of ideas and, restructure ideas with a more coherent view" (Bell and Linn 2000, p. 797). Students often come to the classrooms with fragmentary ideas, and the KI framework aims at *eliciting* students' ideas and *adding* new normative ideas by engaging students with scientific visualization, experiments, and hands-on activities, and scaffolds students' processes of organizing, *distinguishing* between, and connecting these ideas, emphasizing students' continual reflection as they construct and articulate their *integrated* understanding (Linn and Eylon 2011).

In a typical WISE inquiry project (e.g., the deformed frog mystery), most of which lasts 5–10 days, student dyads work on a shared computer and navigate through a sequence of inquiry activities. A WISE project involves students completing different activities in set sequence, by clicking on successive steps in the WISE inquiry map, one at a time. Students respond to online inquiry activities such as using visualization to explore simulations, design experiments, and interact with media, supported by technology-enhanced scaffolds that guide students to visualize the inquiry process and emphasize the use of evidence and scientific argumentation.

Over the years, different WISE instructional patterns and inquiry tools have been developed to help students work on diverse problems and projects, use complex scientific models, and track their learning process in complex projects (Slotta and

Linn 2009). For example, *Idea Manager*, a web-based, curriculum-integrated tool suite, was designed to help students construct evidence-based explanations from dynamic scientific visualization as they generate, distinguish between, and reconcile their ideas, to facilitate students' reflecting on and sharing of ideas, and to record students' understanding. Other examples include *Data Visualizer*, which presents tables and graphs; *Sensemaker*, wherein students sort out scientific evidence; and *Causal Map*, where students arrange causal factors in interactive maps (Slotta and Linn 2009). Continuing efforts are given to the development of different WISE tools to support different instructional patterns and KI processes. This research program also investigates its impact on student learning: for example, Linn et al. (2006) showed the WISE cohort (N = 4520) scored significantly higher than the regular cohort (N = 3712) on complex science items (not regular multiple choice), while Linn and Eylon (2011) used learning trajectory studies and found students' improvements from pre- and posttests to delayed posttests across different units.

This tradition of work provides an important example of design-based research (DBR) for the sequence of design, formative evaluations guiding iterative revisions to the designs, and sets of design principles. This program comprises four meta-principles: (a) make science accessible by connecting it to what students know; (b) make science visible by explaining scientific processes and illustrating connections; (c) help students learn from each other through respectful in-classroom collaborations; and (d) promote autonomous lifelong learning by supporting project work, and reflecting on scientific ideas (Linn et al. 2004). These key principles (and numerous subordinate principles) were developed from numerous studies in complex classrooms. Linn and colleagues worked with multidisciplinary teams of researchers, scientists, teachers, and technology experts – Participants exchanged insights relevant to design, learning, and teaching, including the development of curricula materials and professional development strategies including teachers' participation in the design of technology to support their practice.

Project-Based Science and Inquiry Model in Science

Technology-enhanced project-based science. In the last two decades, Krajcik and colleagues have developed project-based science curricula, supported by learner-centered technologies that allow students to learn by doing, inquiring, applying ideas, and solving problems (Blumenfeld et al. 2000; Krajcik and Shin 2014). In project-based science, students engage in meaningful problems and carry out activities that mirror what scientist do. Project-based science emphasizes constructing knowledge through problem-solving by "asking and refining questions, designing, and conducting investigations, gathering, analyzing, and interpreting information and data, drawing conclusions, and reporting findings" (Blumenfeld et al. 2000, p. 150).

Based on extensive classroom implementation of project-based science curricula (Beyer et al. 2009), several key principles and features for the design of the inquiry environments are identified: (1) starting with a meaningful, driving question, a problem that needs to be solved; (2) setting learning goals that align with science standards and assessments; (3) engaging students in inquiring into the question by participating in scientific practice; (4) involving different actors, including teachers, students, and the community, in tackling the problem; (5) scaffolding student inquiry with learning technology; and (6) supporting students in creating a set of tangible product and artifacts as representations of their learning (Krajcik and Shin 2014).

These project-based learning contexts consist of authentic, challenging, and open-ended problems that require deep disciplinary knowledge and metacognitive skills. Frameworks for scaffolding and technological tools have been developed to support students' metacognition and inquiry. For example, *Model It* supports the development of qualitative model building (Jackson, Stratford, Krajcik, and Soloway 1994), *Artemis* helps students search a digital library, organize information, and share questions (Wallace et al. 2000), and *Digital IdeaKeeper* (Quintana and Zhang 2004) provides students with tools to plan their inquiry, search digital libraries, read information, and address questions. Quintana et al. (2005) have developed four guiding principles for tool design/use to scaffold learners' metacognition in online inquiry: (1) facilitate learners' understanding of inquiry task structures through explicit visual representations, (2) incorporate tools to encourage learners to plan their tasks and online inquiry, (3) make the inquiry process, working history, and information common to multiple activities explicit, to support learners' self-monitoring and –regulation, and (4) use prompts to help learners understand what they should reflect on and articulate throughout their inquiry.

In Project-Based Science, development of project inquiry curricula materials for teachers, professional development, and school reform are key themes with collaboration among universities and schools (Krajcik and Shin 2014). Assessment of the impact of this research program indicates that students in project-based classrooms show better domain understanding and processing skills than do students in traditional classrooms (Geier et al. 2008) using state-wide national assessments. Recent developments involve the design of project-based learning materials to support the scaling up of reform efforts and making innovation possible in a wider range of classrooms (Kolodner et al. 2009-2013).

ThinkerTools Inquiry Model and Curriculum. Researchers have considered metacognition to be crucial in facilitating students to engage in complex inquiry (White et al. 2009). *ThinkerTools* curriculum incorporates an inquiry cycle and reflective assessment in pedagogical and technology design to support students' metacognition (White and Frederiksen 1998). The inquiry cycle – question, hypothesize, investigate, analyze, model, and evaluate – is developed as a general model of the inquiry process. Student groups design science projects guided by the cycle, constructing and applying increasing complex causal models of Newtonian principles, asking questions, testing hypotheses, conducting research through computer simulation, and revising theories via investigation. As well, students engage in self- and peer-assessment as they monitor and reflect on their metacognitive inquiry process. Evaluation of the interventions show that inquiry supported by reflective assessments are particularly beneficial for students with low academic achievement (White and Frederiksen 1998).

Eslinger et al. (2008) extended their earlier work in designing an interactive learning environment, *Inquiry Island*, in which students conducted scientific inquiry projects on genetics curriculum topics, supported by a framework of inquiry and self-assessment tools. Students in the intervention showed significant gains in inquiry skills, and the software also helped to gather and analyze qualitative data about students' learning process. Herrenkohl et al. (2011) created the web-based system called *Web of Inquiry*, which aimed at scaffolding students to develop and/or test theories; learn language of science and scientific tools, and take up a scientific worldview about the social nature of science. These research programs demonstrate the importance of addressing students' cognitive and metacognitive processes and developing pedagogical principles when designing technology-enhanced environments, technology in turns illuminates and makes complex processes more accessible to different learners.

Virtual World Environments

The Multiuser virtual environment (MUVE). Another major research program is the design of multiuser virtual environments to help students develop both science content and science process skills (Dawley and Dede 2014). Virtual worlds are highly motivating and can engage students in scientific practice, working on socio-scientific issues. In the River City MUVE, a nineteenth-century historical city, students immerse themselves in the virtual world and interact with computer-based agents and other digital objects. They behave like scientists and collaborate in teams of three/four to figure out why people in River City are getting sick (http://muve.gse.harvard.edu/rivercityproject/). They communicate, navigate, and share experience through chat and virtual gestures using different digital tools and artifacts. Students engage in different inquiry practices, including observing the city, posing questions to agents, finding different sources of information (e.g., River City library), hypothesizing and collecting/analyzing data, reviewing experimental evidence, developing explanations, and communicating results. Compared with a similar, paper-based curriculum, students in MUVE were shown to be more able to engage in inquiry, were more motivated, and learned as much or more science content (Ketelhut et al. 2010).

More recently, the EcoMUVE curriculum (http://ecomuve.gse.harvard.edu) employs immersive authentic simulation to help students develop a deeper understanding of inquiry, experimentation, and content in ecosystem science. EcoMUVE consists of two virtual worlds that simulate ponds and forest ecosystem; students investigate the research questions and collaborate, analyze, and share data, working as ecosystem scientists engaged in scientific inquiry into the causal relationships of ecosystems (Dede et al. 2017). Virtual worlds also open up opportunities for assessment using analysis of log data addressing aspects of assessment of inquiry.

Dede and colleagues, working with networks of teachers, researchers, and technologists, adopted DBR in implementing MUVE curriculum in networks of schools and examined scaling issues to increase the sustainability and spread of this technological innovation (Clarke-Midura and Dede 2009). MUVE curriculum helps students increase their motivation, learn biology content, and inquiry skills, develop twenty-first-century skills, and engage in scientific practice (Ketelhut et al. 2010).

Virtual Singapura and Omosa. Similar to River City MUVE, Virtual Singapura and Omosa are virtual worlds and the aim is to help students learn scientific inquiry skills in systematic ways (Jacobson et al. 2010). Following up the work on Virtual Singapura when they started exploring instructional sequence of inquiry, Jacobson and colleagues developed *Omosa*, a collaborative virtual planet wherein students inquire into ecosystems and food web, aligned with secondary science curricula. In the scenario-based immersive 3D virtual world, student scientists worked in teams to find out the causes of and possible solutions to declining food source and decrease of animals, and they reported their findings to the Environmental Agency. Students are scaffold to engage in different kinds of inquiry practice; they also conduct computational experiments using *NetLogo* to formulate and test their hypotheses. A special feature is the use of a "productive failure," a pedagogical design that first involves students in low-structure open inquiry, followed by high-structure and consolidation (Jacobson et al. 2016). Ongoing research to examine the effects of these different pedagogical approaches would enrich the design of technology-enhanced inquiry-based learning.

Virtual worlds are highly engaging for students from diverse backgrounds made possible with technological supports. All different MUVEs featured problem scenarios that elicit and support scientific inquiry; students navigated the MUVEs as scientists – questioning, hypothesizing, experimenting, collecting data, communicating with virtual agents; processing and interpreting data. While River City and EcoMUVE involve large-scale professional development and *Singapura* and *Osmosa* are small-scale researches, all are closely linked to schools and emphasize classroom practice.

Knowledge Building and Knowledge Forum

Knowledge Building (KB), supported by Knowledge Forum® (Scardamalia and Bereiter 2014), is one of the pioneering models in computer-supported collaborative learning (Sawyer 2006). Knowledge building/creation can be understood as a community's efforts to advance the state of knowledge in that community (Scardamalia and Bereiter 1994, 2014). Knowledge building/creation, as an educational goal, emphasizes students' creative use of ideas and the sustained pursuit of inquiry as innovative capacities in the knowledge era. Scardamalia and Bereiter (2014) argued that even school-aged students can contribute to and engage in knowledge-creation processes similar to those practiced by communities of scientists.

Knowledge forum (KF) is specifically designed to support students' knowledge creation and sustained inquiry (Scardamalia and Bereiter 2006, 2014). KF provides a digital space in which students can contribute, build-on, reflect, synthesize, and "rise-above" as they collectively work toward knowledge advancement. The basic unit in a KF database is a *view*, which is essentially a canvass upon which student-generated notes are placed; different views can be interconnected to facilitate the emergence and synthesis of ideas. Within a specific "view," students write computer notes and create networks of notes expressing their questions and ideas, and collectively build upon them to develop theories. When writing a *note*, students can use modifiable *scaffolds* (e.g., "my theory," "I need to understand," "new information"), which mirrors the inquiry processes of theory building. KF provide different tools that allow students to link ideas, synthesize different lines of inquiry, and make their learning trajectories visible. Design efforts aimed at KF's further development are ongoing (see Scardamalia and Bereiter 2014).

KB inquiry environments focus on emergent inquiry, with no specific end goal or predesigned curriculum materials. In a KB classroom, each KB inquiry initiative (e.g., How does the body work?) spans several months. While the inquiry is situated within a specific curriculum area; it is the students who take cognitive responsibility for identifying their driving questions and inquiries into core concepts. Typically, students start with face-to-face discussions, in which diverse student ideas are elicited and made public for improvement. Through both online KF and classroom KB talk, they identify problems of understanding, advance theories, build on each other's ideas, construct explanations, compare different models, and revise their theories. In this process, new questions arise in emergent inquiry. KB classroom inquiry design is informed by a set of principles, key among them being students taking agency (epistemic agency); all ideas are improvable (idea improvement); and the centrality of collective inquiry (community knowledge) (Scardamalia 2002).

Recent developments in KB have emphasized the development of technology-enhanced assessment and tools (Scardamalia and Bereiter 2014). To engage in complex and sustained scientific inquiry, students need to track their learning trajectory and discourse on KF, examining what the community has accomplished and setting new goals. Researchers have designed KB portfolios, with which students take agency in assessing their own knowledge building discourse (van Aalst and Chan 2007). van Aalst et al. (2012) developed the *Knowledge Connection Analyzer* (KCA) to facilitate students' reflection on their KF online discourse, and their findings showed that low-achieving students can benefit from using these approaches (Yang et al. 2016). Zhang et al. (2016) created the Idea Thread Mapper (ITM), a time-based collective discourse mapping tool that helps students visualize their collective online discourse journey to facilitate their inquiry practices. Chen et al. (2015) developed the *Promising Ideas Tool* (PIT) to support young students' selection of promising ideas from their online KF discourse and charting of directions for deepening inquiry. While learning analytics are generally used by researchers, the KB approach involves students using these analytic tools themselves and use evidence to assess the process of inquiry and community progress.

Chen and Hong (2016) reviewed 30-years of design-based research in KB with iterative classroom implementation that informs changes in theory, pedagogy, and leading to new KF designs. Research on the instructional impacts of KB – including different analyses encompassing research measures as well as standardized tests have shown positive results related to students' understanding of science and the nature of science, and their scientific literacy development (see review, Chan 2013;

Chen and Hong 2016). Knowledge building extends beyond the confines of classrooms, and includes networks of researchers, teachers, policy makers, scientists, and technologists from different countries working collectively in knowledge-building communities. In design-based research, researchers and teachers are codesigners, and work with multidisciplinary teams to pursue synergistic advances for theoretical progress and professional development.

Implications and Further Issues

This section considers the theoretical and educational implications of designing technology-enhanced inquiry learning environments by comparing the different programs based on four key themes – learning and learner processes, the nature of collaboration, pedagogical design, and assessment (see section "Contemporary Theories of Learning Underlying Design of Learning Environments"). Challenges and future directions in designing and implementing technology-enhanced learning environments are also discussed.

Theoretical and Pedagogical Implications

Learning and learner processes. These different technology-enhanced learning programs illustrate how learning theories underpin the design of the environments, and how these environments illuminate the learning processes to enrich the diverse meanings of learning. All these learning sciences inquiry programs are primarily informed by constructivist and social-constructivist theories, which view knowledge as actively constructed, distributed, and socially situated. Nevertheless, these programs vary in their meanings of inquiry and emphases on the learning process. KI emphasizes students' *constructive processes* and how technology can make scientific processes visible; inquiry involves students' *connecting* prior knowledge using technology and curriculum materials to support students' learning of science concepts. Project-based Science and ThinkerTools curriculum highlight *problem solving* and *metacognition*; inquiry is student-designed and more open-ended, technology elicits and supports metacognition, and students are to reflect on their inquiry processes and monitor their knowledge gaps. Virtual Environments (VE) emphasize situated aspects of cognition and authentic practice; inquiry emphasizes creating learning scenarios and students developing an *understanding of scientific inquiry processes.* KB emphasizes the *sustained pursuit of inquiry* in community; new knowledge emerges from ever-deepening explanations and theory revision. Examining these traditions reveals the different *learner processes* they elicit and cultivate, and how these varied approaches mirror and enrich meanings of learning and inquiry. Educators can consider the different possibilities of inquiry for enriching learner processes when designing the learning environments.

Nature of collaboration. Comparison of these programs illuminates different perspectives and designs on collaboration. KI and VEs include designs wherein students can engage in scientific inquiry, individually or as *dyads*; teamwork is seen to facilitate inquiry, but not key design or analytic goals. Project-based environments typically involve *small groups* carrying out scientific inquiry; student groups also engage in self- and peer assessments. KB is *community-based*, and focuses on collective inquiry and examines the progress of collective knowledge; individual learning is a by-product.

Technology provides an important medium for theorizing and designing collaboration. For example, metacognition is traditionally investigated as an individual learner process; these technological-inquiry environments require students to develop social metacognition and coregulation when they engage in complex collaborative inquiry, that is, students need to regulate own learning as well as group inquiry. Technology design brings about new opportunities for theories of learning and collaboration – there need to be reconceptualization of what metacognition and regulation involves in a social context. There are also educational implications for considering how to support students to develop social metacognition and collective regulation. Recent development in large community-based environments (e.g., knowledge building, wiki) illustrates how participants collaborate in new, different ways, and how new technology can enrich our understanding of the nature of collaboration needs to be investigated.

Pedagogical design. In designing inquiry-based environments, there have been controversies regarding the levels of support provided to learners and how much scripting should be given (Kirschner et al. 2006). Review of these research traditions reflect differences in underlying theories, and highlight different pedagogical approaches ranging from structured to emergent approaches. KI generally uses high-structure, providing guided and sequenced approaches using rich curriculum materials. Project-based learning involves open-ended inquiry, with student groups designing their projects, and driving questions may be provided. VEs use open inquiry – *Omosa* uses a mixed pedagogy approach called "productive failure," involving low-structured inquiry followed by high-structured inquiry. KB, the least-structured inquiry approach, emphasizes opportunistic principle-based approach rather than prescribed activities or tasks – KB pedagogy focuses on students initiating and directing their own inquiry, rather than relying on guidance from teachers.

While all programs emphasize inquiry, these varying pedagogical approaches reflect different epistemologies and goals. For example, if the focus is to teach students difficult science concepts, guided inquiry in KI may be more relevant. Alternatively, when the goal is to develop knowledge-creation innovative capacities, students need to take up epistemic agency and more open-ended principle-based pedagogy would be more appropriate. Primarily, the controversies and choice of pedagogical design in inquiry-supported learning environments, whether structured or emergent, scripted or unscripted, need to be considered in relation to the epistemology and learning goals of the programs.

The different ways in which scaffolds are used further illuminate different aspects of learner processes and inquiry-based learning designs. These programs employ different kinds of scaffolds including cognitive, metacognitive, conceptual, and epistemic ones. For example, the inquiry map in KI/WISE scaffolds students' conceptual understanding of science and cognitive processes; the Cycle of Inquiry provide scaffolds to help students with metacognitive understanding; and knowledge building engages students in the epistemic scaffolds of theory building. Scaffolds may make inquiry learning meaningful and productive, or superficial or complex. Reiser (2004) considered scaffolds' purpose was not only to *structure* but also to *problematize* learning. Different kinds of scaffolds need to be considered when designing and implementing inquiry-based environments supporting students' cognitive, metacognitive, conceptual, and epistemic processes.

Assessment for inquiry-based learning. Research on technology-enhanced learning environments illuminates different perspectives on assessment. Assessment in KI generally focuses on evaluating students' knowledge and skills; *formative assessment* emphasizes examining students' performance and providing feedback to guide their inquiry. Project-based learning (e.g., *ThinkerTools*) focuses on reflective *assessments* for metacognition; students actively monitor and reflect on how their inquiry processes align with scientific inquiry models for making changes. VEs use online data to gauge students' inquiry processes, and such information is used to diagnose students' learning processes. KB emphasizes collective reflective assessment; students are engaged in *transformative* assessment and have agency in using analytics and assessment tools, using evidence to chart their collective knowledge advance.

These examples illustrate the different ways assessment can be undertaken in TELEs. They all highlight the importance of using assessment to promote learning and inquiry, and how technology now opens up new opportunities for tracking student growth. These approaches also vary in terms of students' role in assessing their own learning; use of assessment tools for summative, formative, and transformative purposes; and whether assessments are for individual or collective growth. These examples provide possibilities for integrating assessment with student inquiry when designing inquiry-based learning environments.

In sum, all the above programs consider sociocognitive and technological dynamics in promoting inquiry and embed assessment tools/learning analytics to track students' inquiry process; they all employ design-based approaches to improving theory and design. While these programs have different emphases on inquiry in relation to theory, pedagogy, and assessment, comparisons and analyses of these various designs and learning goals and contexts can enrich theory, design, and classroom practice.

Issues and Further Research

Scaffolding inquiry. Inquiry-based learning environments provide rich opportunities for inquiry, problem-solving, and metacognition to meet twenty-first-century education goals. However, questions exist as to how well students can collaborate in constructivist-based and open-inquiry environments. Inquiry-based learning environments are primarily rich and complex, yet students may not know how to work to realize these affordances; typically, students may lack the epistemology needed for engaging in inquiry, metacognition, and knowledge creation. How technology and pedagogy can shift students' epistemic understanding need to be investigated.

A related question is the use of scaffolds. Different technology-enhanced learning environments (TELEs) focus on developing different forms of scaffolds to support inquiry. However, how to develop and employ scaffolds so that students do not become reliant on them, and how scaffolds can be faded in or out to help students internalize the inquiry processes are important questions for further investigation.

Assessment of inquiry. It is also important to examine how to develop assessment in TELEs to serve both functions of scaffolding and measuring inquiry. In view of the increasing popularity of learning analytics, how teachers and students can use learning analytics for assessment merits investigation**.** Many programs include assessment of conceptual knowledge, performance, and science knowledge, but assessment of inquiry and related twenty-first-century skills remains complex. In line with the current review, it is important that assessment be student-driven and transformative to facilitate progress. How technology-enhanced environments can support students' assessment of inquiry, and how learning and teaching analytics can be effectively used in classrooms to support learner processes are now major research areas.

Teachers' beliefs and knowledge. All these inquiry-based environments emphasize understanding and promoting such learner processes as examining students' knowledge models and cognitive-collaborative strategies, rather than focusing on technology or tools *per se*. In relation to these demands, teachers face many challenges and their belief in and capacity for the productive use of these environments need to be considered. To implement these designs and models, teachers need to view students as knowledge contributors, not information receivers, and to become colearners with students in inquiry and knowledge-building communities, rather than information providers. In inquiry-based teaching, teachers must also develop inquiry-based learning epistemology and become inquiry teachers to support student learning. How pedagogy, technology, and teacher epistemology are intertwined are critical issues to explore.

Classroom implementation and scaling issues. Many challenges exist regarding how technology innovation and practice can be implemented, sustained and scaled up. Research on computer-supported learning often focuses on technological affordances and features in a bound setting (Kim and Hannafin 2011), rather than on the dynamic nature of classroom interactions, and accompanying social and cultural factors (Jeong and Hmelo-Silver 2016). Technologies *per se,* even with these sophisticated environments cannot generate positive effects on student learning and learner processes; the positive influence is based on the ways of integrating pedagogy with technology – developing teacher expertise in relation to social context and supporting teacher professional communities to meet these challenging goals are fruitful research areas (Chan 2011).

Scaling up is another complex issue and often technology innovation cannot be implemented as intended. This chapter has emphasized employing design-based methodology and there are both benefits and challenges. Studies using design-based research are complex and efforts to document changes and improvements over iterations of designs are often unsystematic. Design-based research is most suitable for studying and tuning designs in classrooms; however, examining scalability would require refining DBR or developing new methodology to study changes in classroom systems and networks.

Conclusion

In this chapter, we have discussed the theory, pedagogy, and design of technology-enhanced inquiry-based environments, focusing on how technology-enhanced inquiry-based environments can be designed and implemented in classrooms, and how they can foster student inquiry and related twenty-first-century competencies. We have also discussed theoretical issues and changing views of learning and assessment and how they impinge on technology designs. Four examples of major research programs on technology-enhanced inquiry-based environments were provided, and all of them have developed design principles from iterative studies, that would have classroom implications for designing inquiry. All programs focus on developing students' scientific inquiry; students are scaffold by technology, to develop a deeper understanding of science and to engage in scientific practice, like what scientists do, with the development of a range of inquiry processes elicited and enriched in these environments. These programs have been evolving over two to three decades and continuing with current development in new assessments and technology in support of student learning and learner processes in the knowledge era.

Our analysis of these technology-enhanced inquiry-based environments shows that there are different ways of theorizing and scaffolding inquiry, which highlights the intertwined relationships among theories, pedagogy, and technology. This chapter has emphasized design-based research as a promising methodology for synergistic improvement of theory and design in classrooms, and to support technology integration in classroom contexts through a partnership of teachers and researchers, and multidisciplinary teams of technologists and scientists. The key implications are that theory, pedagogy, and technology need to be integral to each other – The design of technology-enhanced inquiry-based environments needs to be informed by theories and principles of learning; reciprocally, their implementation can help elicit and scaffold the learning process, and thus enrich our theoretical understanding of how students learn.

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13 Cultural and Social Issues in Using Social Media to Support Learning

Royce Kimmons and Olga Belikov

Contents

Abstract

The widespread use of social media (e.g., Facebook, Twitter, YouTube) has led many researchers and practitioners to explore their benefits for education, including their ability to connect people together in ways that value diverse perspectives, creativity, and individual expression. However, there are some complex cultural and social aspects of these tools that deserve attention and that educators and students should be aware of. In this chapter, we explore a variety of issues through the themes of (1) literacy, (2) privacy, (3) civility, and (4) identity. Literacy issues include digital participation divides and the ways that differences in abilities among students to use these tools lead to inequities in educational and social opportunities. Privacy issues include those involving the sharing of personal information via ubiquitous, persistent technologies and the subsequent

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hierarchical and lateral surveillance that this enables. Civility issues include cyberbullying and other utilizations of these media to manipulate the emotional states and social standing of others through dehumanization, decontextualization, and persistent abuse. And identity issues include those arising from the incomplete, skewed, or performative expression of identity via social media and subsequent tensions that arise between the use of acceptable identity fragments and the reductionism that occurs as authentic identity is translated into online spaces. With each of these themes, we explore pertinent problems that arise in social media (e.g., echo chambers, incivility, identity collapse) and also provide suggestions for educators to alleviate their severity.

Keywords
Social media · Literacy · Civility · Identity · Privacy · Digital divides · Cyberbullying

Cultural and Social Issues in Using Social Media to Support Learning

Social media include a rich variety of technologies and platforms that are now used on a daily basis to connect people together. Among these media, features, functions, and goals are very diverse, and various social media are therefore quite distinct from one another even though they have some common characteristics. Today, some of the most prominent social media platforms include juggernauts like Facebook, Twitter, Pinterest, LinkedIn, Snapchat, Wordpress, YouTube, Wikipedia, and many others. Facebook alone boasts 1.7 billion monthly active users, or roughly one-quarter of the earth's population (Statista 2016), and YouTube serves almost 5 billion videos per day through its video sharing service (Statistics Brain 2016). Social media have successfully permeated everyday life for people throughout the world, and educators have understandably considered how to use such ubiquitous tools to improve teaching and learning and to address educational problems. Though there are some clear potential benefits to using such media to support learning, there are also many social and cultural issues to consider for safely and effectively guiding their use.

Social media are defined as web-based services that allow users to create a profile, to friend others, and to view the profiles and friends of others (boyd and Ellison 2008) or, more inclusively, as "anything that uses the Internet to facilitate conversations" (Solis and Breakenridge 2009, p. xvii). This broad group of services may provide a diverse range of functions including the following examples:

- Profile creation (e.g., LinkedIn)
- Status updating (e.g., tweets, posts)
- Instant messaging (e.g., direct messages)

- Linking (e.g., URL inclusion, mentioning)
- Media sharing (e.g., images, videos)
- Tagging (e.g., hashtags)
- Social networking (e.g., Facebook, MySpace)
- Image sharing (e.g., Instagram)
- Video sharing (e.g., YouTube, Snapchat)
- Microblogging (e.g., Twitter)
- Blogging (e.g., Tumblr, Wordpress)
- Synchronous discussion (e.g., Skype, Google Hangouts)
- Asynchronous discussion (e.g., 4Chan, Reddit)
- Social bookmarking (e.g., Reddit, Pinterest)
- News aggregation (e.g., Buzzfeed)
- Social gaming (e.g., FarmVille, Mafia Wars)
- Collaborative editing and creation (e.g., Wikipedia, Google Docs)

By allowing for new methods of communication, expression, and sharing, such services empower students and teachers to share and engage with one another in new and more efficient ways. With microblogging and status updates, for instance, learners can share their commentary on social issues and provide links to pertinent news stories with private circles or the public. With social networking, students and teachers can connect with one another, with professionals, or with their communities either from inside or outside of class and can cultivate learning networks that extend beyond the confines of the brick-and-mortar classroom. And with social bookmarking, learners can aggregate, evaluate, and share resources in a structured way, both to support individual and collaborative research efforts. In each of these cases, social media serve as nexuses for bringing people and resources together in ways that permit people to create meaning, artifacts, relationships, and experiences together.

Many of the greatest benefits of social media for education are based in how they connect people together in ways that value diverse perspectives, creativity, and individual expression (West and Kimmons 2017). By removing traditional communication barriers and empowering new forms of connection and expression, such tools can lead us to rethink the purposes of educational systems, the goals of learning, and how learning can be supported throughout life (Siemens 2005). However, there are some complex social aspects of these tools, and their use that deserves attention and that educators and students should be aware of when using them for personal, professional, and educational purposes. Due to their ubiquitous nature, many of these issues have been partially explored in popular books and magazines, while others have been given treatment in research journals and have warranted empirical study. Moving forward, we will organize our conversation on these issues around four main categories: literacy, privacy, civility, and identity. We will explore each of these categories in turn and provide suggestions for how educators can address relevant concerns and exhibit exemplary social media practice in both their own lives and the lives of their students.

Literacy

Just as the advent of written language gave rise to new literacies (in the form of reading and writing), new digital media create a need for new forms of literacy regarding sharing, creating, and communicating (Kimmons 2014). Social media are designed to foster participation and the development of a participatory culture around multiple forms of media insofar as these tools: (1) provide low barriers to artistic expression and civic engagement, (2) support sharing and creation, (3) enable informal mentorship, (4) engender a belief from the community that contribution is important, and (5) provide a degree of social connection between participants (Jenkins et al. 2009). This means that just because learners can read or write, it does not follow that they can meaningfully engage in social media to support learning. Rather, to engage with participatory culture, social media users must develop concomitant literacies that may be unnatural or unexpected in traditional social and classroom settings. In fact, learners of all ages may have difficulty in developing the skills and dispositions needed to meaningfully engage with participatory culture, may not be able to reflectively utilize online experiences to enhance learning, and may not be able to develop the ethical and behavioral norms required to navigate complex online environments. While educators might find the promises of participatory culture appealing for supporting learning, they must recognize that there are a variety of challenges involved in helping learners to develop the literacies necessary to meaningfully and fully engage with that culture, and until those challenges are addressed, the potential benefits of social media will not be realized.

Educators have long recognized that a digital divide may exist between learners, in that learners from poorer families might have less access to digital resources than their more affluent peers, but in the current age of technology ubiquity, children in the USA and many other nations have "at least minimal access to networked computers at school or in public libraries" (Jenkins et al. 2009, p. 17). Most teens in the USA use social media, spending over 2 h per day on sites like Facebook and SnapChat (Common Sense Media 2015), and 92% of US teenagers go online daily, with most having access to a laptop, desktop, or smartphone (Lenhart et al. 2015). Although this may vary by country dependent upon cultural practices or access to technology and internet, similar patterns of use exist throughout the world as teenagers are spending hours of their time online. However, differences exist between teen use of media based upon race/ethnicity and family income. For example, in the USA, black and Hispanic learners spend considerably more time watching television, listening to music, and using social media than their white counterparts, while white learners are more likely to use computers and to read (Common Sense Media 2015). Socioeconomic differences exist worldwide and these patterns are likely reflected in various regions throughout the world, with different members of the community having different access to and prioritizing of technologies. When economic differences are considered, higher income learners are more likely to use social media, but when they do use social media, lower income learners spend about 1.5 h more per day with these tools (Common Sense Media 2015). Such differences in patterns of participation may suggest differences in literacies necessary to benefit from participatory culture and its associated learning potentials.

That is, if learners use digital technologies primarily for passive media consumption (e.g., watching television, listening to music, following celebrities, skimming feeds), then such practices may not provide the same benefits as more participatory activities (e.g., creating content, engaging in discourse, sharing resources, networking, building civility). As one set of researchers explained:

> No longer are children and young people only or even mainly divided by those with or without [digital] access. . . . Increasingly, children and young people are divided into those for whom the Internet is an increasingly rich, diverse, engaging and stimulating resource of growing importance in their lives and those for whom it remains a narrow, unengaging, if occasionally useful, resource of rather less significance. Hence, a new divide is opening up, one centred on the quality of use (Livingstone and Bober 2005, p. 34).

Just as social media can empower learners to engage in participatory culture, differences in quality of use may arise as many may use these media in distracting or educationally unbeneficial ways (Andersson et al. 2014).

For instance, though social media can help to expose learners to a diversity of perspectives on culturally significant issues or to encourage critical thinking about social issues, unexamined use can contrarily become a vehicle for promoting narrowness of thought, misinformation, and groupthink. In fact, many technologies naturally lend themselves to the development of online echo chambers as people gravitate toward or intentionally structure their accounts to only interact with those with similar ideological beliefs (Colleoni et al. 2014; John and Dvir-Gvirsman 2015), and similar phenomena may be mimicked in the form of search engine results and news feeds wherein the content that users access is algorithmically determined by previous behaviors and demographic data (e.g., filter bubbles). Learning to determine information accuracy, to recognize biases, and to understand issue complexity and diversity in opinions are essential skills in an information society. Without explicit guidance on how to think critically about their online participation, learners will continually find themselves at the mercy of these technologies' distractive, controlling influences rather than their empowering potentials.

To counteract this problem, educators and educational institutions should (1) recognize that learners are already using these media in their personal lives, (2) enact policies that value and encourage beneficial personal participation, (3) help learners develop critical thinking skills related to their media use, and (4) seek to connect classroom practices to the most beneficial aspects of these media (e.g., diversity, connectedness, expression, creation). Exemplary practice, then, involves explicit classroom learning opportunities that help students to navigate these media and to develop beneficial personal habits related to their use. Students should be taught to critically analyze the information they encounter online, its source, and its merits. They should be encouraged to identify and analyze the biases in a manner that values diversity of backgrounds and democratic pluralism (Goodlad et al. 2004). And they should be challenged to create, express, and share through these media rather than to remain passive consumers of others' content (Jenkins et al. 2009).

Privacy

Democratic societies have always looked upon institutions of power with some degree of skepticism and distrust, as the ideological anthem of such societies has been to ensure and safeguard the rights and privileges of individual citizens by guarding against totalitarian overreach into their personal lives. One popular image used in this regard has been that of the panopticon or a circular prison surrounding an observation tower in which guards have constant vision of the incarcerated, but the prisoners have no contact with one another. According to Foucault (1977), the panopticon was an "enclosed, segmented space, observed at every point, . . . in which all events are recorded, . . . in which power is exercised without division, according to a continuous hierarchical figure, in which each individual is constantly located" (p. 197). Using the panopticon as an image of the police state, Foucault and others have argued that totalitarian power structures are established and maintained by segmenting the population and establishing a constant expectation of recorded observation, and such imagery has regularly been invoked with the advent of new technologies, such as closed-circuit television, geotagging, and other recording technologies, to warn against potential hierarchical incursions into the privacy of individuals' lives.

In addition to enabling additional methods of hierarchical surveillance, such as Facebook's collection of data on users that might be shared with governmental agencies, social media also introduce surveillance in a new form: citizen-to-citizen. According to Andrejevic (2005), this *lateral surveillance* consists in "the use of surveillance tools by individuals, rather than by agents of institutions public or private, to keep track of one another" (p. 488) and represents "the redoubling of the panoptic model whereby the subjects of the panoptic gaze come to take on some of the responsibilities not just of monitoring themselves, but of keeping track of one another" (p. 485). Social media empower lateral surveillance by giving users deep access to the lives of one another (e.g., the Facebook timeline) and allowing the sharing of vast amounts of private data with little consent and expectation of observation. In this way, individual privacy in the digital age is threatened both by hierarchical attempts at surveillance and by lateral attempts, in which users of social media engage in constant forms of surveillance upon one another to decide whom to hire, date, befriend, and elect.

When it comes to learning, educators must recognize that data that are shared via social media are different than data that exist in a school database or a sanctioned learning management system, which are generally more secure, transitory, and impersonal in nature. Social media data are persistent, are typically not owned by the individual (but by the service provider), and could include private information that, if improperly shared, might have life-changing impacts on students and educators alike. Despite their sensitive nature, these data are often shared publicly and are available to family, friends, future employers, and the general public, and if students use social media as part of their classroom learning experiences, then the data associated with this use could follow them for the rest of their lives and be used by those engaged in hierarchical or lateral surveillance to make high-stakes judgements about them.

For this reason, requiring a student to create a Twitter account to complete an assignment is very different from requiring a student to post to a private discussion forum within a school-sanctioned system. By forcing students to use social media, educators may be requiring them to provide information about themselves, their online activities, their habits, their social circles, their identifying information, and their personal lives with others without fully considering the potential long-term ramifications of such sharing. Similarly, by requiring students to connect with one another or the teacher in a popular platform (e.g., friending on Facebook), the teacher might inadvertently require the student to self-disclose private information to others in a way that ignores the student's right to privacy and collapses the student's complex social interactions into something more simplistic and potentially volatile.

Thus, educators should consider the privacy of their students as they engage in social media learning activities and recognize the power that these media have to enable both hierarchical and lateral surveillance. To help ensure privacy, educators should (1) help students to draw clear lines between personal and classroom use of social media, (2) teach students not to post content to these media that could be personally harmful or misconstrued if taken out of context, (3) guide students in self-evaluation and self-critique of the digital footprints they are creating online, and (4) train students to realize that content shared via social media are never truly private (Zheleva and Getoor 2009).

Civility

Many people have discussed civility in recent years in relation to politics, education, social media, and a variety of other topics (Mower and Robison 2011), and students and teachers need to grapple with this issue, because incivility is generally considered to be a rampant problem in social media that has serious implications for students and teachers alike. In social media, incivility is evidenced through verbal and written abuse, such as vulgar, threatening, prejudicial, stereotypical, or aggressive statements often used in a harassing manner, which may be used to bully or intimidate others. At its heart, incivility is intended to have a dehumanizing effect on the target and has been evidenced most clearly among K-12 students in the forms of cyberbullying, trolling, flaming, shaming, and stalking. In this manner, incivility is a form of dehumanizing abuse that invites conflict and seeks to control others through manipulation and the fostering of misunderstandings (Phillips and Smith 2004). As an illustration, many logical fallacies and sophistry techniques, such as ad hominem attacks or vulgar language use, could be said to be uncivil in nature, because they seek to manipulate others by relying upon argumentative approaches that demonize or trivialize the humanity of opponents. Thus, a YouTube personality might engage in a vulgar tirade on a topic they are passionate about for the purpose of intimidating others and preventing critique. Similarly, a Facebook bully may mock or disparage a person in order to manipulate their emotional state or social status. In its most severe forms, extensive cyberbullying may lead victims to disengage socially or to harm themselves, and many high-profile cases of teenage suicide in recent years have led communities to recognize the seriousness of this issue and to seek remedy (Hinduja and Patchin 2010, 2012; Rice et al. 2015).

In contrast, civility is expressed through humanizing activities that invite interaction in order to seek understanding or to respectfully persuade others. In this way, civility is much more than mere manners or etiquette (though these can be guidelines for promoting civility), and the heart of civility is empowerment of people and interactions through a process of valuing one another's perspectives, experiences, agency, and inherent value as people (Mower and Robison 2013). Thus, civility counteracts abuse in all forms – physical, emotional, intellectual, and social – by emphasizing respectful, humanizing interaction as a precursor for sharing, argument, and critique.

Since incivility is a means to the intended end of dehumanizing and manipulating others, perhaps the reason that incivility has received so much interest in recent years in relation to social media is that these tools may empower us to dehumanize others in new, more persistent, and more effective ways. For instance, a traditional bully in a K-12 schoolyard might effectively dehumanize their victim through physical violence, verbal aggression, or social shaming, but that victim could anticipate some reprieve from such behaviors when class bells ring, when the school day ends, or when the weekend or summer comes around. With social media, however, a cyberbully has a persistent, instant connection to the intended victim that can be manipulated at any time and at any place and that permits for a wider audience to witness the abuse. Even if the victim disconnects from the medium in order to create a buffer with the bully, the bully would still be able to use the medium to socially shame the target in front of peers by sharing photos, memes, or abusive language that would then influence the victim's daily interactions with peers. In such ways, social media may not be the cause of incivility, but they provide mechanisms for more effectively enacting uncivil behaviors across time and locations.

Beyond improving the effectiveness and persistence of uncivil behaviors, there are at least three ways in which social media tools actually invite incivility due to the nature of their designs. These include pithiness, social distance, and ad hominems. First, most social media are designed to provide users with the ability to send very short, focused messages to each other and to attach some other piece of audio, video, or animated media (e.g., emoji) as a supplement. Twitter and text messages, for instance, enforce a limit on the number of characters that can be sent in a single message, and even more text-generous platforms like Facebook are nonetheless designed to encourage just-in-time, quick interactions between users. These design decisions allow such media to facilitate quick, sustained conversations, but the trade-off is that users are not encouraged or expected to put much time into crafting (or reading) lengthy messages to one another, and this means that they will generally be more pithy than what might be expressed through a formal letter or even verbal interaction. If civility requires us to respectfully consider and respond to the perspectives and experiences of others, then media that favor fast, limited responses will lose contextual richness and will focus upon aspects of disagreements that are most divisive, flagrant, and emotive. Any argument expressed in 140 characters or less will by its nature be a strawman argument.

Second, anonymity and perceived distance can lead users to indulge in uncivil behaviors that they might otherwise eschew. In one study of online news comment boards, anonymous users were shown to be three-times more likely to exhibit incivility when talking about a controversial topic than those whose comments were connected to their authentic identities in some manner (Santana 2014). Social distance is not a strict binary between anonymous and nonanonymous, however, since different methods of communication are more intimate and connected than others. A person might say something to another through a letter or group message that they might not say face-to-face or one-on-one, because the added layer of the medium gives the person a feeling of distance from the intended recipient and makes the communication less intimate. In politics, it has been shown that incivility can be effective for persuading voters, even though politicians do not want to be labeled as uncivil (Carraro et al. 2012). It is for this reason that politicians are notorious for allowing or encouraging others to make uncivil attacks against their opponents in a vicarious or distanced manner, thereby reaping the perceived benefits of incivility without any of the social repercussions. Similarly, social media users who feel distanced from their targets may feel free to engage in incivility for its effectiveness at manipulating others without fear of accumulating stigma for such incivility. Thus, this social distance helps users to feel more secure in uncivil practices, because they do not anticipate that such behaviors will elicit the social criticism and dismay that would arise in a traditional setting.

And third, because interactions in social media are generally organized around profiles of users, this means that any type of disagreement in the platform will be directly connected to the people involved, thereby making any disagreement feel like an ad hominem attack. If a student posts a political stance on a controversial topic to their Facebook feed and another student disagrees with that stance by providing a comment, the author must grapple with the fact that they are publically being denounced for their stance directly upon their profile feed, which will persistently serve as a means of identifying themselves to the public, in front of their entire social circle, which might include friends, family, parents, and teachers. This makes it difficult for the author to separate the argument from themselves, because in order to save face, they must react decisively both to safeguard the integrity of their profile and to protect their social standing with their connections. There tends to be little neutral space for disagreement or debate in such media, because every interaction is connected directly to the performance of a user's profile, which represents them as a person. Thus, the dispassionate and leveled discussion necessary for civil disagreement to occur is supplanted by attempts to save face and to perform before a social audience, and failure to win a disagreement may be viewed as a mark on the author's profile for the community to see in perpetuity.

Against this backdrop, it is essential for teachers to engage students in addressing instances of incivility and to model exemplary civility in their own practice. By having classroom discussions and lessons specifically focused on addressing cyberbullying, for instance, teachers can help students to understand the effects of their actions and give them strategies for coping with incivility and abuse when they occur. However, in this process, teachers need to be careful not to employ incivility as a means to punish or ridicule the perceived incivility of others. In many high-profile cases, for instance, social media users have resorted to public shaming or vulgar tirades of others whose behaviors they considered to be uncivil without holding themselves to the same standards of civility. In such cases, the message of civility is lost in a milieu of anger, disgust, and self-righteous indignation that is unaware of its own hypocritical stance and that often is not based upon reality, such as data-supported evidence of others' participation (cf. Kimmons et al. 2017). Incivility is often easy to perceive in others but is difficult to identify in ourselves, but if civility and the resulting humanizing of people is our goal, then we should ensure that civility permeates both how we engage with those who we believe are behaving civilly and those who are behaving uncivilly alike.

That having been said, civility is contextual, and norms of civil participation in one setting may not transfer to another setting in a one-to-one fashion. For instance, whether or not a particular word is vulgar, inappropriate, or offensive might vary based upon the community where it is used, who the speaker is, and how the word is used. Thus, when exploring civility with students, teachers should be willing to critically examine the contexts of interactions surrounding actual language use and behaviors in social media with the goal of determining the intent of the behavior and not as an attempt to justify incivility. Anyone can be civil, and anyone can be uncivil, but teachers need to work with students to decipher the anticipated effect of behaviors within social media and to determine if the goals are uncivil (dehumanization, manipulation, misunderstanding, abuse) or civil (humanization, understanding, empowerment) and to engage in practices that continually exemplify civility.

Identity

Perhaps the most problematic category of issues related to social media use for learning deals with identity. Identity is a complicated construct that various researchers and philosophers have grappled with for a very long time, but at its heart, identity deals with who we are as people, how we see ourselves, and how we present ourselves to others. When using different social media, people may be said to express their identities through the intentional creation of acceptable identity fragments or AIFs (Kimmons and Veletsianos 2014), as we explain elsewhere:

> The notion of an AIF grows out of the premises that educators [and students] (a) consider relationships with others to belong to different types (e.g., friends, family, colleagues) and (b) act differently when they are interacting with others of different relationship types or when relationship types in a given context are mixed. . . . [Thus,] the AIF suggests that participants in a given social context may limit their participation or expression of identity in a way that is appropriate to that specific context or is acceptable to the specific relationships they have with others in that context (p. 295).

Unlike other theories of identity expression in social situations that rely upon dramaturgical metaphors to explain a person's acting in a fake or exaggerated manner (Goffman 1959), AIFs represent authentic images of the self that present pieces of a person's identity to different groups in a fragmented manner (Kimmons and Veletsianos 2014).

The actual self, then, may be said to represent a multifaceted crystal constructed by various AIFs or as a "highly adaptable constellation" (Lemke and Van Helden

2009) of AIFs, thereby transcending any singular social situation and encompassing all of the AIFs that an individual might construct (encompassing, for example, relationships with family, friends, colleagues, etc.):

> If we consider each social context that a person expresses an AIF within to be a single point in space (i.e., stars in the sky), then authentic identity is the plotted representation of the self (i.e., constellation) that a person utilizes to create a meaningful self-concept (Kimmons and Veletsianos 2014, p. 299).

This construction of the self may change over time as a person matures and goes through transitional stages in life (e.g., child to teenager, university student to professional, young adult to parent), thereby interacting with different groups of people with different norms of participation (e.g., language patterns, civil norms) and different goals (e.g., exploration, dating, professional growth). Furthermore, each AIF is responsive to the social interactions around it, changing the behaviors of the individual to accommodate the norms of groups, thereby further complicating the identity constellation into a transitional phenomenon that changes and adjusts shape as each AIF's point in space adjusts to its environment. Thus, identity through the AIF lens is something that is authentic but that is also complex, intentional, transitional, socially-responsive, and necessarily incomplete.

This last point deserves additional attention, because it suggests that a person's identity cannot be readily perceived by observing a single AIF any more than the constellation of Orion can be perceived by viewing one star on the hunter's belt. When drawing conclusions about others' identities, then we should be thoughtful about the social structures and other considerations that have elicited the specific AIFs that we can perceive. In the case of social media, however, identities are typically essentialized, simplified, or trivialized as technologies attempt to structure and represent these very complex constructs in a manner that can be readily consumed via a profile page or smartphone interface. That is, rather than presenting a complex, shifting constellation, popular social media sites may present a view of the self that is monolithic (i.e., everything is presented in one place and is shared the same way with all groups), historically persistent (i.e., all behaviors remain connected to the user's identity via a timeline or history), or disfigured (e.g., emphasizing particular aspects of identity, like sexual interests or geographic location, over others, like ideology). For instance, according to the Facebook terms of service, users of that service are not allowed to "create more than one personal account" and are required to use their "real names and information" and to "keep [their] contact information accurate and up-to-date" (Facebook 2015). Furthermore, each user's personal timeline represents a chronological, persistent record of their Facebook posts and interactions, which suggests linearity and singularity in identity rather than multifacetedness and transition. According to this model of identity, a person's name, contact information, friends, and timeline cumulatively represent their identity, but it ignores the possibility that this identity might be incomplete, decontextualized, hyperbolic, or transitional.

This tension between the complex notion of the self as presented by AIFs and the essentialized representation of identity as constructed in social media presents a conundrum that educators must grapple with (Kimmons 2014). Because the self is complicated and multifaceted, it resists essentialist attempts at classification, and people will understandably reject misrepresentations and misjudgments about their identities that arise through the representation and interpretation of a single AIF, even though social media platforms are generally only designed for and equipped to handle a single AIF. As people participate via a social media platform, they will construct their AIF in accordance with their imagined audience for the platform (Kimmons and Veletsianos 2014; Litt 2012; Marwick 2011; Vitak 2012). Thus, if a student is interacting with peers through the platform, then the AIF will be different than if the student were interacting with their parents or their teachers. However, since such platforms only allow for a single AIF, contexts and imagined audiences quickly become collapsed as students begin connecting with a variety of groups including other students, teachers, parents, siblings, extended relatives, and even strangers, thereby reducing the student's ability to maintain a useful AIF for self-disclosure and expression (Kimmons and Veletsianos 2014; Marwick 2011; Vitak 2012). The representation of the self, then, is essentially colonized within the medium by those who connect with the student, dictating an ever-decreasing set of appropriate behaviors that are deemed suitable for an ever-increasing collapse of social contexts.

A critic of this argument might counter that such colonization is beneficial in education, because by connecting with a student, the teacher can help to counteract the problems of incivility and abuse discussed above, having a civilizing influence on the medium. But such a stance should give us reason for concern, because it smacks of colonial-era arguments for colonization of indigenous peoples by assuming cultural superiority of the teacher and ignoring (or actively seeking to counteract) student agency in the change process. There are undoubtedly a host of appropriate and meaningful behaviors that students engage in that would be lost if teachers sought to insert themselves and classroom-style norms of participation into existing social media, and this seems to especially be true of cultural minority students who may use the space as an alternate means of participation than that afforded by their everyday school contexts. For instance, an ethnic minority student might not feel comfortable posting information about her quinceanera or bat mitzvah for teachers and students to see, because this might elicit unwanted attention, questions, or misunderstandings or require her to become an unwilling spokesperson for her ethnic group to her classmates. Similarly, a religious student might no longer feel safe sharing Christian Bible videos or Muslim Koran verses for fear that teachers or classmates will misinterpret a genuine act of sharing as a form of proselytization or bigotry or operate on the expectation that such behaviors are not acceptable for public discourse (Bobkowski and Pearce 2011; Davidson and Farquhar 2014; Kimmons and Veletsianos 2015). A student whose home language is not English might find herself posting less in her native tongue, because the teacher and other students might not be able to understand her and look upon such expression as excluding and rude. Or a student with unpopular political or ideological beliefs may not feel able to support her candidate or to voice her opinion on a contested issue for fear that her stance might not be shared by the class or that since classroom standards of behavior are being imposed that such forms of expression are better suited elsewhere (Kimmons and Veletsianos 2015). By colonizing and reshaping students' existing social media AIFs, teachers run the risk of eradicating valid and important forms of expression and potentially destroying the only opportunity that those students had for sharing those aspects of their identities.

Such practices may lead to disfigured digital identities for students, wherein they feel compelled to restructure their behaviors in a manner that no longer feels authentic or meaningful. Thus, educational practices with social media that embrace the complex, transitional, and negotiated nature of identity are preferable to those that take an essentialist view; those that rely upon tools that imply monolithic identity constructs or elicit persistent data to create a stagnant vision of the self; or those that seek to impose classroom-like standards of participation upon all social media interactions. As a negative example, consider one colonization approach to using social media to support learning in a monolithic-identity manner. Seeing that students love using Facebook to interact with one another socially, a teacher might consider using a Facebook group to facilitate class discussion. She friends her students and requires them to friend one another. She then begins to connect classroom discussions to the likes and interests of her students expressed in the platform and encourage her students to extend classroom discussions beyond the group to their family and friends in the platform. The problem with such an approach is that by forcing connections with students and enforcing certain behavior expectations, the teacher requires all students to renegotiate their Facebook AIFs in a manner that focuses on schoolwork and appropriate, classroom-like, student-teacher interactions. The resulting AIF is shaped to reflect the power structure between teacher and student and may not be suitable for other interactions. Though the teacher might believe that such a result would effect a positive policing or etiquette benefit among students by improving civility or professionalism, it seems that such activities might rather serve a colonizing influence in the medium and have a subtractive influence on cultural identity expression (Valenzuela 2010). Such students might change their language norms or cease to share sensitive, unpopular, or potentially misunderstood experiences and beliefs through the medium, and peers with whom these students had previously been connected might now see that they are behaving differently or are participating less in the medium (for fear of being observed by their teacher) and may therefore disconnect from or become dismissive of those whose AIFs have now become school-like. Also, sensing that they can no longer participate with their peers in their desired ways on Facebook, students in the class may begin to resist this colonizing influence by seeking out alternative methods for connection that are unknown to the teacher where they may once again express AIFs that they deem to be more suitable and socially useful (e.g., Snapchat).

In contrast, a teacher who recognizes and values the complexity of their students' identities might resist inserting themselves and classroom norms into their students' negotiated lives and might therefore seek to structure social media learning experiences with their students in a manner that focuses upon the creation of an isolated AIF (1) that is not collapsed with other AIFs and (2) that would not extend beyond the temporal and structural confines of the classroom. For example, using a closed, Facebook-like platform like Edmodo, Schoology, Ning, or Elgg, the teacher could construct a classroom-oriented social networking experience with their students wherein each student's AIF would only be constructed by interactions with the teacher and peers in the class. This would allow the teacher to establish norms of participation in the medium without forcing these norms to have a subtractive influence on students' other AIFs, because only one AIF would be expressed in the platform, and it would be specifically geared toward learning. This would also ensure that the AIF constructed in the medium would be transitional (i.e., not going into a persistent timeline for future employers and colleagues to see). However, the drawback of such a structured and isolated approach would be that it subverts many of the potential benefits of social media for learning that are identified in literature on sociocultural learning (Selwyn 2012; Vygotsky 1978), connectivism (Siemens 2005), open pedagogy (Hegarty 2015), and lifelong learning (Blaschke 2012). Such structured social media practice ignores the preexisting socially constructed lives of students by not valuing or incorporating their existing social connections; reinforces traditional educational barriers that separate the classroom experience from the outside world; ignores student agency by not allowing students to incorporate the learning experience and its artifacts into their larger social media practices; and establishes a temporal end to learning activities, wherein all student learning and sharing ceases with the end of the semester's class. These tradeoffs may counteract the greatest benefits for using social media for learning and suggest that exemplary practice may require a discerning teacher to counterbalance identity and cultural participation concerns with pedagogical benefits.

Exemplary practice in this regard, then, will take into consideration the age and maturity level of students and their ability to make informed choices about their AIF construction and sharing choices. For instance, using a closed platform like Edmodo might be very useful for teaching primary students about civility in online interactions and for facilitating class-confined sharing, but it would be less useful for more mature students who could more thoughtfully negotiate their AIFs and would benefit from connecting learning activities with learners or professionals outside the classroom. In contrast, secondary students might be encouraged to create a Twitter account for class where they microblog about social topics and connect these conversations with larger social movements and leaders, but recognizing the importance of identity transition and privacy, the teacher might encourage students to use pseudonyms for Twitter handles and to keep the class-constructed Twitter AIF disconnected from the students' other social media accounts.

In this vein, anonymous and pseudonymous participation can be a useful method for encouraging social media learning activities without resorting to identity colonization. Students might be encouraged to create individual accounts using pseudonyms, or they might participate as a group through a single, shared classroom student account, representing the co-constructed AIF of all students in the class. Rather than being purely arbitrary, pseudonym use can also have clear connections to learning objectives, as students might be encouraged to create a Twitter account for a prominent historical figure and to tweet as if they were that person, thereby engaging in roleplay and exploring the perspectives of different historical figures in a manner that cannot be connected to their identities. Such activities allow students to benefit from the connected, social, and exploratory aspects of these media without having to restructure their AIFs and to do so in a manner that defies the problems associated with persistent data.

Not all participation need be anonymous, however, because students should be encouraged to think about their AIFs and to thoughtfully structure their participation in social media in a manner that aligns with their interests, values, and cultural norms. The key with using identifiable social media with students, however, is to ensure that they are able to construct their own AIFs in an agentic manner with minimal compulsive oversight or surveillance from their teachers or classroom peers. For instance, students might be given a task to complete in social media (like having a civil conversation with a friend on a controversial topic) and then to selectively report out on the experience without being forced to give their teacher or classmates full access to their social media profiles. Such reporting might take the form of an essay, screenshots, or oral report and allows the student to maintain an AIF that will not be scrutinized according to classroom expectations while at the same time using their social connections within the medium to construct meaning and explore important topics in a culturally appropriate manner, thereby paving the way for lifelong learning.

Similarly, not all social media participation needs to be expressive or creative in nature, because one can participate through observation or analysis. That is, there is great value in observing the social interactions, perspectives, and artifacts of others without being compelled to interact or to take a stance on a controversial topic oneself. Thus, social media can be a tool for studying the behaviors of others or for aggregating subject-area content (as in following a Twitter hashtag), and this is a form of legitimate peripheral participation that students can be required to engage in without forcing identity colonization (Lave and Wenger 1991). As they observe the interactions of others, students might begin to feel comfortable to create or share themselves, but such sharing should be natural and student-driven (rather than teacher-driven) in order to prevent identity colonization.

In short, identity is a complex construct that is intertwined with social media participation in important and unpredictable ways. For this reason, teachers should be thoughtful in how they require students to use social media for learning and should favor activities (1) that allow for student agency, (2) that do not unduly compel AIF reconstruction or colonization, (3) that allow for culturally valuable forms of expression that may not fit classroom norms, and (4) that capitalize upon the social, connected, open, and lifelong pedagogical benefits of social media.

Conclusion

This chapter has explored some of the primary cultural and social issues that students and teachers must consider when using social media to support learning. Major takeaways from this chapter include the following: (1) teachers should guide students in the development of critical thinking skills in relation to online information and social media content; (2) teachers should carefully consider the privacy needs of their students when requiring them to participate via social media; (3) teachers and students should thoughtfully exemplify civility in their interactions; (4) teachers should be mindful of the colonizing influence that classroom-driven social media use can have on student identities, favoring activities that allow for more complex, transitional, and authentic forms of identity expression; and (4) pedagogical benefits should be counterbalanced against other considerations to ensure that students have safe, meaningful learning experiences through social media. These technologies are new and ever-changing, and they hold great potential for improving educational opportunities and experiences for our students. Yet, they are also fraught with dangers and considerations that teachers must thoughtfully and proactively address if they are going to positively impact lives and improve learning.

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Bridging Formal and Informal Learning Through Technology in the Twenty-First Century: Issues and Challenges

14

Cathy Lewin and Amina Charania

Contents

Abstract

This chapter presents a comprehensive review of the current debates surrounding bridging informal and formal learning, from the perspective of improving the learner's experience in formal educational provision. Firstly, the chapter reviews the literature defining informal and formal learning, noting the complexity and the lack of consensus. Secondly, it discusses how technology can be used to bridge learning through harnessing the digital practices that young people engage with informally such as social networking, game-based learning, and digital making.

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The authors then outline some pedagogical issues which need to be considered to maximize the potential of bridging formal and informal learning. Next, the pedagogical strategies needed to enhance learners' opportunities for autonomy, collaboration, and authentic learning are discussed. The chapter also explores the divides, cultural tensions, and ethical concerns that shape practices such as the constraints of a performativity culture and the invasion of young people's private space. A vignette of a project in India is presented as an illustration of good practice. Here, despite limited access to technology, young people have been supported to engage in authentic learning projects involving the creation of digital artifacts, both in- and out-of-school. The chapter concludes by arguing that there must be a shift from transmissive to collaborative pedagogical strategies; school cultures need to change. In order to do so, teachers need professional development and support to take risks and experiment. More research is needed so that the interrelationship between technology-enabled formal and informal learning can be better understood but also because good models of practice need to be identified and shared.

Keywords
Informal learning · Formal learning · School · Everyday knowledge · Bridging · Pedagogical support

Bridging Formal and Informal Learning Through Technology in the Twenty-First Century: Issues and Challenges

Formal learning (education and training), broadly conceived as organized through educational institutions and leading to recognized qualifications, is considered by many to be the tip of the iceberg (see Rajala et al. 2016; Rogers 2014; Yang 2015; Werquin 2010). That is, learning can and does take place in many different contexts beyond formalized schooling including after school clubs, homes, peer cultures, museums, galleries, and other community settings.

Technology, such as social media and mobile devices, offers many benefits for informal learning. Many argue that technology changes the way people learn through enabling new and more immediate ways of accessing and creating knowledge shaped through social interaction, increased ability to cross time and space, and new modes of representation (Banks et al. 2007; Cox 2013; Davies and Eynon 2013; Erstad and Sefton-Green 2013). Technology enables young people to engage in participatory and collaborative models of knowledge production that are interest-driven and authentic, with increased agency and opportunities to develop new skills (Ito et al. 2013). However, many young people only engage in passive interaction such as communicating with their friends and posting photographs in social networks rather than creating, editing, or remixing digital artifacts (Clark et al. 2009).

Technology can disrupt the boundaries between types and sites of learning (Greenhow and Lewin 2016) (see also ► Chap. 8, "Dissolving the Digital Divide: Creating Coherence in Young People's Social Ecologies of Learning and Identity Building" by Kumpalainen et al. in this Handbook). Formal educational institutions are increasingly trying to harness the potential of technology for making connections to the different types of learning that take place (Ito et al. 2013; Rajala et al. 2016). This is often driven by political demands to improve outcomes and address issues such as student retention by making learning more engaging and relevant (Kumpulainen and Mikkola 2016). However, this shift in school culture is not without its tensions as outlined below.

This chapter reviews the current debates surrounding the conceptualization of informal, nonformal, and formal learning. It then considers recent attempts to bridge young people's formal and in/nonformal learning through the adoption of technology. In the light of this shift in focus, the chapter discusses some of the pedagogical issues arising as educationalists attempt to realize this vision. In an attempt to avoid a biased Western view, it then presents an exemplar of a project in India designed to connect learning across sites. Finally, it concludes by highlighting future challenges and considering the implications for life-long learning.

Conceptualizing Informal Learning

As noted by many, there is a lack of consensus regarding the complex, slippery concepts of in/nonformal learning (Colley et al. 2003; Sefton-Green 2004, 2013; Rogers 2014; Werquin 2010). Policy makers, alongside others, have presented discrete definitions of the concepts and avoided discussion of the difficulties in doing so (Eshach 2007; The World Bank 2003; UNESCO 2012). However, as Sefton-Green (2013, p. 18) notes, "it is easy to think of exceptions and challenges" to discrete definitions. In response, many have argued that instead of viewing these terms as discrete they should be viewed as on a continuum (Lai et al. 2013; Werquin 2010; Yang 2015). That is, definitions should be relative rather than absolute as conceptualizing each term as distinct and bounded is impossible (Sefton-Green 2013). In acknowledging the struggles of many who have focused on this area, Colley et al. (2003) argue that "It is more sensible to see *attributes of formality and informality* (emphasis as in original) as present in all learning situations" (p. 29). This conceptualization is becoming increasingly more important as pedagogical practices combining formal and informal attributes to varying degrees become more commonplace in educational contexts (Weigel et al. 2009).

It is insufficient to define formal and informal learning according to where it takes place (Sefton-Green 2004); instead, it is more important to consider the purpose and structure of the learning (Sefton-Green 2004). Informal learning can thus be broadly conceived as "what happens outside the structures and boundaries of formal education, the topic or focus of which is determined by the person doing the learning, on their own or with others" (Davies and Eynon 2013, p. 330). Informal learning is concrete, interest and practice-driven, open-ended, and highly contextualized (Arnesen et al. 2016; Lemke et al. 2015) as compared to the relatively abstract and decontextualized knowledge delivered through formal education. Informal learning may not always be planned; rather it may be reactive and spontaneous (Eshach 2007). It may also include incidental learning, described as "the everyday experiences through which we learn a great deal without ever being conscious of 'learning'" (Rogers 2014, p. 18).

A distinction is also often made between nonformal learning and informal learning. Nonformal learning is commonly used to describe planned but flexible learning that takes place in after-school programs and other activities held outside school hours, in- and out-of-school (Eshach 2007). These activities are organized to some degree around purposeful activities (e.g., football training) but the learner has more agency and choice than in formal settings and more opportunities for social engagement (Lemke et al. 2015; Sefton-Green 2013).

More recently, some researchers have avoided the regular use of the terms in/nonformal learning (and thus the need to conceptualize them), instead referring to sites of learning across space and time including in-school and out-of-school (Erstad 2012; Rajala et al. 2016). In their "learning lives," young people are conceptualized "as learners [moving] between different contexts of learning, both offline and online, in a constant flow of activities" (Erstad 2012, p. 26). This conceptualization focuses on boundaries and boundary crossings between different learning practices, which demand ongoing complex negotiations (Erstad et al. 2013).

Bridging Formal and In/Nonformal Learning: The Role of Technology

The benefits of connecting to informal learning practices include authenticity, greater engagement, development of social capital, opportunities to develop twenty-first century skills, and the potential to enhance learning (Banks et al. 2007; Hung et al. 2012; Ito et al. 2013; Lemke et al. 2015). Many recent initiatives have tried to capture informal learning and "institutionalize" it (Erstad and Sefton-Green 2013). Everyday experiences are important learning opportunities that can support many different curriculum areas. Schools can draw on everyday knowledge and skills held not only by young people but also their families and the wider community, thus involving a wider range of "teachers" (including the students themselves) (Banks et al. 2007; Erstad et al. 2013; Kumpulainen and Mikkola 2016). Life-long learning policies are also being developed to formally recognize, validate, and accredit the in/nonformal learning that occurs outside formal education (e.g., home, community, workplace) for young people and adults (see Werquin 2010; Yang 2015).

The rapid uptake of technology in many societies and the developing digital youth culture has generated greater interest from policy makers, educators, and academics in bridging formal and in/nonformal learning (Erstad and Sefton-Green 2013; Sefton-Green and Erstad 2016). Technology has created new possibilities for connecting learning taking place in different sites, connecting people with shared interests and expertise, and for integrating informal attributes within formal learning practices (Laru and Järvelä 2015). Concerns have been repeatedly raised about the mismatch between young people's digital practices in- and out-of-school, often described as a "disconnect" (e.g., Clark et al. 2009; Erstad and Sefton-Green 2013; Ito et al. 2013). School needs to be viewed not in opposition to youth culture but as “an important part of a network of learning contexts that optimally create a supportive ecosystem for engagement and learning for a diverse range of students” (Kumpulainen and Mikkola 2016, p. 32).

Nonformal learning is perhaps a special case in relation to bridging formal and informal learning. After-school clubs can connect academic and everyday knowledge, enabling students to focus on interest-driven activities with more flexibility and without high-stakes testing but still with recognizable benefits for academic learning outcomes (Deng et al. 2016; NRC 2015). However, schools do not provide enough opportunities for nonformal learning as part of their standard offer to students although most teachers recognize its academic value (Birdwell et al. 2015).

Many argue that schools should take account of young people’s uses of technology outside formal education although Crook (2012) cautions that digital practices are shaped by context leading to tensions if they are imported from one to another. Young people’s everyday digital practices can complement formal education but may require what counts as knowledge to be reconceptualized (Sefton-Green 2004). Additionally, the informal skills and practices developed through social media, gaming, mobile learning, engaging in online communities, and digital making can be appropriated in the classroom to support schoolwork when it seems beneficial to do so (Erstad et al. 2013).

Social media can readily be used to support discussion and collaboration (Chen and Bryer 2012) and a participatory culture (Mao 2014) both within the classroom and beyond, including with experts and community members when appropriate. However, uptake in the classroom remains low, lacks purpose, or is tightly structured (Mao 2014) despite interest in its potential for over 10 years (Crook 2012). Young people may utilize such technology informally to gain peer support outside the classroom (Schuck et al. 2017) but little is known about the extent of such use. Alternatively, personal learning environments have been proposed as formal mechanisms for harnessing social media and other digital tools to support self-regulated learning through access to informal networks and peers, access to additional content, and sharing and cocreating knowledge (Dabbagh and Kitsantas 2012). However, young people are not making the most of the opportunities that social media offers for supporting formal learning, partly because they do not possess the skills to do so effectively (Clark et al. 2009; Dabbagh and Kitsantas 2012).

Game-based learning is another popular youth pastime which has been proposed as a means of supporting learning in classrooms for decades. Kluge (2016) concludes that teacher support and scaffolding is required in order to make connections between game playing and academic learning as the transfer of learning from games does not always take place, even with games designed to explicitly support learning and used in classroom contexts. He suggests that young people engaging in trial-and-error gaming strategies as a means of improving game results can undermine the learning aims built into educational games. Therefore, even though game-based learning can be very engaging for students, it may not facilitate productive learning. From a different perspective, Brevik (2016) suggests that gaming outside school can have a positive impact on language development. However, the students involved in this study did not make connections between their development of English outside school and their language use in school, supporting the argument for teacher support to maximize learning opportunities.

Seamless learning, facilitated by mobile technologies, enables "a continuity of the learning experience across different scenarios or contexts" (Chan et al. 2006, p. 23) enabling collaboration, personalization, and authentic learning to take place (Schuck et al. 2017). Seamless learners are viewed as being on a spectrum from those who self-direct their learning to those requiring more structure and support (Sharples 2015); that is, as with formal and informal learning, self-directed and facilitated learning are not discrete polar opposites. Boticki et al. (2015) developed a mobile learning platform for primary-aged children enabling them to spontaneously capture media, comment, and share. Students also received prompts, either periodically or triggered by location, to scaffold learning. The intention was that young people would use the technology for both teacher-directed and self-initiated activities linked to school learning. However, students mainly undertook teacher-directed activities; the authors conclude that self-initiated activities still require teachers' pedagogical support and structure.

In developing nations like India where access to education remains difficult in the rural and remote areas, mobile technology offers tremendous potential (Adhikari 2014; Brewer et al. 2005). Where other basic infrastructure and technology has failed, mobile technology use has grown even in the remotest areas of India, which now has the second largest user base in the world (Raman 2014). However, while its potential to support learning has been explored at the higher education level through platforms such as MOOCs, its adoption in school education has yet to take place. Reasons could include the lack of pedagogical knowledge for connecting formal and in/nonformal education and too much emphasis on content creation, which is difficult to customize for the many local languages and culture. A similar trend of low uptake occurs in adult learning: 80% Indian employees find mobile learning useful, but only 27% of the companies have adopted this approach for capacity building of their employees (Srivastava 2015).

Online communities enable people with shared interests to come together. Connected learning "is that which is socially embedded, interest-driven, and oriented toward educational, economic, or political opportunity" (Ito et al. 2013, p. 6). Drawing on learners' interests can beneficially connect learning across sites (Weigel et al. 2009) developing skills such as resilience and adaptability, and a positive disposition to academic learning (Ito et al. 2013). Technology is central to this approach, facilitating greater opportunities for access to knowledge, information, and supportive communities, and the means to produce multimodal digital artifacts (Kumpulainen and Sefton-Green 2014). Ito et al. (2013) suggest that connected learning can be facilitated through creating opportunities for students to engage in creative and collaborative project work strongly linked to their own interests, with an emphasis on production and performance.

The maker movement is growing in after-school settings (Peppler and Bender 2013), one aspect of which is digital making (Quinlan 2015) while much maker activity draws on technology in some way. Making generally involves the collaborative pursuit of technical projects related to personal interest and include

3D printing, programming, and e-textiles. Making can develop skills in creativity, computational thinking, evaluation, reflection, collaboration, communication, problem solving, and resilience, and contribute to learning outcomes (McKay and Peppler 2013). It provides strong connections to both everyday practices and academic knowledge. It is already being appropriated in school contexts for open-ended and interest-driven activities where institutional structures allow (McKay and Peppler 2013).

Technology can also be used to bring informal resources into the classroom. Stocklmayer et al. (2010) describe how students in Australia accessed presentations given by staff at a science center through video-conferencing; here technology acts as a technical bridge connecting to learning resources outside the classroom. Virtual reality is another such example, providing opportunities for learners to experience “authentic” contexts such as geographical and historical sites that they might not otherwise be able to do (Freina and Ott 2015). This can also be achieved through simpler technologies; for example, lower socioeconomic children at a learning center in Kolkata, India were able to explore the Taj Mahal and its history through videos, and London through google searching.

Pedagogical Issues in Using Digital Technologies to Integrate Informal Learning Practices in Formal Education

As discussed above, bridging formal and informal learning through technology fosters connected authentic and seamless learning across settings. However, this bridging remains a major pedagogical challenge, with limited uptake to date, despite the growing interest from policy makers and practitioners in doing so (Khaddage et al. 2016; Lai et al. 2013; Rajala et al. 2016). The ubiquitous nature of technology has made the learning landscape more complex, thus increasing the “transfer problems” (the difficulties of applying knowledge in new contexts) that occur in transitions between spaces (Illeris 2009). Bridging learning through technology demands pedagogical change to ensure that everyday practices and knowledge are integrated and assessed in meaningful ways (Kumpulainen and Mikkola 2016; Lai et al. 2013). The need for teacher professional development in digital pedagogical practices has always remained an important factor to integrate technology in school classrooms (Chen and Bryer 2012). However, teachers also need specific professional development in nonformal pedagogies (Birdwell et al. 2015; Quinlan 2015). Without pedagogical change, technology may be used to replicate rather than enhance existing practices (Erstad and Sefton-Green 2013; Khaddage et al. 2016).

Pedagogical Strategies for Bridging Formal and Informal

It is suggested that traditional formal pedagogies focus on the individual rather than the sociocollective more commonly found in informal learning (Deng et al. 2016; Hung et al. 2012). A variety of pedagogical strategies commonly found in out-of-school contexts could, however, be incorporated into formal learning, using technology, to ensure that learning in the classroom is more social, participatory, experiential, and experimental (Deng et al. 2016; Hung et al. 2012).

Informal learning strategies can be introduced through project, inquiry, and problem-based learning approaches facilitating authentic and experiential tasks (Banks et al. 2007; Erstad 2012; Illeris 2009). The adoption of informal learning practices (concrete, interest and practice-driven, open-ended, and highly contextualized) can require a shift in roles as teachers become knowledge managers and students become self-directed learners (Schuck et al. 2017). This shift in control from teacher to learner can readily be facilitated through technology (Cox 2013). In addition, integrating informal learning practices in the formal classroom, drawing on the personal and social contexts of the students for knowledge construction, often remains challenging due to timetabling restrictions, mismatch with assessment practices, and lack of technology infrastructure.

Bridging formal and informal learning needs teachers' guidance to enable learning to take place across contexts (Boticki et al. 2015). This is particularly important given that generic digital tools rarely offer pedagogical support (Laru and Järvelä 2015). Teachers must be more flexible and creative in order to integrate informal learning practices and exploit the resources available outside the classroom (Deng et al. 2016; Sharples 2015; Stocklmayer et al. 2010) or to build learning activities around students' personal interests (Deng et al. 2016). For example, Sharples (2015) notes that teachers can use learning undertaken outside the classroom, such as science inquiry activities, as a starting point for a lesson but that this requires them to improvise and actively make connections to the curriculum. Providing support to learners to help them make connections across sites can ensure that learning experiences are recontextualized and that students pursue their interests and develop them further (Hung et al. 2012; Lopez and Caspe 2014). Family support is also an important enabler of bridging learning across sites (Lopez and Caspe 2014). Technologies, such as social media and mobile devices, can enable a variety of stakeholders to support students.

Students' interest-driven learning out of school is also connected to their extracurricular activities in school (Deng et al. 2016). After-school extracurricular activities run by teachers can provide further opportunities for learners' personal interests to be leveraged and linked to formal learning (Deng et al. 2016). In addition, teachers can extend support to other after-school providers through participating in their events, planning, and designing lessons collaboratively with informal educators to ensure the topics taught in both the settings connect enabling knowledge to be deepened for students.

Divides, Cultural Tensions, and Ethical Concerns

Students need to have ubiquitous access to technologies including mobile devices to harness the potential benefits of bridging learning across sites (Lai et al. 2013), and as noted above, this is often not the case in developing countries (Davies and Eynon

2013). Limited finances can constrain access to out-of-school resources such as technology and Internet access leading to inequalities in relation to informal learning opportunities (Lopez and Caspe 2014). After-school clubs and informal learning centers (as provided in India) can bridge this digital/cultural divide. When ubiquitous access is a possibility, young people's everyday practices with smartphones, such as texting and checking social media accounts, can be perceived be educationalists as disruptive (Hsi 2007) with some arguing that their adoption in formal education has a negative impact on learning outcomes (Beland and Murphy 2015).

Although it is commonly reported that young people's uptake of technology is high, levels of engagement vary from none at all to sophisticated practices. Children can be "passive recipients" of online content rather than active producers of it (Ito et al. 2013); that is, they may not engage fully in sociocollective and rich learning activities through technology. Students do not always have the skills or interest in using technology such as social media to support learning (Erstad 2012; Chen and Bryer 2012).

Young people can associate technology use outside school with play and everyday activities, whereas acceptable school use is typically linked to work and academic learning (Hsi 2007). They do not feel that their everyday uses of technology are valued by their teachers nor recognize the ways in which they could be appropriated to support formal learning (Chen and Bryer 2012). Indeed, some students consider accessing social media in the classroom inappropriate and a distraction suggesting that pedagogical scaffolding is required to maximize its impact in classrooms (Mao 2014). Even when the learning activity is orchestrated by a teacher across multiple contexts, students can find it difficult to apply the knowledge from outside the classroom to the learning that takes place inside it (Sharples 2015).

From an institutional perspective, increasing accountability, high-stakes testing, and a curriculum based on declarative knowledge constrain opportunities to integrate informal learning practices (Erstad and Sefton-Green 2013; Ito et al. 2013). This leads to a culture clash between in- and out-of-school learning (Ito et al. 2013). Furthermore, assessment practices can be challenged by the adoption of informal learning practices (Birdwell et al. 2015). Formal assessment structures do not always value and/or recognize knowledge acquired from everyday informal experiences and social learning (Chen and Bryer 2012; Lemke et al. 2015). School structures inhibit recognition and accreditation of learning that takes place outside established systems and curricula. Yet, learning arising from informal practices needs to be valued and the knowledge legitimized (Hsi 2007; Rajala et al. 2016). Authentic and ongoing strategies such as rubrics, portfolios, and badges can support the assessment of informal learning (Boticki et al. 2015; Chen and Bryer 2012).

Teachers may resist the changes required to integrate the seemingly contradictory informal learning practices in their pedagogies (Chen and Bryer 2012; Weigel et al. 2009); they need to be open to change, recognize the value of everyday learning, and make connections to students' interests (Eshach 2007; Schuck et al. 2017). Time constraints may also be an issue (Birdwell et al. 2015; Chen and Bryer 2012). In some cases, nonformal educators may have different levels of experience and qualifications from formal educators; this difference could lead to tensions if these educators from different backgrounds work together to support learning across sites.

Tools and Internet sites commonly used outside school (e.g., YouTube, MSN) are often restricted inside school for safe-guarding reasons (Chen and Bryer 2012; Davies and Eynon 2013; Merchant 2012); in particular, collaboration and communication through technology is prevented or minimized. In comparison, access to technology outside schools is more open and sometimes not controlled in any way whatsoever. Controlled access in schools can be partially addressed by encouraging the use of digital tools and resources to support homework (Davies and Eynon 2013) although of course not all young people have access to technology outside school.

It is also argued that incorporating informal learning practices in formal education can be viewed as an invasion of private spaces and a "pedagogization of everyday life" (Sefton-Green and Erstad 2016) with the possibility that students may resist such endeavors (Weigel et al. 2009). From an alternative perspective, the ubiquity of technology meaning that learning can take place anytime and anywhere can have negative implications for the work–life balance (Chan et al. 2006).

Bridging Formal and Informal Learning Through Technology Without Ubiquitous Access

Of course, in many developing countries, access to the Internet and technology is not ubiquitous (Davies and Eynon 2013). The uptake of technology in developing countries is constrained by insufficient access to electricity, Internet connectivity, and bandwidth, particularly in rural areas (Brewer et al. 2005). In many parts of India, the digital divide is all too apparent and is mediated by the variables of gender, age, and socioeconomic status (Kumar et al. 2010). In many developing countries like Brazil and India, informal learning can enhance formal education by fostering learning centered on life skills, cultural identity, and respect for diversity (Hoppers 2006). In addition to classroom use, research shows that mobile phones can increase access to and support learning beyond the classroom walls and lifelong learning (Kumar et al. 2010).

A vignette of an after-school learning context in a rural- and tribal-dominated region in Bengal, East India, drawing on coauthor Charania's work, is now presented. Inhabited by Santhal and Kora tribes, some villages are underdeveloped in socioeconomic terms. Most of the tribal children attend the government-funded schools, but they struggle with the official language of instruction, Bengali, which is different to their native language. Similarly, teachers and parents face communication challenges. Standardized state textbooks dominate the instruction at schools and have no relevance to their immediate culture; teaching practices tend to be teacher-centered. Suchana, a local non-government organization (NGO), established an after-school learning center for the tribal children, providing academic support, bridging the language barriers, and welcoming parents as active participants.

In 2013, Suchana adopted and implemented the Tata Trusts initiative, "Integrated approach to Technology in Education" (ITE) (Charania 2015). ITE is a pedagogical framework designed to foster authentic and project-based learning for young people who live in some of the most underprivileged locations in India. Students, mostly first-time computer users, create learning artifacts to deepen their learning of content, for example, graphical representations of jute production in India. Through Suchana, all the projects assigned to students are carefully selected by the informal educators and match the local school curriculum. Suchana also engaged with local school teachers, inviting them to exhibitions at which students showcased their projects, providing opportunities for educators to meet parents. These events served as platforms of exchange and boundary crossing between formal (school) and nonformal (learning center) sites. Three remote-learning centers were subsequently opened by Suchana with funding from Tata Trusts; a mobile van carried charged-up laptops, solar lights, Internet dongles, and also books between them.

ITE projects multiplied at these learning centers and many authentic projects connected to school curricula were created. For example, students used video and spreadsheets to measure speed, distance, and time in cycling and athletics. The adoption of ITE at the learning centers improved: student attendance and interest in school subjects; digital skills including showcasing work; collaboration skills; authentic learning experiences; and improved teaching processes.

In 2014, Suchana introduced community projects during vacation periods using project-based learning and authentic activities to focus on social issues, rather than school curricula. In one example, adolescents created a video about their local river, interviewing community members to understand its changing flow over time and how it affected the community's lifestyle. This project also raised awareness about cultural and environmental change. Students seemed more engaged in community projects compared to those focusing on school subjects. Vacation periods offered more and flexible time; the community projects were relevant to their immediate lives, providing opportunities to change their own social realities.

In 2015, Suchana strengthened their interaction with the government schools and extended ITE to formal education, directly implementing ITE in four government schools. They trained school teachers and administrators, negotiated space in the school timetable, and supported teachers implementing ITE projects in the schools. These schools had no computers or Internet connectivity and had irregular power supply. Suchana provided charged-up laptops and dongles to facilitate connectivity. Through this initiative, the schools have realized the potential of digital technologies to facilitate learning and student interest, both very difficult goals to achieve in a lower socioeconomic context where even the benefits of completing formal education are unclear.

Thus, the initiative that was developed initially at the learning centers was subsequently integrated within the mainstream schooling system shifting informal learning practices into the formal context of school. Suchana continued to run its learning centers before and after school serving as resource points for schools taking up ITE: creating lesson plans, organizing events for showcasing students work, and bringing teachers and the community together. They also provided technical support, charged the laptops, and prepared dongles for delivery to schools.

The learning centers are not bound by timetabling and language of instruction at schools; they have access to community space and culture to explore subjects in real-life situations, and greater flexibility when working on community projects. They provide deep authentic learning experiences and a sense of agency for young people, developing life-long learning skills, supporting social and personal transformation in young people's lives and their communities. The adolescents cross contextual boundaries using their newly developed digital skills and basic technologies (i.e., laptops), working toward similar goals, using the framework of ITE. The deep and authentic learning experiences undertaken outside the school context intersect with formal education while utilizing a flexible and open environment. Given the tribal and school culture which is largely compliant with members accustomed to being directed by those in authority, this learning was not self-directed. ITE uses technology, links to school subjects, and develops skills such as collaboration, problem solving and critical thinking, and creativity. These being lifelong learning skills, it is likely that in the long run, these adolescents will become more self-directed in creating such learning opportunities for themselves.

Conclusion

A comprehensive review of recent literature on how informal learning, including everyday knowledge and informal practices, could help to reshape formal education has been presented. To harness the potential benefits of informal learning in formal contexts, there is a need to shift formal pedagogical practices from transmissive approaches to collaborative, student-centered and self-directed approaches to create opportunities for young people to draw on everyday knowledge and practices (Khaddage et al. 2016). Indeed, a recent Horizon report for K-12 (Adams Becker et al. 2016) predicts greater uptake of problem-based learning, collaborative, self-directed, and active learning, with the growth of remote interaction, all facilitated by technology.

However, while there are strong arguments for bridging formal and in/nonformal learning, there is still limited understanding of the interrelationship between using technology in school for learning and using technology outside school for a wide range of learning activities (Cox 2013; Hung et al. 2012). It is also clear that there remain many challenges in relation to pedagogy, technology, policy, and research (Khaddage et al. 2016; Kumpulainen and Sefton-Green 2014; Schuck et al. 2017). Indeed, there are broader cultural tensions, and moral and ethical concerns relating to bridging learning, as discussed above. Khaddage et al. (2016) argue that the difficulty of developing a shared understanding of informal learning is one barrier to the development of pedagogies that bridge different types of learning. However, it is better to accept informal learning as a slippery and complex concept, and to focus instead on the formal and informal attributes of learning (Colley et al. 2003; Greenhow and Lewin 2016). Khaddage et al. (2016) also note that it is difficult to capture informal learning as it happens and assess its outcomes. In addition, there are relatively few models of good practice for bridging formal and in/nonformal learning

(Merchant 2012). From an ethical perspective, the danger of blurring boundaries and attempting to capitalize on learning that takes place outside the school is that people's personal spaces are invaded potentially having negative impact on learners' engagement and outcomes (Sefton-Green and Erstad 2016).

In the past, a lack of infrastructure has been noted as a significant barrier to integrating technology in formal education. This is not necessarily the case any longer in developed countries although further investment is still required to support increased use of mobile technologies in classrooms. Infrastructure capabilities are also being improved in many developing countries. For example, the Digital India initiative funded through the Indian Government aims to provide universal mobile connectivity. In the future, this should ensure better access to digital educational resources particularly in rural areas of India. Formal institutions like the National Institute of Open Schooling in India which allows nontraditional learners to pursue secondary-level education in a nonformal context, should harness the growth in mobile connectivity to increase their outreach and quality of delivery.

In order to maximize the potential of bridging formal and in/nonformal learning, school cultures need to change. The boundaries between in- and out-of-school need to be recontextualized to create "possibilities for participation, interaction, and collaboration across a diversity of sites and contexts, both within and across institutions" (Kumpulainen and Sefton-Green 2014, p. 13). It would be beneficial to view learning as an ecosystem, considering a community's rich assets such as designed settings (e.g., after-school clubs, museums), natural settings (e.g., geographical areas, historical sites), people and networks of people (enthusiasts, experts), and everyday encounters (at home, online) (NRC 2015). It would also be beneficial to reconsider "what constitutes appropriate kinds of knowledge, ways of learning and pedagogic relationships" (Sefton-Green and Erstad 2016, p. 3). Strong collaboration between all stakeholders including learners, teachers, parents, and policy makers is necessary to ensure that all knowledge is valued and recognized (Banks et al. 2007). However, it is unlikely that such cultural shifts will take place while curriculum constraints, timetabling, high-stakes testing, subject silos, and risk aversion continue to act as barriers to innovation and change (Adams Becker et al. 2016; Schuck et al. 2017).

Professional development for teachers and out-of-school educators is one means of addressing current challenges (Khaddage et al. 2016; NRC 2015), both in developed and developing countries. Teachers need to understand the possible benefits of harnessing both informal learning practices and the knowledge and skills developed through everyday practices to support the achievement of formal learning outcomes (Banks et al. 2007). Teachers also need to be prepared to take more risks and experiment with their classroom pedagogies. This requires support and encouragement from school leaders. In addition, more work around assessment is required. There is a need for mechanisms to recognize the complex and varied outcomes that arise in out-of-school learning and to develop ways of comparing data from in- and out-of-school learning (NRC 2015).

Students also need to be offered more support and guidance from their teachers in order to make more connections between learning in and outside school. It would be beneficial to ensure that they have the skills required to harness the full potential of technology to support all forms of learning, particularly in relation to the development of supportive networks and identifying relevant online communities. This is essential if students are to be equipped with the means to continue using technology to support lifelong learning.

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Computer-Supported Collaborative Learning: Mediated and Co-Present Forms of Learning Together

15

Lara Johanna Schmitt and Armin Weinberger

Contents

Abstract

Computer support offers versatile opportunities for learning together at a distance as well as for colocated scenarios of collaborative learning, in which learners construct arguments, share knowledge, and jointly produce task solutions themselves. In this chapter, we explore different computer-mediated and co-present forms of computer-supported collaborative learning (CSCL). We will discuss both the potential and the problems of CSCL. Finally, we will show how current instructional approaches aim to overcome CSCL problems to realize its full potential.

Keywords

CSCL · Computer-supported collaborative learning · Co-Present · Computer-mediated

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A straightforward and concise way of defining computer-supported collaborative learning (CSCL) is to state that it involves some form of learning together with peers and computer-based support for learning. Starting from there, however, multiple approaches to collaborative learning can be distinguished, and computer support can vary considerably and is rapidly progressing along with information and communication technologies (ICT).

Collaborative learning. One of the most widely disseminated and intuitive distinctions of learning together with peers is the one between collaborative and cooperative learning. A well-established definition of collaboration is "Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (Roschelle and Teasley 1995, p. 70); thus, collaborative learning is different from cooperative learning, in which a group of learners splits the work into individual, additive sub-tasks. While per definition being a "synchronous activity" (Roschelle and Teasley 1995, p. 70), asynchronous CSCL can still host collaboration with learners' reasoning processes being not temporally but transactively intertwined (Roschelle and Teasley 1995), i.e., learners address and build on the reasoning of their peers. Respectively, the "interactions among peers" (Dillenbourg et al. 2009, p. 3) were termed as the main feature of collaborative learning. Furthermore, learners can convergence in collaboration and share knowledge as a result (Weinberger et al. 2007). One of the foci in investigating collaborative learning is to analyze how learners acquire knowledge by engaging in specific argumentative discourse activities, which have been classified along different epistemic, argumentative, and social dimensions (Weinberger and Fischer 2006).

- Regarding the *epistemic quality* of discourse, learners may be more or less on-task, may demonstrate a more or less correct understanding of concepts, and may more or less adequately link and apply concepts when solving a problem case.
- *Argumentative quality* refers to how learners elaborate their line of reasoning in formal argumentative structures, including the extent learners warrant their claims, produce evidence, and anticipate and include counterarguments in their line of reasoning.
- The *social modes of interaction* regard how learners refer to and build on each other's reasoning, which has been termed the degree of transactivity (Stahl 2013). Here, learners could use peers as additional resource and elicit knowledge from each other or agree and disagree with each other's stances.

Past research has shown that transactivity is a core quality of learners' discourse, strongly related to individual and group learning outcomes (e.g., Noroozi et al. 2013). A highly transactive act is, for instance, to relate to peer contributions in a critical way with the goal to sort out differences of perspectives by subsequent negotiation, integration, and modification of understanding. Transactivity also builds on the establishment of a common ground among collaborative learners (Beers et al. 2006). Common ground refers to the externalization and transformation or re-contextualization of the group members' knowledge or "grounding," to reach mutual understanding (Bechky 2003, p. 534), the base for all further interactions and knowledge construction processes (Bechky 2003).

Specifically, in the context of early school education, the success of collaborative learning largely depends on a sense of intimacy and mutuality through sharing experiences and common goals (Crook 1998). The concept of common ground relates to the question of how learners co-develop more or less similar knowledge structures when learning together and converge on knowledge. Knowledge convergence has been conceptualized and investigated as an important quality of collaborative learning (Weinberger et al. 2007). Through processes of establishing common ground and transactive discourse, learners may acquire equivalent amounts of knowledge and share knowledge as a result of learning together. This group-level perspective on collaborative learning underlines the importance of epistemic, argumentative, and transactive qualities of discourse. While successful groups of learners spontaneously display elaborated and critical forms of consensus building, there are robust findings that collaborative learners typically benefit from additional scaffolding promoting these discourse qualities and facilitating knowledge convergence (Kreijns et al. 2013; Noroozi et al. 2013). Hence, scaffolding learners to engage in productive interactions is a major focus in CSCL.

Computer support for collaborative learning. Computers can be used to support remote learning as well as face-to-face learning settings (colocated CSCL); they enable asynchronous discussions, e.g., discussion boards, and synchronous learning and working, e.g., simultaneously drafting documents in shared workspaces together. Computers are tools for representing and sharing ideas and knowledge. Externalized knowledge that is being developed jointly, e.g., as a mind map, can help learners to focus on important concepts and foster the quality of learner products as well as learning outcomes (Janssen et al. 2010).

The following two sections introduce and discuss two main branches of CSCL, mediated and colocated computer-supported collaborative learning. We will give insights into exemplary learning environments and research done in this field, drawing on seminal work, constitutional to the research area of CSCL, as well as recent developments.

Computer-Mediated Collaborative Learning

Building on the "communication" function of ICT, computer-mediated learning entails all forms of learning together at a distance. Computer-mediated communication (CMC) can be relatively synchronous or asynchronous, that is, participants in online interaction may use platforms, in which an immediate response is expected, such as in chats or videoconferences, or may expect any kind of delay on platforms such as discussion boards or email. Moreover, communication may be more or less enriched by media formats building on platforms that support sharing of, for example, videos or text only.

Computer-mediated learning scenarios are often designed for online learning groups of adult learners but can enable learning across schools (Ligorio and Van der Meijden 2008), in blended scenarios of learning in and out of schools and combining online and face-to-face dialogue. Computer-mediated learning scenarios mainly address secondary school students and adults, which we will outline in the following paragraphs.

Typical Scenarios of Computer-Mediated Collaborative Learning

Computer media for communication span from asynchronous, text-based emails and discussion boards to synchronous multimedia environments like videoconferencing and virtual worlds. Video is playing a major role in transmitting lectures or providing one-on-one tutorials, but only few CSCL studies have been focusing on videoconferencing (e.g., Ertl et al. 2006). In these scenarios, learners are communicating by video chat and simultaneously work in a shared workspace, e.g., creating a concept map together or co-constructing arguments.

Asynchronous and text-based scenarios of CSCL, in contrast, have been widely investigated and applied in different platforms and contexts (Tsovaltzi et al. 2015). Learners in asynchronous environments have equal opportunities for participating in argumentative discourse by constructing arguments at their own time without being interrupted with the ability to search for and include additional resources. Small groups of online learners can be composed to jointly inquire scientific problems and phenomena, but also larger online courses and MOOCs (massive open online courses) do partly build on collaborative scenarios and typically provide a platform for social interaction. Likewise, CSCL in social networks is moving beyond small group interaction and is supporting collaboration among larger communities. Here, learners provide personal profiles and share information across different groups of friends and larger communities fostering social interaction (Kreijns et al. 2013). A recent study found how learning in social networks strongly builds on knowledge sharing and co-construction to the extent that individual preparation can lead to premature knowledge consolidation and impede learning gains in argumentative online learning scenarios (Tsovaltzi et al. 2015).

In other advanced, but under-investigated computer-mediated scenarios of CSCL, learners direct avatars through virtual landscapes, where they meet and interact with avatars of peers. These scenarios are strongly influenced by massive multiplayer online games and often build on the respective game environments. For instance, *Second Life* is a game environment in which, for instance, foreign language learning is being investigated utilizing the virtual context as a visual and linguistic support (Hsiao et al. 2015).

Platforms sometimes support different types of communication media. For instance, *Euroland* offers both asynchronous discussion boards and a virtual world, in which learners need to be carefully introduced to the tools and possible courses of action for expanding a local classroom into a larger online community (Ligorio and Van der Meijden 2008). The seminal *Virtual Math Teams* project (Stahl 2006) connects people over the Internet to collaboratively discuss and solve math problems using a shared whiteboard and a chat tool. This project shifted from a local intervention to building an online math community connecting students from different classrooms all over the world to participate in discourse for a deep understanding of mathematical principles (Stahl 2006).

Issues of Computer-Mediated Collaborative Learning

Regardless of the communication media, there are indications that computer-mediated communication requires learners to more explicitly coordinate themselves than in face-to-face (FTF) environments (Van Der Meijden and Veenman 2005). The "poorer" the medium is, the less socially present peers are and the more pronounced are effects of the medium on different qualities of communication. So, for instance, the effect of an increased need for coordination is more pronounced in text-based communication and mitigated but still observable in "richer" videoconferences (Ertl et al. 2006). Social context cues are what seem to be lost in poorer scenarios, such as discussion boards, in comparison to rich communication scenarios like FTF or videoconferencing. At the dawn of CMC in the late last century, lack of social context cues has been related to problems of deindividuation, i.e., submergence in an anonymous group with a loss of identity and individual responsibility leading to violation of social norms online; however, later CMC models indicated how lack of social context cues may also increase group identity and foster social attraction (for an overview, see Walther 2011).

Walther's hyperpersonal model of CMC exceeding face-to-face interaction in allowing to control, edit, and optimize presentation of one's self (Walther 1996, 2011) appears to be particularly relevant for communication in social networking sites (SNS) like *Facebook*, in which users can cultivate a profile and intentionally disclose their personality to a high degree. In this way, Facebook and other SNS may foster social aspects of academic life including actual friendships (e.g., Selwyn 2009), which can contribute to study-related knowledge sharing (Wodzicki et al. 2012). SNS can also greatly support active information seeking and building social capital that increases the connectedness with people for future support and cooperation (Lampe et al. 2012). Interestingly, media effects may not necessarily impede learning, because learners can compensate media effects over time or can be additionally supported to overcome media limitations. Hence, advantages of asynchronous CMC for learning – independent of place and time – also factor into how learners can harness CMC for higher levels of CSCL. In online discussion boards, learners have the time they individually need to inquire additional resources, construct elaborate arguments, and transactively build on the reasoning of their peers.

Another issue of computer-mediated collaborative learning is, however, how motivational problems, well-known in collaborative learning research, translate and potentially aggravate in computer-mediated scenarios. Online learning seems to particularly suffer from attrition and lack of participation. Up to half of learners drop out of regular online courses, a rate that can go up to 90% in MOOCs learners take by free choice (Jordan 2015). Moreover, participation within online courses drops rapidly after the first week and often precedes dropout (Nistor and Neubauer

2010). Reasons for dropping out are numerous and include personal motivational problems as well as technical difficulties (Park and Choi 2009; Sitzmann et al. 2010). Registration to online courses can be easy enough for learners to have a peek at the learning material but participation hard enough to quickly reconsider and refocus on alternative courses, or learners do not intend to complete the course in the first place. Within dedicated CSCL scenarios that build on student agency and engagement, lack of and heterogeneity of participation have been discussed as particularly harmful to motivation and learning (Weinberger and Fischer 2006). Motivationally detrimental effects in CSCL work on the group level, i.e., peers influence each other's motivation, and can be enhanced as learners may have difficulties to contact each other online, i.e., online learning partners can be more elusive than FTF learners. One well-known problem is free riding, which refers to a team member not investing the required effort assuming that other team members will do (Kerr and Bruun 1983) and vice versa the so-called sucker-effect of one learner covering major parts of the task and hence losing motivation. This suboptimal distribution of group work can tremendously reduce the potential of collaborative learning for equal participation in argumentative elaboration activities (Cohen and Lotan 1995). While collaborative learning aims to establish equal participation and access to opportunities for argumentation and active learning, there are robust findings that collaborative learning often produces the exact opposite (e.g., Nihalani et al. 2010). Advanced learners benefit, in particular, from complex, collaborative learning scenarios, whereas participants with suboptimal preconditions for learning are left behind. Finally, it has been found that a sensible argumentation culture in online scenarios cannot be expected as a short-term goal but needs time, even weeks or months, to develop (Puhl et al. 2015).

Co-Present Computer-Supported Collaborative Learning

Contrary to computer-mediated collaborative learning discussed above, in co-present CSCL scenarios, learners are physically together, interacting with each other face-to-face and with one or several technologies in order to construct knowledge. Devices to support co-present collaborative learning are interactive whiteboards, desktop computers, handhelds, tablets, or tabletops. The "social situation" positively affects learners' motivation and communication (Roschelle and Teasley 1995, p. 69). In early co-present CSCL scenarios, e.g., Logo programming, learners typically had to share the access to the input devices (mouse, keyboard). Only one learner at a time could manipulate the representations on the screen, while the learning partner was cast back to a more passive role or the role of 'thinker'. Roles and actions had to be negotiated. With the advent of multi-touch interfaces (tabletops, tablets), several learners of all age groups can simultaneously access and directly manipulate a shared representation. Thus, new ways of interacting with each other and with the learning environment emerged, which may be conducive to embodied cognition (Schneps et al. 2014). In the context of learning, embodiment refers to the role of the body in interacting with the (learning) environment to construct knowledge and is gaining more and more attention in the learning sciences (Abrahamson 2017).

Typical Scenarios of Co-Present Collaborative Learning

Primary Education

Taking the role of embodiment into account, researchers have been designing for *collective* embodied learning experiences. For example, in the *STEP* (Science Through Technology Enhanced Play) project (Danish et al. 2015), 7- to 8-year-old children playfully learn about chemical concepts by acting out particles. A projection on the wall depicts a chemical element that changes its matter of state depending on the children's (the particles') movements through the classroom.

CSCL among primary school children can also be realized around a multi-touch table, in which, for instance, students in groups of four can be encouraged to discuss complex tasks and organize and distribute responsibilities and roles within their groups (Mercier et al. 2014). In another project utilizing iPads as mini-tabletops, fourth graders (on average 10 years old) collaborated in dyads on one shared tablet to work out proportional reasoning tasks with the *Proportion* app (Rick et al. 2015). Though tablets are personal devices, usually not used by several people at once, this scenario intentionally brings learners together. The pedagogical idea is to combine an embodied and immersive way of learning (moving two bars on the tablet to map volumes with numbers) with the benefits of collaboration (reasoning together). Peculiar interaction patterns can emerge in such a scenario: a case analysis of "Tarzan and Jane" (Rick et al. 2015), who were notably heterogeneous in their approach to learning, showed remarkable learning gains. Tarzan and Jane started with under-average pretest results but ended up being exceedingly successful in solving the Proportion tasks and acquiring knowledge. Beyond this specific case, significant learning gains were found in a sample of $n = 162$ primary school children that collaboratively used Proportion (Schmitt and Weinberger 2017), pointing at the benefits of embodied collaborative learning.

For a scenario to be classified as co-present collaborative learning, learners do not necessarily need to share one device. In the *TechPALS* (Technology-mediated, Peer-Assisted Learning) learning environment (Roschelle et al. 2010), fourth graders were working in groups of three solving math problems with everyone using their own handheld device. However, the students had to work closely together, agree on solutions, and share resources in order to make progress, and feedback was only provided on the group level. The collaboratively working students gained significantly more domain knowledge compared to a control group working individually (Roschelle et al. 2010).

That said, collaborative and individual learning approaches are not mutually exclusive, but can be effectively orchestrated as parts of a larger learning unit. For example, in a study by Gijlers et al. (2013), children aged 10–11 years first created representations of a scientific phenomenon (photosynthesis) on separate tablets. Individually creating a first version of the drawing was then followed up by sharing and comparing drawings with a peer and finding a joint solution. The orchestration of individual and collaborative learning phases showed to enhance the quality of dialogue and knowledge outcomes compared to a collaborative-only control group (Gijlers et al. 2013).

Secondary Education

Shifting the focus to older students, the next paragraphs will focus on exemplary studies of co-present collaboration at the secondary education level.

Quite common are learning environments that enable simulating phenomena of natural sciences. In their seminal paper, Roschelle and Teasley (1995) delineate the learning processes of two 15-year-old collaborative learners who are acquiring an understanding of Newtonian physics with the *Envisioning Machine* that served as a joint problem space. *Co-Lab* is a scientific inquiry-learning environment that students use either individually or collaboratively (via the Internet using a chat tool or face-to-face sharing a computer). It was found that providing high school students (16–18 years) with a regulation tool (i.e., supporting the processes of planning, monitoring, and evaluating) has positive effects on planning and evaluating activities, supposedly because of the complex and novel task the students had to carry out (Manlove et al. 2009).

The learning environment *WISE* (web-based inquiry science environment) was employed to help 16-year-old students in web-based inquiry learning (Raes et al. 2016). Groups of two shared one computer to search the Internet and collect information about the topics global warming and climate change. Central to the activity was critically assessing the quality of the information found on the Internet. To facilitate advantageous interactions, like equal participation between the students, a collaboration script was added.

Issues of Co-Present Collaborative Learning

Despite the advantage of interacting directly with each other, there are also issues of co-present collaborative learning. The challenges addressed in the following paragraphs add to the general requirements, like transactivity, regulation of learning, and task focus that need to be met for effective collaborative learning.

One issue is the question of access to the environment and territoriality, i.e., the subdivision of available workspace in a jointly used device. The available space might either be open and accessible for everyone, so that learners would need to negotiate and co-regulate their input activities and times, or the instructions might steer toward specific interaction patterns (Dillenbourg and Evans 2011). Designing for productive territorial interaction in the context of young learners may be difficult. For example, in the Tarzan and Jane case study (Rick et al. 2015), peers could reach over and interfere with the partner's virtual objects. In spacious tabletop environments, each participant may have their own territory and input devices at their disposal. After having worked on a tabletop and produced input, e.g., when jointly constructing a mind map, learners may, however, at times move altogether to one side of the tabletop, rotate all concepts to be read upright, and look at and reference their map when discussing their work. Hence, usability issues are to be taken into account when designing co-present learning environments: How should learners share the workspace? To what extent does the workspace enable equal sharing of activities? Where should learners be positioned? Does everyone get their own input opportunity or working space?

Closely related to questions of territoriality are dominant interaction patterns in co-present CSCL. Especially in desktop computer settings, one learner might dominate the other(s) by controlling the mouse and not sharing access to the input device. Solutions proposed to address this issue are, for example, encouraging turn-taking and providing a split-screen (Moed et al. 2009) or providing several mice (Stanton et al. 2002), so that every learner would have the chance to interact with the learning environment, which may, however, render the learning scenario cooperative rather than collaborative. Providing several mice, albeit beneficial for student engagement and participation overall, fosters co-operative and parallel interactions (Stanton et al. 2002). Also, dominant behavior does not necessarily disappear when every learner has access to his/her own mouse (Moed et al. 2009). When multiple input opportunities via multi-touch vs. multiple mice on a tabletop were directly compared, multi-touch was found to support fluid interactions and reduce coordination effort compared to the multiple mice condition (Hornecker et al. 2008).

There are also concerns that playful, embodied learning environments might be overly hands-on, neglect verbalization and elaboration of concepts and thus do not support abstraction to the underlying concepts. For example, in Danish et al.'s (2015) study where children acted out particles, the situation sometimes got a bit out of hand, and children would run around the classroom and even play tag. To prevent learners from being "lost in action," sensibly combining hands-on environments with phases of reflection is needed (Danish et al. 2015), in order to improve the quality of learners' epistemic and social activities. However, reflection phases need to be introduced and intertwined carefully with the hands-on activities, to not interrupt learners' flow and disengage them (Schmitt and Weinberger 2017).

Finally, the practical-technical and pedagogical issues of integrating computer-based tools into everyday classroom practices are a not to be underestimated challenge for teachers, calling for systematic professional development measures (Vanderlinde et al. 2014).

Solutions/Facilitating CSCL Environments

The following paragraphs will discuss two fundamental strategies to support effective collaborative learning: structuring vs. regulating interactions (Dillenbourg 2002).

Structuring Interactions

One well-investigated method to structure social interactions in CSCL is collaboration scripts. These scripts assign learning activities and roles to the learners and reduce time spent on organizational issues and generally show a positive impact on learning (Scheuer et al. 2010). Encouraging high schoolers to develop joint group norms regarding their communication and task solving positively affected their collaborative interactions and learning outcomes (Zahn et al. 2012). The Guided Reciprocal Peer Questioning script successfully fostered primary school children's collaborative discussions and quality of the learning product (Gelmini-Hornsby et al. 2011). The beneficial effects of scripting seem to be rather consistent, bearing in mind that too much scripting might lead to "over-scripting," meaning that an overly tight specification of interactions would ruin the nature of collaboration, negatively influencing interactions and acceptance of the script (Dillenbourg 2002). Consequently, the question of amount, content, timing, and general presentation of scripts is a complex one (see also Fischer et al. 2013). One of the future directions is seen in the development of adaptive scripts (Fischer et al. 2013).

Supporting learners' behavior in computer-supported learning environments is needed for both reducing disadvantageous behavior (for instance, gaming the system) and fostering advantageous behavior, like reflecting, abstracting, and elaborating. The goals of scaffolding are helping the learner to solve the task at hand but also to increase the understanding to support future task solving (Reiser 2004). Scaffolding can come in two forms (Reiser 2004): making the task easier (structuring) and making the task harder (problematizing concepts). Fourth graders working in dyads with a tablet app benefitted from prompts that problematized concepts by requesting explanations in that they had a higher discussion quality, but they also displayed more negative emotions and more off-task behavior (Schmitt and Weinberger 2017). Seventh graders were found to perform better in a physics game running on tablets when they worked with peers compared to working alone (Chen and Law 2016). This positive effect was even strengthened when question prompts were provided. However, there are also indications that both collaborative condition and question prompts had a negative impact on self-reported motivation (Chen and Law 2016), pointing again at the need of challenging learners to increase their opportunities to learn while keeping their motivation flow high (see also Deater-Deckard et al. 2014).

Fostering Regulation of Interactions

While structuring methods are usually set before the learning activities start, fostering learners' regulation can occur during the ongoing learning activities. One prominent way of regulation is awareness tools that visualize qualities of learners' interactions while they take place, e.g., showing how much learners are participating (Gijlers et al. 2013). On one hand, raising awareness showed to positively influence variables like transactivity and shared task focus (Gijlers et al. 2013), cohesion, positive attitude toward collaborative learning, and reduced conflicts (Phielix et al. 2010) or fostered coordination of the collaborative learning situation (Janssen et al. 2007). On the other hand, the overall influence of awareness tools remains limited as the aforementioned studies could not find a general effect of an awareness tool on the quality of the group product (Phielix et al. 2010) or equality of participation (Janssen et al. 2007). It appears to be a crucial factor to what extent learners are motivated and able to effectively use an awareness tool to alter their behavior patterns in order to foster positive group interactions and learning (Janssen et al. 2011). This goal may be achieved by scripting the use of the awareness tool (Janssen et al. 2011; Tsovaltzi et al. 2015).

Conclusion

In this chapter, two major branches of computer-supported collaborative learning, namely, computer-mediated vs. co-present collaborative learning, were discussed. Computer-mediated collaborative learning scenarios encompass asynchronous as well as synchronous learning activities. The learning scenario might be reduced to a text-based forum or simulate a richer social situation, like in virtual worlds or videoconferences. The scenario might foresee one-to-one communication or address large amounts of users at the same time, as in the case of MOOCs. Learning anywhere and anytime at one's own pace is one of the benefits of such learning environments. Typical issues in computer-mediated collaborative learning are the lack of social context cues, free riding, a greater need for explicit coordination, higher attrition, and large dropout rates. In co-present collaborative learning scenarios, learners are physically together and engage in synchronous learning activities. The scenario might foresee to share one device, which is particularly suited for tabletops and tablets, or to provide every learner with an own device, for example, a handheld. Co-present scenarios can take into account the growing recognition of the role of the body in learning and afford hands-on embodied learning experiences. Typical issues in co-present collaborative learning are how learners divide the available working space when the device is shared, how to prevent individual members of exclusively controlling input and dominating the group, and how to sensibly combine embodied learning experiences with phases of reflection (Danish et al. 2015; Schmitt and Weinberger 2017).

Scripting interactions or providing awareness tools showed to be promising means in supporting CSCL. Next to the positive effects, scripts can come with negative side effects, such as over-scripting or demotivation (see, e.g., Chen and Law 2016; Dillenbourg 2002; Schmitt and Weinberger 2017), and awareness tools' effects might fall short of expectations. Hence, more research is needed in refining instructional means to further develop CSCL practices in primary and secondary education. Another emerging topic concerns the question on how to increase salience of feedback through awareness tools and leverage their effectiveness in CSCL environments. To that end, for example, scripting the use of awareness tools has been proposed (Janssen et al. 2011; Tsovaltzi et al. 2015).

Beyond designing for productive but isolated CSCL scenarios, orchestration of collaborative with individual learning scenarios, enriched with various types of computer support, will allow learners to encounter diversified challenges, finally leading to progressively expanding knowledge and skills. While CSCL practice typically is embedded in larger learning arrangements, research on how to productively coordinate scaffolding across learning experiences occurring at different social levels is still scarce (Prieto et al. 2015). Future research will need to focus on the conditions of productive orchestration of learning scenarios and their support, for example, awareness tools and scaffolding, with the ultimate goal of fully developing CSCLs potential for acquiring both domain knowledge and key competencies. Beyond sequencing learning arrangements, the question expands to how learners use different devices and link and document their learning activities in a larger learning landscape. Such a learning landscape bridges formal and informal learning in schools, social networks, and any other place and time using mobile devices.

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Section IV

Attitudes, Competencies, and Dispositions for Teaching and Learning with Information Technology

Section Introduction: Attitudes, Competencies, and Dispositions for Teaching and Learning with Information Technology

16

Gerald Knezek and Rhonda Christensen

Abstract

Key developments in attitudes, competencies, and dispositions for teaching and learning with information technology are presented through seven chapters in this section and described in this overview. The perspective of the teacher is the focus of several chapters, with the understanding that enhanced learning by the student is the end goal. Developments that have evolved since the printing of the first edition of this handbook are the focus of the section. These developments are featured in the write-ups for each chapter provided in this overview.

Keywords

Attitudes · Competencies · Dispositions · Teaching and learning · Information technology

In this section of the handbook, attitudes, competencies, and dispositions that are important for the effective integration of information technology are presented for both teaching (for educators) and learning (for students).

In the opening chapter by Knezek and Christensen, ▶ Chap. 17, "The Evolving Role of Attitudes and Competencies in Information and Communication Technology in Education," a discussion of how the field has changed over the past decade, since the publication of the first edition of the handbook, is pursued. Attitudes and competencies were previously viewed as related but independent entities. Now they are typically contextualized as part of an integrated whole. The authors discuss how mediating variables have emerged to a status of their own. Learning sciences is proposed as one interdisciplinary field holding promise for integrating knowledge

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and wisdom to chart the best paths forward, contributing to the continual refinement of best pedagogical practices for teaching and learning with technology.

In ► Chap. 18, "Information and Communication Competences for Students," Aesaert and van Braak present the problems associated with discrepancies between theoretical and empirical dimensionality of Information and Communication Technology competences with the assessment of mastery not matching the objectives of the curriculum intended to be measured. These authors argue for the delineation of ICT competences as a necessary condition not only for creating ICT curricula that reflects the dimensionality of ICT competences but also for creating ICT curricula that will be measureable in a valid and reliable way. The authors propose that research should focus on the development of user-friendly assessment instruments that enable teachers to identify for each student the ICT competences of the ICT curriculum that need attention.

In ► Chap. 19, "The Influence of Information and Communication Technology Use on Students' Information Literacy," Sakamoto presents the different ways in which information literacy is defined in both Japan and other nations. The chapter includes findings of empirical research on the impact of children's ICT use on information literacy. Different research method techniques that support the inference of causal relations among variables are discussed including specific examples of research findings that use these methods.

► Chapter 20, "The Interaction of Psychological Constructs with Information Technology-Enhanced Teaching and Learning," by Katz, presents research that indicates that the effective use of IT-based tools by teachers leads to the enhancement of elementary and secondary school students' learning achievement and all-round educational performance. Constructs that characterize teachers such as teacher change, teacher knowledge, and pedagogical beliefs as well as affective constructs that typify both teachers and students such as autonomy, creativity, flexibility, motivation, satisfaction, and self-efficacy are presented as vital tools to maximize the positive effect of IT-based tools in the classroom. The author implores educational administrators to formulate teacher professional development programs that include the enhancement of those constructs needed to successfully mediate the efficient use of IT-based tools that will conceivably lead to the promotion of student achievement.

Ottenbreit-Leftwich, Kopcha, and Ertmer's, ► Chap. 21, "Information and Communication Technology Dispositional Factors and Relationship to Information and Communication Technology Practices," reviewed a variety of research that addresses an important question regarding the specific dispositions teachers need to use ICT in the classroom. Research suggests that a teacher's self-efficacy, attitudes, openness to change, and pedagogical beliefs each have a relationship with a teacher's use of ICT for teaching and learning. The chapter includes the importance of exploring the practical strategies that best support teachers in articulating and addressing their dispositions that may interfere with their efforts to use ICT for teaching and learning.

In ► Chap. 22, "Instructional Technology Integration Models and Frameworks: Diffusion, Competencies, Attitudes, and Dispositions," Niederhauser and Lindstrom provide an overview of current models and frameworks that inform teacher adoption of technologies that support the integration of technology into student learning experiences in K-12 school settings and to link them to theories of diffusion, adoption, and change that underpin them. Relative to classroom technology integration, models can be useful in helping us understand and explain how technology integration occurs, allow us to better make decisions about how to effectively utilize technology resources, and provide insights that support development of strategies to more effectively and efficiently promote the kinds of pedagogical reforms that reformers hope to see in schools.

Christensen and Knezek's, ▶ Chap. 23, "Measuring Teacher Attitudes, Competencies, and Pedagogical Practices in Support of Student Learning and Classroom Technology Integration," features instruments to measure teacher attitudes, competencies, and pedagogical practices judged to be important for effectively integrating technology into the classroom learning environment. Specific instruments that serve as exemplars for teacher appraisal are introduced and discussed in the chapter.

The Evolving Role of Attitudes and Competencies in Information and Communication Technology in Education

17

Gerald Knezek and Rhonda Christensen

Contents

Abstract

Attitudes and competencies related to ICT in education have evolved over the past decade from being viewed as separate but related entities to now being viewed as part of an integrated whole. As of 2018 the prevailing view of competencies relevant to teaching and learning with technology is that they often span the cognitive, affective, and psychomotor domains of psychology and are best appraised by concepts such as self-efficacy that lie at the intersection of two or more of these domains. New developments in social media technologies stretch the limits of relevance of psychology as pertaining to the behavior of an individual and move into the realm of sociology, or behaviors of groups of individuals. Noncognitive

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variables beyond attitudes have assumed a more prominent role in ICT in education, as of the second decade of the twenty-first century. Learning sciences is proposed as one interdisciplinary field holding promise for integrating knowledge and wisdom to chart the best paths forward, contributing to the continual refinement of best pedagogical practices for teaching and learning with technology.

Keywords
Attitudes · Competencies · Domains of psychology · Learning sciences · Teaching and learning with technology

Introduction

Since the publication of *The Importance of Information Technology Attitudes and Competencies in Primary and Secondary Education* (Knezek and Christensen 2008), much has changed. In general the recognition of the importance of emotions, motivation, creativity, grit, and other noncognitive variables related to attitudes toward teaching and learning with technology has increased. Likewise recognition of the importance of understanding the process of acquiring many kinds of competencies needed to be productive in a modern society (e.g., communication, confidence, collaboration) related to ICT in education – rather than simply focusing on the end-goal performance of a mastered ICT skill – has become universal. This chapter focuses on new perspectives emerging and especially the evolving definitions and roles of attitudes and competencies regarding ICT in education. The chapter will begin with a description of the evolution from technology as an affordance for better mastery of knowledge and skills, toward technology as a catalyst aiding potential positive teaching and learning outcomes in the complex field of learning sciences.

Three Domains of Psychology Relevant to ICT in Education

Psychology can be defined as the science of human behavior at the individual level (Henriques 2004). The portion of psychology most directly relevant to ICT in education is focused on learning. More than 60 years ago Benjamin Bloom and colleagues described three domains of psychology focused on learning: cognitive, affective, and psychomotor. The group published their framework in 1956, in *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain* (Bloom et al. 1956). How technology can contribute to teaching and learning in each of these domains is the focus of this section.

The Cognitive Domain

Bloom and his colleagues completed a detailed taxonomy for only the cognitive domain in the original taxonomical work in the 1950s (Bloom et al. 1956). The

Table 1 Original and revised categories of Bloom's taxonomy for the cognitive domain from lowest to highest cognitive level

1956	2001
Knowledge	Remembering
Comprehension	Understanding
Application	Applying
Analysis	Analyzing
Synthesis	Evaluating
Evaluation	Creating

cognitive domain is generally defined as pertaining to mental skills or knowledge. Forty-five years after the original publication, Anderson et al. (2001), including Krathwohl who was an author of the original taxonomy, developed a revision of the taxonomy of educational objectives for the cognitive domain. The revision changed the names of the lower and higher order thinking skill levels from nouns to action verbs and placed "creating" at the highest level of the cognitive domain (Anderson et al. 2001). Category names for the original and revised taxonomies are shown in Table 1.

Alignments have been developed to illustrate how interactions between the user and the technology can contribute to learning at each of the cognitive domain levels. The technology examples in Table 2 illustrate ways in which current technologies can be used for learning activities in the cognitive domain. One instructional designer (Carranza 2016) has created a visual representation of the how various technologies can be affordances in the development of lower and higher order skills in the cognitive domain (see Fig. 1). This graphic has been used to aid instructors in planning for technology-enhanced curricula in university courses (Boston College Libraries 2017; Sneed 2016).

The Affective Domain

Approximately 20 years after Bloom and colleagues published a taxonomy for the cognitive domain, Krathwohl et al. (1973) also published a taxonomy for the affective domain, which includes "the manner in which we deal with things emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and attitudes (Clark 2015, np)." Jones and Issroff (2005), when writing about affective and social issues in learning technologies, observed:

> Traditionally in learning there has been a division between cognition and affect: where cognition is concerned with skills and processes such as thinking and problem-solving and affect with emotional areas such as motivation, attitudes, feelings. Affective issues have been viewed as somewhat problematic in studying learning, so although it is well known that learner attitude, motivation, and emotional state are very important, they have often been excluded from the frame of research, or studied separately from cognitive learning. This position is gradually changing [. . .]. (Jones and Issroff 2005, p. 395)

Table 2 Revised cognitive domain categories with learning verbs and illustrative technology affordances

Revised Bloom category	Related action verbs	Sample technology applications by category
Remembering	Recall, list, retrieve, find, name, recognize, identify, locate, describe	Searching for topics in a browser; bookmarking topics in browser for retrieval; identify and download apps
Understanding	Interpret, summarize, rephrase, explain, classify, compare	Creating a comparison table in a word document; playing a 360 degree video of the solar system from YouTube using virtual reality glasses
Applying	Produce, implement, practice, illustrate, demonstrate	Creating a Powerpoint presentation on a topic; producing a 360 degree video using an iPad and camera
Analyzing	Compare, organize, question, research, deconstruct, outline	Creating a budget in an electronic spreadsheet; searching the Internet for two points of view on a current event topic
Evaluating	Check, judge, critique, experiment, hypothesize, test, detect	Collaborating online with colleagues; responding to topics in a blog; retweeting related information to colleagues
Creating	Design, build, construct, plan, produce, devise	Creating a podcast; creating an avatar; designing a web presence; creating a digital story; designing a 3D object to print

Affective domain attributes in recent decades have been gradually added as co-variates in the prediction equation shown in Fig. 2. In the twenty-first century, promoting more positive affect such as more positive attitudes toward information technology is sometimes recognized as an outcome measure (end goal) on its own. The assumption is typically that more positive affect leads to better performance, as shown in Fig. 2. Professional development workshops for elementary and secondary teachers aimed at removing computer anxieties or increasing comfort level are based on this assumption.

Variables used for studies with ICT are generally classified in the affective domain when they have emotional (as opposed to logic or reasoning) components in their foundations. One of the most important human attributes in the affective domain is that of attitude. Many studies conducted in the late twentieth and early twenty-first century cite Fishbein and Ajzen (1975) who defined attitude as “a learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object” (p. 6).

While the definition of attitude has stayed intact, the term disposition, which is generally regarded as longer persisting, has also assumed a prominent role. ICT in education trends over the past decade align well with the general definition of dispositions published by Allen et al. (2014): “We call these human qualities dispositions—a person’s core attitudes, values, and beliefs demonstrated through both verbal and non-verbal behaviors as one interacts with oneself, others, one’s

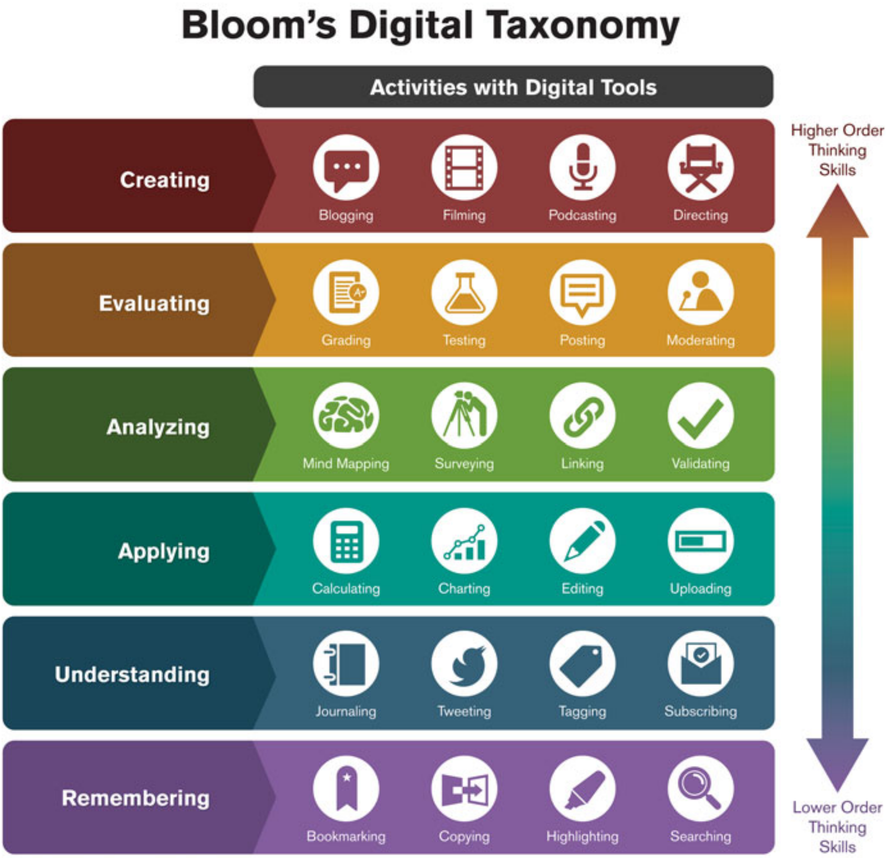

Fig. 1 Bloom's digital taxonomy listing technology affordances for each skill level. (Source: Created by Ron Carranza (2016) and used with permission)

Fig. 2 Affect as an outcome variable, or mediating variable en route to performance

purpose, and frames of reference" (p. 2). This definition of dispositions appears to align well with the original taxonomy of learning in the affective domain (Krathwohl et al. 1973) as shown in Table 3. In the words of Morshead (1965), "This classification scheme, or taxonomy, is made up of five hierarchically arranged categories which provide individual descriptions of different changes that occur in behavior as values or attitudes are learned" (p. 165). Illustrative technology affordances appropriate for human development in areas such as core values and beliefs, respect

Table 3 Affective domain categories with learning verbs and illustrative technology affordances

Bloom's taxonomy of affective domain	Learning objectives and related action verbs	Sample technology applications by category
Receiving phenomena	Become aware: Accept, listen, notice, acknowledge	Watching a TED talk and viewing a contrasting YouTube video on a topic, respecting the different points of view; following a peer on Twitter
Responds to phenomenon	React: Answer, greet, aid, consent, follow, cooperate, conform	Responding to a blog in an appropriate manner; giving proper credit for sources used in a paper or digital presentation
Valuing	Understand and act: Adopt, assume, choose, cherish, exhibit, express, respect	Respecting the privacy of others when tagging them in social media; being aware of the digital footprint left when posting information about yourself or others
Organization (of values)	Develop value system: Compare, relate, discriminate, synthesize, prioritize	Creating a wikispace for a group project that includes multiple points of view; determining the most useful media sources for current event paper
Internalizes values	Become proactive: Advocate, defend, exemplify, influence, justify, serve, support	Creating an online community that is positive and respects others; recognizing your role in protecting others who may be victims of online cruelty

for others, and personal, social, and emotional adjustment were added by the authors of this chapter to form Table 3.

Although ICT in the form of computer programs and user interfaces has traditionally been considered to be void of emotions or other affective components, Table 3 illustrates that the broad expansion of social media systems has created the need to focus on teaching and refining affective competences. Examples referred to in Table 3 include respect for the views of others expressed in online environments, giving proper credit for use of resources available in digital form and having compassion for and protecting victims of online bullying and other forms of social media disrespect. Proficiency in these human social skills would likely be considered important as twenty-first century skills in almost all societies of the world. ICT in general, and especially new information technologies incorporated into social media systems, would appear to increase the complexity of contributions to human development in this realm.

The Psychomotor Domain

The psychomotor domain pertains to physical movement, coordination, and motor skills, all of which include both fine and gross motor movement. The committee

Table 4 Psychomotor domain taxonomy for simple to complex abilities with example technology affordances

Psychomotor categories	Related action verbs	Sample technology applications by category
Observe	Hear, taste, touch, observe, identify	Observe the teacher showing how to use a touchscreen tablet; watch a how-to video online to learn how to use VR glasses
Model (attempt to replicate)	Copy, imitate, repeat, try, reproduce	Touch the screen on an iPad; imitate the proper pronunciation of a foreign language word generated by a technology-based language drill system
Recognize standards (recognize and follow accepted standards)	Detect, distinguish, recognize, notice	Determine which app to touch to launch the instructed application; touch the app to make it open; avoid clicking on off-topic web sites during an academic subject internet research exercise in school
Correct (self-evaluate performance and make corrections)	Adapt, adjust, alter, correct, improve, practice, revise	Close the app and re-open it independently; review YouTube video of ballet performance to improve one's own dance routine
Apply (apply skills to real life situations)	Create, design, originate, produce	Choose an app that is of learning value and manipulate the software; produce a video illustrating ideal back stroke swimming techniques
Coach (instruct others to perform skill in generalized situations)	Demonstrate, exhibit, instruct	Teach another student how to use an iPad; analyze slow motion images of a sprinter's start of a race to suggest a better positioning in the starting blocks

headed by Bloom in the 1950s did not produce detailed psychomotor domain specifications, but others have since that time. Modern professional development guides for instructors writing student learning objectives related to the psychomotor domain often include categories such as the ones created by Scherr (2006), with six categories from simplest to complex. Table 4 includes examples of uses of technology that are centered in the psychomotor domain, including using a mouse, trackpad, voice recognition software, and so forth. The psychomotor domain is somewhat different from the cognitive and affective domains in that most of the activities are visibly measurable and typically will include the development of a skill from simplest to most complex.

For learners with physical disabilities, technology can often be an accommodation tool to enable expression of cognitive processes, or measurement of activities in the cognitive domain. For example, a student who may be unable to write his or her thoughts on paper or a keyboard can use voice recognition technology to dictate thoughts and have them printed in a word document for others to read. Often traditional mechanisms (test formats) for measuring cognitive ability are not adequate, and therefore not accurate, for a student with a physical disability and therefore a students' abilities may be more accurately assessed through the use of technology.

Technology is also often used to track physical movement and vital signs and give feedback to the user. For example, a physical activity monitoring device can track user's activity, sleep cycles, and heart rate, to provide ongoing performance improvement. Recent developments in learning analytics and big data have led to great interest in the capabilities of technology-based systems for tracking the process of and recording milestones of acquiring expertise in abilities while showing incremental levels of progress from beginning to end.

Learning Sciences: Integrating the Three Domains of Psychology with Technology

Other conceptualizations useful for ICT in education have evolved that are broader than the three domains of psychology previously described. Learning Sciences is an interdisciplinary/multidisciplinary field that extends beyond the psychology of learning and includes computational, sociological, and anthropological approaches to the study of learning. The field draws on theoretical frameworks from diverse fields such as cognitive science, sociocultural theory, educational psychology, computer science, and anthropology (Sawyer 2005) with the main focus on understanding the processes, tools, and contexts, as well as outcomes, of learning regarding learners and their needs.

While much educational research is focused on the institution of education – including practices, organizational structures, and policies – learning sciences focuses on how people learn and what is needed to enable and support learning (Roschelle et al. 2014). Learning scientists are often concerned with learning that is not yet measured well nor currently considered to be an important knowledge, skill, or ability. Because learning science includes multiple disciplines such as psychology, they are also focused on social and emotional outcomes (Roschelle et al. 2014).

Noncognitive Variables and Psychosocial Behaviors

Learning scientists often study human characteristics that do not exclusively belong to one of the domains of psychology previously described. For example, psychosocial behavior involves both psychological and social aspects, at the intersection of psychology and sociology. As ICT in education has moved beyond the simplest case of a human interacting with a program running on a machine – in the case of drill and practice or tutorials, for example – and into the realm of ICT serving as a communication conduit for two or more humans interacting with each other, the learning and behavior of persons using such systems moves into the realm of the study of the behavior of groups of individuals. Social media systems such as Facebook, Twitter, Instagram, Snapchat, and even email would all appear to fall into this realm. Texting and especially group texting would be in this category as well. Much of the study of

ICT in education in the near future might be focused on psychosocial attitudes and competencies.

Human attributes that learning scientists study outside the realm of cognitive psychology have evolved to have a designation of their own, called noncognitive variables. Attitudes are one human attribute that have been studied extensively related to technology (Knezek and Christensen 2008), but there are many others that are now recognized as important as well. The emerging importance of other noncognitive variables as they relate to teaching and learning with technology is illustrated by the trend toward studies including many intervening factors that influence whether or not a teacher well trained in technology skills is able to foster the enhancement of twenty-first century skills in students. "Noncognitive is used here to refer to variables relating to adjustment, motivation, and student perceptions, rather than the traditional verbal and quantitative (often called cognitive) areas" (Sedlacek 2011, p. 191). Non-cognitive skills may include self-concept, leadership abilities, creativity, motivation, accurate self-appraisal, empathy, and persistence. Creativity is one example that is spotlighted by others such as Liu (▶ Chap. 61, "Toward Creator-Based Learning: Designs That Help Student Makers Learn") related to creative designers with technology, and Schrier (▶ Chap. 59, "Guiding Questions for Game-Based Learning") related to desirable outcomes of game-based learning. Grit (Duckworth and Yeager 2015; Shechtman et al. 2013) is another noncognitive variable that has come to be accepted as very important as an intermediary variable influencing under which conditions technology is effective in enhancing learning. Noncognitive variables are becoming more valued in the twenty-first century because they can function in research designs as important intervening or mediating variables that " ... stand between the independent and dependent variables, and [...] mediate the effects of the independent variable on the dependent variable" (Creswell 2002, p. 50).

Many noncognitive variables are traits deemed desirable in both teachers and students, such as enthusiasm, excitement, and sustained interest. There is some empirical evidence that for these kinds of attributes related to ICT in education, positive or negative valences are transmitted from teacher to student (Christensen 2002). Such findings have implications for preferred pedagogical style to transmit the motivation to learn from teachers to students, among the alternatives for technological pedagogical approaches to be described in the sections that follow.

Evolution of Competencies for Teaching with Technology

Competencies have evolved over the past decade from a focus on being able to demonstrate technology skills to being able to (a) solve a problem with technology in collaboration with others and communicate the solution (for students) or (b) being able to integrate technology into the teaching and learning process (for teachers) with confidence and appropriate pedagogical expertise. Technology integration has become the primary goal of technology initiatives for teachers as of 2018, and many proven models have emerged. For example, early work by Shulman (1986) on pedagogical content knowledge paved the way for Technology, Pedagogy, and

Content Knowledge (TPACK) (Mishra and Koehler 2006), and several other prominent models that feature the combination of many attributes to profile a high-integrating teacher are described in further detail by Niederhauser and Lindstrom (▶ Chap. 22, "Instructional Technology Integration Models and Frameworks: Diffusion, Competencies, Attitudes, and Dispositions"). Research over the past two decades has demonstrated that teachers who are competent also need to be confident in their competence in order to perform well, and this has led to a strong focus on self-efficacy as an important attribute for technology-using teachers. Katz (▶ Chap. 20 ,"The Interaction of Psychological Constructs with Information Technology-Enhanced Teaching and Learning") discusses how the integration of will (affect or attitude) and cognitive skill are both important in modern conceptions of competence.

A new kind of competence verification has taken on increasing importance over the past decade. This involves verification of completion of steps along the way and tracing the path by which desired technology-infused performance comes to fruition (▶ Chap. 46, "A Futures Perspective on Information Technology and Assessment" by Lodge). This new kind of tracking could enable detailed formative evaluation of the type that has come to be called assessment for learning (▶ Chap. 41, "Assessment as, for, and of Twenty-First Century Learning Using Information Technology: An Overview" by Webb and Ifenthaler). The emerging ways of viewing development of competencies would appear to align with Vygotsky's (1978) ideas of scaffolding learning.

In the competency-based testing environment that surrounds twenty-first century education, proficiency in technology itself has also assumed an important role, whether it is used to enhance instruction, for communication between teachers, students, and parents, or to assess student learning. The ability to integrate twenty-first century technology for learning in schools is an expectation for teachers in most parts of the world today. Because technologies are constantly changing and the most productive use of technology is dependent on content, it is now considered more important to develop more general competencies focused on how technology can be used for teaching and learning. In particular, rather than focusing on how to use technology in the classroom, educators should start with the content or topic that is being taught and look for the ways to enhance learning outcomes through the use of technology (Keengwe et al. 2008; Richardson 2013). Technology should not drive the learning, but using the benefits and strengths of technologies can enhance student learning (Jonassen 2000).

Proficiency in technology integration is a goal that is beginning to supersede concepts such as mastery of skills or acquisition of competencies, regarding expectations for a teacher's level of performance in the integration of technology into teaching and learning. Here we define technology integration as the meaningful and effective use of technology to enhance learning in students (Christensen 2002). Acquisition of foundation skills is still necessary, but may not be sufficient without acquisition of other essential components such as effective pedagogical practices, teaching self-efficacy, and positive attitudes and dispositions toward information and communication technology.

Attributes That Contribute to Competency in Integrating Teaching and Technology

Teachers need to feel comfortable using the new technologies that are rapidly permeating education, and they also need to understand the pedagogical strategies for effectively integrating technology into learning. Teachers are the key players in the success or lack of success of any technology initiative in the classroom (Ertmer et al. 2012). While it is important to develop confidence and skills, the knowledge and ability to use technology for personal use does not necessarily translate into the integration of technology into the classroom. Ertmer (1999) categorized barriers to technology integration in the classrooms into two types. First order barriers were those considered to be external regarding ability to integrate technology. These external barriers included tools, training, and support. The second type of barriers are second order or internal and include attitudes, confidence, and beliefs in the need for technology (Ertmer 1999). While many of the external barriers have been reduced over recent decades, the internal barriers still exist and are more complicated to overcome (Ertmer et al. 2012). Researchers suggest that it is the internal barriers that are the gatekeepers to successful technology integration and these barriers should be acknowledged and addressed (Ertmer et al. 2012; Rogers 2000).

Demonstrating Competencies in Pedagogical Practices

One commonly used dichotomy related to pedagogy focuses on two opposing ideologies – teacher-centered versus student-centered teaching (Meirink et al. 2009). The teacher-centered approach is considered to be the more traditional teaching method and is related to the transmission of knowledge from teacher to student. The student-centered method emphasizes student agency in learning and is focused on knowledge construction and a more social learning environment among peers (Liu 2011). Teachers who teach with technology tend to practice the pedagogical approach with which they feel more affinity. Researchers have found that there is a positive correlation between teachers who hold more constructivist (student-centered) beliefs and the extent of their use of technology in the classroom; conversely, holding more traditional beliefs tends to be negatively correlated with extent of technology use in the classroom (Kim et al. 2013). Niederhauser and Stoddart (2001) found that the pedagogical style teachers practiced influenced the type of software they chose to use in the classroom. Sang et al. (2010) confirmed that teachers with the strongest constructivist beliefs were more likely to integrate technology into instruction compared to those teachers who did not hold constructivist beliefs.

Opportunities made possible through the maturation and wide scale dissemination of new information technologies may be making the adoption of constructivist practices regarding ICT in education more practical. Evans (▶ Chap. 54, “From Engagement to Empowerment: The Evolution of Mobile Learning in the United States”) argues that new information technologies, and in particular mobile devices, have transitioned into the realm of empowerment for self-directed learning that organically aligns better with student-centered pedagogical approaches. Initially it was thought because students were using mobile devices they were engaged, but it was difficult to assess whether they were truly engaged in learning. However, with an increase in the number of students who have access to mobile technologies, a shift has occurred that allows teachers the opportunity to create more self-directed learning options with mobile technologies that are aimed at empowering students to use technology for more meaningful, problem-based learning. This type of learning environment typically has built-in assessment in that finding a solution is evidence of learning. This type of affordance of ICT would appear to align best with a student-centered pedagogical approach based on constructivist beliefs. It would also appear to be relevant to learning inside as well as outside the classroom, with motivations, incentives, and options for creative approaches to solutions designed into the learning exercise, based on research-grounded design principles and knowledge of the influences of attitudes, dispositions, and other noncognitive variables.

The End Goal: Competencies in Support of Student Learning

Most countries of the world agree that technology competencies are important for twenty-first century teachers and students. Reviewers of the 2016 US National Educational Technology Standards (NETS) have stated the issue succinctly as "Technology is a reality but students and teachers need new ways to envision its purpose and possibilities" (Stoeckl 2016, np). Therefore, technology integration proficiency for teachers involves more than just technology skills; it includes being able to envision technology's purpose and possibilities and having confidence in the path chosen. Several kinds of competencies to support learning with technology integration are addressed in this section.

Self-efficacy is well established as a factor that influences the effectiveness of teaching (Hoy et al. 2009). Self-efficacy is one of several important components required for successful technology integration in the classroom. Self-efficacy is based on Bandura's (1986) Social Development Theory and is sometimes defined as the expression of beliefs of individuals related to their own capacity to perform a certain behavior (Gencturk et al. 2010). The authors of this chapter have proposed an operational definition of self-efficacy as *confidence in one's competence* (Christensen and Knezek 2017).

Research has shown a strong relationship between perceived self-efficacy and technology usage (Albion 2001; Cassidy and Eachus 2002) and between perceived self-efficacy and technological abilities (Anderson and Maninger 2007). These relationships are consistent with Social Cognitive Theory which supports the idea that confident individuals believe their actions will produce successful results (Pajares 2002). As established by Bandura (1993), self-efficacy is a good predictor of behavior. As reported by Gencturk et al. (2010), teachers with higher self-efficacy are more ambitious and passionate in their teaching. Koh and Frick (2009) found teachers' self-efficacy beliefs to be indicators of success for technology integration.

Teachers must have confidence in their skill and ability to use technology with their students before they are willing to use it (Ward and Parr 2010).

Competencies in fundamental technology skills can also be a problem for teachers – even for new teachers entering the field. An emerging problem among preservice teachers appears to be a decline in the level of fundamental IT skills among students entering teacher preparation programs. In particular, preservice candidates typically know how to text, surf the web, and use social networking tools, but frequently have little or no experience with using blogs, wikis, or other applications appropriate for teaching tools and lack the preparation to use these technologies in the classroom (Lei 2009; Schrum and Levin 2016). If prospective teachers lack fundamental knowledge of respected learning technology tools, then who will convey them to the next generation of students?

Summary and Conclusions

Attitudes and competencies related to ICT in education have evolved over the past decade from being viewed as separate but related entities to the current status of their being viewed as parts of an integrated whole. Competencies relevant to teaching and learning with technology are now frequently recognized as spanning the cognitive, affective, and psychomotor domains of psychology and are often best appraised by constructs such as self-efficacy that lie at the intersection of two or more of these domains. New developments in social media technologies involve concepts from psychology and sociology and appear to have found a home in the interdisciplinary field of learning sciences. Learning sciences is suggested as holding promise for integrating knowledge and wisdom to chart the best paths forward, contributing to the continual refinement of best pedagogical practices for teaching and learning with technology. Bloom's Taxonomies and their extensions are time-honored frameworks that can aid in the identification of specific technology affordances having the greatest potential for facilitating a targeted type of learning among the multifaceted goals of twenty-first century education systems and societies. Technology affordances, including specific technologies' purposes and possibilities, must be familiar to teachers if we expect teachers to foster quality technology-enhanced learning in students.

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Information and Communication Competences for Students

18

Koen Aesaert and Johan van Braak

Contents

Abstract

The general aim of this chapter is to provide an overview of the main results of educational research studying 1) the concept of ICT competence; 2) the assessment of ICT competences and 3) characteristics related to differences in ICT competences. More specifically, the relationship between student, teacher and school level characteristics and primary school students' ICT competences is described in the context of direct, performance-based assessment. At the end of the chapter, three underlying topics that are important for future research are discussed, that is, 1) the difference between the theoretical and empirical dimensionality of ICT competences; 2) the development of user-friendly assessment instruments; and 3) the need for research focusing on alternative ICT competences.

Keywords

ICT competences · Primary education · Assessment

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Introduction

In the last four decades, information and communication technologies (ICT) have permeated virtually all aspects of our daily lives by contributing to the economic, social, and educational transformations that characterize the present knowledge society (Jara et al. 2015; Kozma 2008). These transformations and challenges ask for the acquisition of specific ICT competences individuals – and particularly children – need in order to develop skills for social interaction, information retrieval and processing, civic participation, and professional success and advancement (Voogt and Pareja Roblin 2012). This significance of being ICT competent is reflected in several international policies on educational ICT use. In Europe, for example, the DIGCOMP framework describes ICT competence as a necessary transversal key competence for lifelong learning that is defined as the confident, critical, and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion, and/or participation in society. In this context, ICT competences are categorized into five ICT competence areas, that is, information, communication, content creation, safety, and problem-solving. For example, the ICT competence area "information" contains the ICT competences browsing, searching, and filtering digital information, evaluating digital information, and storing and retrieving digital information (Ferrari 2013). On a national level, recently more and more governments are administering formal expectations to schools in terms of ICT competence standards and curricula (Aesaert and van Braak 2015). As ICT competence standards and attainment targets define the achievement expectations for students, these ICT curricula formalize the status of ICT competences as official educational outcomes in their own right (Thomas and Knezek 2008). Consequently, the teaching of ICT competences no longer depends on the individual willingness and competence of the teacher. Instead, all teachers have the responsibility of providing all their students with equal possibilities to develop ICT competences.

In general, educational research on students' ICT competences can be divided into three main categories (Litt 2013). The first category of researchers tries to define what comprise ICT competences that students need to deal with the challenges in their everyday life. These researchers are occupied with describing and defining the concept of ICT competence and also with the operationalization of the construct in ICT competence frameworks. The second group of researchers focuses on the assessment of ICT competences and tries to measure students' proficiency in handling ICT-related tasks and problems. In this category, different assessment methods are used to capture students' level of ICT competences such as self-perceived measures of ICT competence or ICT self-efficacy (Siddiq et al. 2016) or more direct assessment methods such as observations (Hargittai 2002) and, more recently, performance-based assessment (Aesaert et al. 2014; Christoph et al. 2015; Huggins et al. 2014; Scherer et al. 2017). The third category of researchers tries to explain the measured differences in students' ICT competences by linking their level of ICT competence to other characteristics such as gender, socioeconomic status, and ICT experience or classroom use of ICT (Aesaert et al. 2015; Claro et al. 2012; Fraillon et al. 2014; Siddiq et al. 2017). This chapter provides an overview of the main results on these three research categories.

Students' ICT Competences

Various concepts and terms are used to describe the range of students' abilities to use ICT. The terms most commonly used in national and international frameworks and research literature are computer and information literacy (Fraillon et al. 2014), Internet skills (van Deursen and van Diepen 2013), digital competence (Ferrari 2013), and ICT competence (Aesaert and van Braak 2015). Although these terms have specific meanings and refer to various set of ICT-related capabilities, they are mostly interchangeably used. For convenience, only the term ICT competence will be further used in this chapter.

Although the formalization of ICT competences into official attainment targets and ICT curricula is only a recent phenomenon, the need for schools and teachers to deliver ICT-competent students has existed since the 1960s. In sum, the different types of ICT competences schools focus on have gone through a three-stage evolution of *mastery (1960s to mid-1980s), application (mid-1980s to late 1990s), and reflection (late 1990s until present)* (Aesaert et al. 2014; Martin 2006). In the *mastery stage* schools emphasized learning about information technology rather than learning with or through computers. ICT competences were perceived as basic knowledge of how the computer works (simple computer science) and rudiments of computer programming, i.e., a fundamental understanding of the components of the machine, of its history, and its principal application, and as acquiring hands-on skill in programming language (Tannenbaum and Rahn 1984).

In the mid-1980s, the potential of ICT for learning was recognized by several authors. As software and operating systems became easier to use, user-friendly, and more powerful, the focus in schools shifted from learning about information technology to using information technology to learn. ICT competences shifted into an *application*-oriented stage and were perceived as practical basic skills to apply common software in education, leisure, and work, rather than on specialist knowledge and technical skills (Martin 2006).

In the third and present *reflective* stage, the technical- and application-oriented ICT competences of the previous stages are considered important, but insufficient to deal with the challenges of the present knowledge society. The focus of ICT competences has shifted from basic skills and the application of basic software to a more reflective, evaluative, and critical approach to computers, the Internet, and digital information (Anderson 2008). As such, ICT competences are perceived as twenty-first-century skills or skills for lifelong learning that are concerned with – among others – problem-solving, information processing, creativity and innovation, critical thinking, digital citizenship, communication and collaboration, and technology operations and concepts (Ferrari 2013; Voogt et al. 2013). Within the context of the reflective stage, several authors have stressed the complexity and hierarchical structure of ICT competences. ICT competences are described as the interactive use of general cognitive capabilities that are underpinned by technical- and application-oriented ICT knowledge and skills in order to successfully complete cognitive information and ICT-based tasks (Aesaert et al. 2015; Markauskaite 2007). For example, in order to find information on the Internet, one needs not only to be able to operate the search engine but also to distinguish between relevant and irrelevant information. This description illustrates that the technical- and application-oriented ICT skills are still considered to be important. The technical- and application-oriented ICT skills are considered to be instrumental to the general cognitive capabilities, and one needs to master the basic technical and application skills to even come to performing the general cognitive ICT competence, i.e., the mastery of basic ICT skills and ICT applications is a condition to solve cognitive tasks in a digital environment (Claro et al. 2012). van Deursen and van Dijk (2016) stress this hierarchical structure in which the skills of the mastery and application stage are subordinate to the reflective stage for the particular case of Internet competences (a subdomain of ICT competences). They make a distinction between two types of higher cognitive ICT competences (i.e., information Internet competences and strategic Internet competences) and two types of application- or medium-related types of ICT skills (i.e., operational or navigation Internet skills and formal or orientation Internet skills). The authors stress that the content-related ICT competences depend on the medium-related ICT skills, i.e., a person without the medium-related skills will not even come to perform the content-related skills.

Measuring ICT Competences

Research on the assessment of students' ICT competences can be divided into studies using direct measures and studies using indirect measures to assess students' level in successfully completing computer- and Internet-related tasks. At present, the research interest is mainly oriented toward indirect measures such as self-efficacy, self-evaluation, and self-reported measures of ICT competences (Litt 2013; Siddiq et al. 2016). In the studies using indirect measures, a student's ICT competence level is based on the analysis of the student's own judgment of his/her ability to successfully complete ICT-related tasks. As these indirect measures are not resource-consuming and easily deployed on large samples for data collection and analysis, several surveys and self-report instruments have been developed to measure students' ICT competences (Litt 2013; Livingstone and Helsper 2010). In general, these self-report instruments are divided into instruments measuring students' computer competences, Internet competences, or both (Fraillon et al. 2014; Rohatgi et al. 2016). Whereas some instruments measure ICT competences in general, others focus on specific aspects of ICT competences. With regard to general ICT competence, Compeau and Higgins (1995) developed the general computer self-efficacy scale, which is used to measure students' perceptions of their ability to apply computer skills to broader tasks in the future. Liang and Tsai (2008) developed the General Internet Self-Efficacy Scale, which refers to students' self-perceived competence in using the Internet in general. Tsai and Tsai (2010) focused on specific aspects of ICT competence and use an Internet self-efficacy scale that measures students' perceived ability in online exploration (navigate and search for information on the Internet) and online communication (communicate via the Internet). Similarly, Aesaert and van Braak (2014) used an ICT self-efficacy instrument to investigate students' judgment of their own competence in communicating, retrieving, and processing information with a computer and the Internet, as well as their underlying technical- and application-oriented skills.

Although these indirect measures are easily administered to large samples, self-reported results often offer a less accurate representation of students' actual proficiency or performance level (van Deursen and van Dijk 2011). Students can over- or underestimate their own ICT competences which makes these indirect measures vulnerable to validity problems of self-report bias (Merritt et al. 2005). For example, results of Ballantine et al. (2007) indicate that students significantly overestimate their ICT competence with regard to general ICT awareness, spreadsheets, word processing, databases and presentation software, and e-mail/Internet. Moreover, the majority of studies that compared students' self-reported levels of ICT competence with their actual ICT competences show low correlations between both measures. This research reinforces the statement that self-report measures of ICT competences are not reliable (Siddiq et al. 2016).

In order to tackle these shortcomings of self-reported measurements, recently researchers have started to assess students' ICT competences in a more direct way. This means that students' levels of ICT competences are based on the analysis of directly performed and observed actions, i.e., students perform hands-on actions on a computer which are then observed and analyzed by the researcher. Being a pioneer in direct assessment of ICT competences, Hargittai (2002) used observations and thinking-aloud protocols to identify differences in adults' ability in retrieving online information. These performance- and simulation-based tasks that come close to reality are valuable because they are a more authentic appraisal of complex competences and therefore more valid than conventional item designs such as survey measures (Wirth 2008).

Although these direct measures based on observations offer a suitable alternative, allowing for more valid measurement of ICT competences, they suffer from practical issues such as being expensive, time-consuming, difficult to replicate, and difficult to conduct on large samples. In order to deal with these practical disadvantages, researchers recently have started setting up large-scale assessment initiatives to measure students' ICT competences in a direct and standardized way using computer software. From an international perspective, for example, ICILS 2013 (International Information and Computer Literacy Study 2013) used a computer-based test in order to measure secondary students' ICT competences (Fraillon et al. 2014). More specifically, the results indicate that on average 78% of 14–15-year-old students have a basic to lower mastery level in collecting, managing, producing, and exchanging digital information. Furthermore, it seems that the evaluation of the reliability, usefulness, and relevance of digital information requires a higher level of ICT competence (Fraillon et al. 2014). A study of van Deursen and van Diepen (2013) produced similar results, i.e., the data of their performance-based test showed that the levels of searching and processing online information of secondary school students still have much room for improvement. More specifically, their results suggest that students still have difficulties defining proper search queries and evaluating the reliability of the information in the results of these search queries. The study of Aesaert and van Braak (2015) confirmed these results for the context of primary school students. It seems that these students are having trouble with assessing and judging the relevance of digital information, with delivering requested digital content in a socially acceptable and understandable way and with information searches that require more complex searching behavior. With regard to the latter finding, students can easily find digital information using a search index, the menu of a website, or a search engine as long as the number of keywords is limited, i.e., students experience more problems with search queries that require more keywords to obtain a correct result. According to Kuiper et al. (2005), students find it very difficult to choose appropriate keywords in a structured and systematic way. In this context, van Deursen and van Diepen (2013) state that students' search queries are often too long and not specific enough. Furthermore, results of Claro et al. (2012) showed that communicative ICT activities, such as writing an e-mail or publishing a post that is adequate in content, require even a higher level of ICT competence compared to other activities such as searching for digital information. Similarly, Aesaert et al. (2014) found that the most difficult ICT activities are those for which students have to formulate a message in which the content is socially acceptable and understandable. According to some authors (Aesaert et al. 2014; Kuiper et al. 2005), these communicative activities often take place in less pre-structured software applications such as an e-mail program or a blog, requiring a more developed ability from students.

The results presented above clearly call into question the widely accepted claims that a generation of digital natives exists. The results suggest that not all students possess sophisticated ICT competences and that students are perhaps not as computer and Internet savvy as it is often assumed. Primary and secondary school students still encounter problems with higher-order cognitive ICT competences such as finding, using, and evaluating the right digital information (Calvani et al. 2012; Kuiper et al. 2005). It is possible that the complexity of these ICT competences will even increase in the future and require even more from students, as the number of websites and the information available on the Internet is growing at lightning speed and everybody can act as an author. Consequently, the results of performance-based ICT competence tests illustrate that the assumption of digital natives has a weak empirical foundation and that it should be studied within the diversity of ICT competences (Bennett et al. 2008). This also means that the popular claim that education must make fundamental adaptations to cope with the needs of the net generation must not be taken for granted. On the contrary, education should especially provide students with opportunities to acquire those competences of the ICT curriculum that are less developed. As students still develop their ICT competences mainly in out-of-school settings (Hatlevik et al. 2015b; Rohatgi et al. 2016), they enter the classroom with different and differently developed ICT competences. The identification of these competences by teachers and schools is an essential condition for providing all students with equal possibilities to become ICT competent.

Characteristics Related to ICT Competences

In general, research exploring characteristics related to students' ICT competences is mostly conducted from the perspective of student characteristics such as socioeconomic status (SES) or gender (Aesaert and van Braak 2015; Litt 2013; Meelissen 2008). However, it is well known that students' educational outcomes – which ICT competences are since they are incorporated in official ICT curricula and attainment targets – are attributed to characteristics at different levels (e.g., student level, teacher level, school level) (Creemers and Kyriakides 2012). Consequently, recent research has elaborated on these traditional student characteristics and focused on the impact of students' cognitive abilities and teachers' and schools' practices that might foster ICT competences (Claro et al. 2012; Fraillon et al. 2014).

Student Level

Most research directed toward ICT competences has tried to explain differences in ICT competences from the perspective of gender. At present however, research still reports inconsistent results (Rohatgi et al. 2016). Whereas some researchers have found a significant relationship between gender and ICT competences in favor of boys (Kuhlemeier and Hemker 2007; van Deursen 2012), others identified a positive association favoring girls. For example, Hohlfeld et al. (2013) found that secondary school female students performed better on the Student Tool for Technology Literacy than their male counterparts. Similarly, the results of the ICILS 2013 study indicate that female students on average outperform their male counterparts in digital information retrieving, processing, and communication (Fraillon et al. 2014). What has become clear out of these studies is that more nuanced measures that focus on specific types of ICT competences are more appropriate than general measures for identifying gender-related differences. For example, Jones et al. (2010) found a significant relationship between gender and certain ICT activities such as using graphics, audio/video, computer maintenance, and spreadsheets, in favor of males. However, this relationship was not found for activities that require digital communication and information processing such as writing on blogs and using online library resources. Results of Aesaert and van Braak (2015) show that girls are particularly better in delivering digital information in a socially acceptable and understandable way, in reacting on a forum, in judging the relevance of digital information, and in using e-mail for communication. The results of these studies clearly tackle the traditional assumption that using computers and the Internet is a male activity. A possible explanation that female students are better in digital communication than male students is that social online activities such as e-mailing, blogging, and using social network sites are more popular activities for girls than for boys (Volman et al. 2005). Similar, Drabowicz (2014) states that boys tend to use the Internet as an entertainment tool (e.g., playing games), whereas girls use it as a communication tool to get something done. Investigating students' ICT use profiles, Scherer et al. (2017) found that girls use ICT more frequently for social communication and exchanging information than boys. As girls participate more in social online activities, they have more opportunities that the results of their conducted communication activities are interpreted as successful experiences than their male counterparts. Within the context of social cognitive theory (Bandura 1986), these successful experiences can increase girls' ICT self-efficacy more than that of boys, which in turn can raise girls' motivation to engage in more challenging and difficult social online activities, and eventually develop better competences in digital communication (Tsai and Tsai 2010).

Although SES has often been linked to ICT competences, this relationship has mostly been studied from self-reported measures. However, the little research that has been conducted on the relationship between SES and students' ICT competences has produced similar results so far. For example, Claro et al. (2012) were some of the first to investigate the relationship between SES and students' actual ICT competences. These authors found that the higher the students' socioeconomic status, the better they score on digital communication, digital information retrieving and processing, and interacting and collaborating in digital environments. A similar positive relationship was found by Aesaert and van Braak (2015) and Siddiq et al. (2017) who operationalized SES as the highest educational degree of the parents. The results of both studies indicate that the higher the educational degree of the mother or father, the better the technical-procedural ICT skills (e.g., adding attachments to e-mails) and higher cognitive digital competences (e.g., integrate digital information into existing information products) of the students. At the international level, the ICILS 2013 study produced similar results, i.e., in more than 50% of the participating countries, a significant positive effect of parental educational level on students' ICT competences was found. These findings are reinforced by the fact that other indicators of SES such as parental occupational status and home literacy are positively associated with students' ICT competences in all participating countries (Fraillon et al. 2014). This finding is problematic as SES is a structural student characteristic that cannot easily be altered (Creemers and Kyriakides 2012). However, it emphasizes the need for the identification of teacher, classroom, and school characteristics that can foster the development of ICT competences of students of specific socioeconomic groups.

Besides these student background characteristics, research on ICT competences has also focused on some cognitive and motivational student characteristics, of which ICT self-efficacy is probably the most frequently studied one. ICT self-efficacy is rooted in Bandura's broader concept of self-efficacy (Marakas et al. 1998). ICT self-efficacy comprises the two domains of computer and Internet self-efficacy. Consequently it refers to a person's belief in his capability to successfully perform computer- and Internet-related tasks (Papastergiou 2010). In general, most studies report a positive relationship between ICT self-efficacy and students' ICT competences, i.e., the higher students judge their own ability for solving computer- and Internet-related problems, the better their actual ICT competences (Rohatgi et al. 2016). Results of Hargittai and Shafer (2006) show that self-assessed net skills are positively related to actual net skills. More recently, Aesaert et al. (2015) found that the higher primary school students' ICT self-efficacy, the better they score on performance-based ICT competence tests. These results clearly illustrate that ICT self-efficacy is not only important for developing ICT competences but also for being able to use technology in learning (Hatlevik et al. 2015a).

Finally, we discuss some important student characteristics of which the relationship with students' ICT competences has been less studied. More specifically, we focus on ICT experience and ICT use at home. Students' ICT experience and ICT use at home are two important student characteristics of which the relationship with ICT competences has been studied in numerous investigations. ICT experience refers to the total number of years a child has been using the computer and the Internet or the time a child daily/weekly spends on computer and Internet use outside the school context (Tsai and Tsai 2010). Although Ballantine et al. (2007) did not find a significant relationship between ICT experience and students' ICT competences, recent studies are more positive. For example, Jara et al. (2015) identified ICT experience as one of the most important characteristics for developing students' ICT competences. Similarly, Aesaert et al. (2015) found that the more hours per week a student on average uses a computer and the Internet at home, the better he or she is in successfully completing tasks that are related to finding, processing, and communicating digital information. ICT use at home refers to students' use of specific types of computer and online application use in an out of school context. Livingstone and Helsper (2007) found that primary and secondary school students who use the Internet in a more conservative way have less developed online competences. Jara et al. (2015) elaborated on this matter. Their results show that students who daily use and communicate through social network sites have better ICT competences than students who do not take up these activities. Moreover, it seems that students who use the Internet mainly for downloading music, games, or programs have less developed ICT competences than students who never do these activities. It is important to stress that the relationship between ICT use and ICT competences is a reciprocal one. van Deursen and van Dijk (2016) found that different types of Internet usage are directly determined by specific Internet skills. More specifically, it seems that higher levels of strategic Internet skills result in more information-directed online use.

To conclude the discussion on the relationship between ICT competences and students' ICT use, we refer to Jara et al. (2015) who stress that rather the way in which students use specific applications than the frequency in which they use them is important for developing ICT competences. It seems that students with high ICT competences use a set of academic skills, i.e., a mix of cognitive skills and organizational skills, that allow them to make more appropriate use of the opportunities provided by computers and the Internet in order to meet their personal objectives. More specifically, these students not only keep focused on their goal when they use ICT, but they also make use of higher-end information processing strategies such as judging the quality of websites, comparing multiple sources, and making summaries. Within this context of the relationship between academic skills and ICT competences, Aesaert et al. (2015) found a significant and positive relationship between "control" learning style and students' ICT competences. This means that the more students plan, monitor, and regulate their learning process while learning, the higher their ability in digital information processing and communication. This relationship can be explained from the perspective of metacognitive skills. Different aspects of digital information processing such as judging information and comparing multiple online sources require metacognitive skills (Eisenberg 2005), which are typical for students using a "control" learning style. Aesaert et al. (2015) also identified analytic intelligence or students' ability to adapt their thinking to new cognitive problems without relying on declarative knowledge derived from previous experience in or outside the classroom, as one of the most important characteristics affecting students' ICT competences. These studies emphasize the importance of training specific general cognitive abilities for the development of ICT competences rather than just increasing the frequency of ICT use.

Teacher and School Level

Although the importance of schools for the development of students ICT competences has been widely recognized, only a few studies have investigated which teacher and school characteristics might affect students' ICT competences. With regard to educational ICT use, the results are rather negative. For example, Aesaert et al. (2015) investigated whether differences in primary school students' ICT competences could be explained by teachers' ICT competences, ICT attitudes, ICT professional development, educational ICT use, ICT experience (teacher level), roles of the ICT coordinator, ICT policy planning, ICT support, and ICT infrastructure (school level). Of all these characteristics, only a positive but weak effect was found between the use of ICT as an information tool in the classroom and students' ICT competences. Similarly, the results of the ICILS 2013 study show that learning about ICT at school has a statistically significant positive effect in only 4 out of 15 countries (Fraillon et al. 2014). Moreover, Appel (2012) did not find a significant relationship between the use of computers at school and students' ICT competences, and Hatlevik et al. (2015b) even found a negative impact of ICT use at school on students' ICT competences. These results provide weak evidence that the specific ICT activities that teachers organize in their classroom pay off in terms of ICT competence development.

However, results of Fraillon et al. (2014) illustrate that among countries 11–53% of the variance in students' ICT competences is located at the teacher/school level. These results suggest that there exist differences in ICT competences between students' from different schools. Taken into account that (1) there exist differences in students' ICT competences between schools, that (2) the proof of the effect of educational ICT use on students' ICT competences is limited, and that (3) research has not yet conclusively identified other teacher and school characteristics related to directly assessed students' ICT competences (as far as we know), the question rises if other teacher and school characteristics such as access to technology, teacher beliefs, and teaching style do explain differences in students' ICT competences.

Conclusions

Our limited review clearly points out that research on ICT competences is still in its infancy. Instead of summarizing the results, we focus on three underlying topics that are important for future research. The concept of ICT competences represents an interesting but fast-evolving and complex construct. In its present state, it is perceived as a multidimensional and hierarchical construct, in which higher-order cognitive skills are underpinned by more technical-procedural ICT skills. None of the studies above were able to empirically validate the theoretical dimensionality of ICT competences. We believe this difference between the theoretical and empirical dimensionality of ICT competences is quite problematic. One can question the validity and reliability of assessing students' mastery of an ICT curriculum if the structure of the empirical data used to assess the specific ICT competences does not match the structure of the objectives of the ICT curriculum intended to be measured. Consequently, we believe that a combination of theory- and data-driven approaches for curriculum evaluation is necessary to develop high-quality ICT curricula. Together with theoretical arguments, empirical data on the dimensions that underlie students' ICT competences should be used to adapt and create more delineated and mutually independent ICT attainment targets. Although some authors plea for a more holistic approach to ICT literacy, the delineation of ICT competences can be seen as a necessary condition for creating ICT curricula that not only reflect the dimensionality of ICT competences but also for creating ICT curricula that will be measureable in a valid and reliable way.

The results indicated that some important and sophisticated ICT competences such as searching, evaluating, and communicating digital information are not always well developed and that students are perhaps not as computer and Internet savvy as it is often assumed. As the information available on the Internet is growing at lightning speed, most likely, the complexity of ICT competences required to handle this unstructured amount of data and information will increase. Further, it seems that these ICT competences are far from universal among young people (Bennett et al. 2008). For example, girls are particularly better in delivering digital information in a socially acceptable and understandable way than boys. Consequently, gender preferences still need to be studied. Moreover, the impact of teachers and schools is limited as almost no teacher and school characteristics seem to contribute to students' ICT competences. Consequently, it can be assumed that students still develop these competences especially in informal, out-of-school settings. This means that students enter schools with different and differently developed ICT competences. If we want to create equal opportunities for all students to develop ICT competences, it is important that teachers and schools can compensate for those specific ICT competences that students do not yet possess. However, teachers themselves are often not fully equipped with ICT competences, which makes it hard for them to identify and assess their students' level of ICT competences. Research should therefore focus on the development of user-friendly assessment instruments that enable teachers to identify for each student the ICT competences of the ICT curriculum that need attention.

To conclude, we believe that future research that tries to explain differences in students' ICT competences should focus on different types of dependent and independent variables. With regard to the dependent variable ICT competences, our results indicate that most studies focus on digital information processing and communication. Research should elaborate and focus on other ICT competences such as collaboration by means of ICT, presenting information by means of ICT, digital media production, or even socio-emotional skills that students need in social networking. This will not only deliver a more comprehensive, construct, and content valid picture of students' ICT competences, but it would also be an important step in the investigation of the dimensionality of ICT competences. With regard to the independent variables, we believe that the relationship between ICT use in the classroom and students' ICT competences should be further investigated. More specifically, research should focus on the mediating role of the instruction of teachers, e.g., to which degree do the teaching style and teaching beliefs of the teacher mediate between using ICT in the classroom and the development of ICT competences.

Research on the development of ICT competences should remain a highly addressed topic for educational researchers, because those competences – among others – that offer children the possibility to engage in a world immersed in digital information and applications.

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The Influence of Information and Communication Technology Use on Students' Information Literacy

19

Akira Sakamoto

Contents

Abstract

In this chapter, the concept of information literacy and research findings on the impact of children's use of ICT (information and communication technology) on information literacy are introduced, with a focus on Japan and including comparisons to other parts of the world. A general explanation of information literacy is first provided; then the concept, history, measurement, and other issues of information literacy are described. The findings of Japanese empirical research on the impact of children's ICT use on information literacy are detailed and aligned with major international research findings and orientations on the issues of impact of ICT use. Major findings are as follows: (a) ICT use can improve information competencies, in particular abilities to collect and evaluate information; and (b) it

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appears that ICT use at school could be more effective than ICT use at home, but even the use at home has effects which cannot be ignored. Findings contribute additional evidence of causality to the current body of literature based primarily on large international studies addressing the issues of the educational impact of ICT use through data gathered across many educational systems but from each subject just one time.

Keywords
Information literacy · ICT use · Quasi-experiment · Panel study · Japanese research

Introduction

This chapter introduces studies on the influence of ICT use on information literacy among elementary, junior high, and senior high school students. Although many references are made to studies from other parts of the world, detailed examples are provided from research studies in Japan.

What Is Information Literacy?

Information literacy has been regarded as being a skill necessary to live well in the information society. According to Virkus (2003), increasing attention to information literacy in recent years is partly due to the result of information overload especially related to the growth of digital information and the new focus on student learning in a lifelong learning context. Although such notice of information literacy has been taken, its concrete concept is not quite clear. In the glossary section of the first edition of the *International Handbook* (Voogt and Knezek 2008), the term information literacy was defined as:

> Computer literacy, digital literacy, e-literacy, e-skills, technological literacy, new literacy – all knowledge and skills that are necessary to participate in an information society; . . . [and] more narrowly defined as skills that are necessary to effectively use technology, e.g., finding and evaluating information on the Internet. (p. 1185)

Based on the explanation provided in the previous paragraph, it is possible to recognize that the term information literacy can have many meanings from narrow to wide definitions. Virkus (2003) described its various concepts and definitions. Some researchers have been engaging in work to overcome such confusing situations. For example, Anderson (2008) presented the term *knowledge-related skills* as inclusive abilities necessary for life in the information society. Knowledge-related skills consist of seven subskills, and Anderson described the subskill *to access*, *assemble*, *and reorganize knowledge*, as being the original information literacy.

Anderson (2008) also discussed relationships between information literacy and its similar concept, that is, ICT literacy. According to Anderson, information literacy is usually defined based on information functions, while ICT literacy is defined based on information skills. From this perspective, he made and presented a comprehensive model to describe the relationships of the two concepts. Anderson's work can also be regarded as an effort to resolve long-standing confusion related to the meaning of the term information literacy.

One reason the concept of information literacy is ambiguous could be that abilities which are regarded as important have changed depending upon the time period (Martin 2006; Voogt 2008). Actually, it seems that skills to operate ICT tools were important before, while the skills of high-order thinking for ICT are important now. It is conceivable that the concept of information literacy which focuses on important skills particular to each time period has so far been presented, and this time period transition has led to the currently existing variety of information literacy concepts.

Since the important abilities are still continuing to change, concepts are also continuing to be presented. For example, Mioduser et al. (2008) presented a new literacy, which consisted of multimodal information processing, navigating the infospace, communication literacy, visual literacy, hyperacy (the ability to deal with nonlinear knowledge representations), personal information management literacy, and coping with complexity.

Researchers have taken notice of such issues regarding the concept of information literacy, but the issue of whether ICT use can enhance information literacy has also gathered their attention, and consequently some studies have been being conducted. As far as the results of these studies are concerned, it seems that they have produced mixed findings as to effects on information literacy (Scherer et al. 2017), although they have in general indicated positive effects on subject learning (Tamim et al. 2011).

In particular, according to Scherer et al. (2017), a mixture of results have been found for research on ICT use at school, and as for the use of ICT at home, its positive effects are more clear. The use of ICT at home was not previously regarded as effective to obtain information literacy, and so the importance of school education was argued, but there is now a view that the home use could be effective (Rohatgi et al. 2016). This is supported by the fact that home use has now become sophisticated (Biagi and Loi 2012; Steinkuehler and Duncan 2008). As for the effects of ICT use on information literacy, it seems that researchers' attention has recently been focused not only on school technology access but also on home technology access. Home use was much more frequently found than school use (Fraillon et al. 2013a), also making issues related to the impact of home use important to study.

Information Literacy Study in Japan

In Japan, the term information literacy has a unique and broad definition in the field of primary and secondary education, This chapter first introduces the Japanese concept of information literacy, its characteristics, measurement methods, and the influence of ICT use on information literacy. The outline and characteristics of quasi-experiments and panel studies in media influence research are briefly described. These methods have often been used for Japanese research regarding the influence of

ICT use on information literacy. While many Japanese studies have addressed some aspect of the influence of electronic media tools use (e.g., Sakamoto 2013; Takahira et al. 2012), this chapter focuses on the relationship between ICT use and information literacy and describes the background and trends in this area.

Historical Development of Information Literacy in Japan

In 1986, the Japanese concept of information literacy (jouhou katsuyou nouryoku) was presented by the Japanese government for the first time. Information literacy was defined as the "basic qualities of individuals necessary for independently selecting and using information and information tools" (Ad Hoc Council on Education 1986, p. 101), and the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) established development of these qualities as the goal of information education in primary and secondary schools (MEXT 2010).

MEXT first described and defined information literacy in 1987 (Curriculum Council 1987) and then refined its description in 1998 in terms of the following three components that remain as of 2018: (1) information competencies, (2) the ability to understand information scientifically, and (3) the ability to contribute to a desirable information society (MEXT 2010).

The first component, information competencies (jouhou katsuyou no jissenryoku), is defined as "the ability to independently collect, evaluate, organize, process, and create necessary information, and to send out or communicate information while taking into consideration the state of the recipient, including appropriately using information tools in accordance with issues or objectives" (MEXT 2010, p. 72). Information competencies defined for Japan seem to be similar to *information literacy* as it is widely used in other countries. Collection, evaluation, organization, processing, creation, and communication of information represent a series of activities from acquisition of information to outputting results in problem solving or research, and the abilities required for these activities are defined as shown in Table 1.

Table 1 Six components of information competencies in Japan

1. Ability to collect information (syuusyuu ryoku): the ability to actively collect all information necessary to the objective in an appropriate way
2. Ability to evaluate information (handan ryoku): the ability to select necessary information from among a vast amount and evaluate it in order to draw out appropriate information
3. Ability to organize information (hyougen ryoku): the ability to organize information in an appropriate way with attention to how it should be expressed
4. Ability to process information (syori ryoku): the ability to appropriately process collected information in order to understand key information
5. Ability to create information (souzou ryoku): the ability to formulate and produce based on one's own ideas and opinions
6. Ability to communicate information appropriately (hassin dentatsu ryoku): the ability to send out or communicate information while taking into consideration the recipient's perspective or ability to process information

Table 2 Examples of scientific understanding of information

Understanding of:
A method to effectively, efficiently, and accurately process written character, numerical, and image data
Statistical approaches to correctly collect and analyze experimental, observational, and study data and a method of developing a model necessary to allow such statistical approaches
An effective simulation method to predict future results or to learn how different conditions can lead to different results
Human cognitive characteristics that support effective and accurate communication of information and prevention of incorrect judgment of information
The mechanism of information technology widely used in home appliances
Functional categories and characteristics of typical information tools for communicating, processing, and recording information

The second component, the ability to understand information scientifically (jouhou no kagakuteki rikai), is defined as "the ability to understand the characteristics of information tools, which are the basic building blocks of information use, and the ability to understand the basic theories and methods in order to not only handle information appropriately but also to evaluate and improve one's information skills" (MEXT 2010, p. 72). It could also include knowledge and skills of information science and computer science. Table 2 lists detailed examples of scientific understanding. While information competencies focus on the ability to achieve good results through information processing activities, the ability to understand information scientifically focuses on the basic knowledge and skills that support such achievement.

The third component, the ability to contribute to a desirable information society (jouhou syakai ni sankakusuru taido), could be rephrased as having the knowledge and attitudes of a desirable digital citizen. It is defined as "the ability to understand the roles and influences of information and information technology in society, to consider the necessity of information morals and responsibilities for information, and to demonstrate a willingness to take part in the creation of a desirable information society" (MEXT 2010, p. 72). Note that the Japanese term *information morals* (*jouhou moraru)* covers both information ethics, such as prevention of harming others and spending unnecessary time and money with the use of ICT, and online safety, such as avoiding being harmed by others. In summary, this third component of information literacy focuses on the ability to understand the positive and negative aspects of digitization of society and to pay the necessary attention or give appropriate consideration in order to overcome the negative aspects.

This Japanese version of information literacy seems to have a unique structure and concept. First, the Japanese version emphasizes the independence of information users. This is particularly explicit for information competencies. In Japan, it has been frequently argued that Japanese lack independence and assertiveness, holding them back from playing an important role internationally. Accordingly, in the field of education, the importance of helping children and students develop independence has been frequently emphasized. The focus on independence in information literacy seems to reflect these values.

Second, the Japanese version of information literacy gives particular weight to the ability to contribute to a desirable information society or demonstration of knowledge and attitudes of a digital citizen. As mentioned earlier, this ability is one of the three components of information literacy. By way of comparison, in the new 2016 National Education Technology Standards for Students by the International Society for Technology in Education (ISTE) (2016), *digital citizenship* is one of seven standards. Japanese school education places importance on teaching students how to avoid problems caused by ICT use, and this is reflected in the weight given to the ability to contribute to a desirable information society.

Third, the Japanese version of information literacy also gives weight to the ability to understand information scientifically or to the acquisition of knowledge and skills of computer science and information science. Similarly, in the 2007 ISTE National Education Technology Standards for Students, one of the six standards called *technology operations and concepts* corresponds to the ability to understand information scientifically. However the 2016 ISTE standards no longer include this technology standard. It appears that recent situations where technological operations and concepts have been deemphasized have often also led to the use of the concept of computer and information literacy (CIL). This is defined as “an individual’s ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society” (Fraillon et al. 2013b, p. 17) and is often used in research and discussion on educational ICT use. It seems that this discussion of terminology has become necessary because researchers often want to deal with the issues of abilities including technical operations and concepts. The Japanese version of information literacy gives relatively greater weight to technical issues, and therefore it might be that Japanese information literacy and CIL can be regarded as being reasonably overlapping concepts but they are not exactly the same.

Recently, UNESCO (2017) presented an ICT Competency Framework which was jointly developed by many nations of the world. The framework addresses three different areas of competencies. The first is technology literacy, enabling students to use ICT in order to learn more efficiently. The second is knowledge deepening, enabling students to acquire in-depth knowledge of their school subjects and apply it to complex, real-world problems. The third is knowledge creation, enabling students, citizens, and the workforce they become to create the new knowledge required for more harmonious, fulfilling, and prosperous societies. Although this framework is based on viewpoints different from those of the Japanese version of information literacy, it seems that topics covered by each overlap to some extent. However, knowledge creation is one of three categories in UNESCO’s framework, which is not emphasized in the Japanese version of information literacy. The ability to contribute to a desirable information society in the Japanese version of information literacy includes some parts of this in knowledge creation, but the other two components (information competencies and the ability to understand information scientifically) do not include knowledge creation to a significant degree. The Japanese version of information literacy has concepts in common with the UNESCO framework but is not exactly the same.

Measurement and Structure of Information Literacy in Japan

Abilities can be measured through tests, observations, and self-evaluation (Christensen and Knezek 2008; Schulz-Zander et al. 2008). Measurement by tests and observations has strength in that it guarantees objectivity, but it seems that self-evaluation can also be useful for measurement of Japanese information literacy. Information competencies focus not only on the abilities to produce good results using information but also on independent information use, the latter of which can often be represented by attitudes. The ability to contribute to a desirable information society is also related to attitudes. Generally speaking, the importance of self-evaluation is high in attitude measurements (Christensen and Knezek 2008), and therefore, self-evaluation can be a useful option when researchers wish to measure a construct which has both aspects of skills and attitudes, like Japanese information literacy.

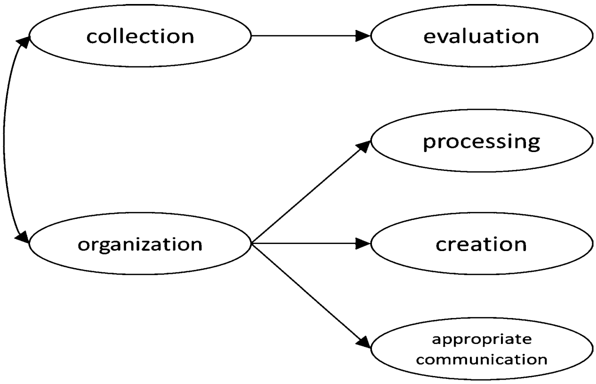
Scales for self-evaluating components of information literacy have been studied and developed. For example, Takahira et al. (2001) developed a 56-item information competency self-reporting scale. This scale covered all six components of information competencies, which include the abilities to collect, evaluate, organize, process, and create information as well as the ability to communicate information appropriately. The researchers administered the survey to 1649 junior and senior high school students and confirmed that the scale had sufficient reliability and validity. Table 3 shows example questionnaire items.

Table 3 Example statements in the scale measuring information competencies

Ability to collect information: ten items
I ask my friends for information materials when I need them more often than collecting the materials by myself [R] I make myself use dictionaries when I encounter information that I do not understand
Ability to evaluate information: eight items
When there are opposing opinions, I always listen to both sides to understand pros and cons of each opinion I am not very good at finding necessary information from a large volume of materials [R]
Ability to organize information: eight items
After I have collected a lot of information, I make myself categorize it by content When I read sentences, I never underline important points [R]
Ability to process information: eight items
When I solve problems, I tend to draw a conclusion more instinctively than logically [R] I am good at identifying a common feature or a rule in information organized in charts and tables
Ability to create information: ten items
I am not good at coming up with opinions different from others [R] Once I solve a problem using a particular method, I will not try to find a better method
Ability to communicate information appropriately: ten items
When I have a message for someone, I try to make the message eye-catching by, for example, underlining important points When I talk with someone, I usually do not wonder what the other person wants to know [R]

Note: Statements marked with [R] are reverse scoring items

Fig. 1 The structure of the information competencies



Using the scale developed by Takahira et al. (2001), Ichihara et al. (2008) examined the structure of information competencies. Ichihara et al. (2008) administered the survey to 714 junior high school students and performed confirmatory factor analysis using the obtained data. As a result, the model shown in Fig. 1 was selected due to its goodness of fit. Based on the results of this study along with others, the researchers argued that it was possible to assume two effective learning activities: (1) acquisition of the ability to collect information followed by acquisition of the ability to evaluate information and (2) acquisition of the ability to organize information followed by acquisition of the ability to process and create information as well to communicate information appropriately. They also emphasized the importance of the former activity for younger students and the latter activity for older students. Note that information competency scales have also been developed by other researchers in Japan (e.g., Okugi and Furuta 2005).

Kobayashi et al. (2000) created a 50-item scale to measure the ability to contribute to a desirable information society. This scale covered all components of the ability to contribute to a desirable information society. These researchers administered the survey to 1639 junior high, senior high, and university students and concluded that the scale had sufficient reliability and validity. They performed confirmatory factor analysis on the obtained data. Figure 2 displays the structure of the ability to contribute to a desirable information society. Table 4 lists example questionnaire items. Note that other researchers have also developed scales to measure this ability (Miyagawa and Moriyama 2011; Miyake 2005).

A wide variety of studies have been conducted using the scales previously described. For example, Mori et al. (2004) used these scales to examine the correlation between individuals' self-teaching ability, information competencies, and the ability to contribute to a desirable information society, finding high correlations. Also, Omi et al. (2004) conducted a survey of elementary school students to examine the correlation between their information competencies and intelligence. The study showed that the magnitude of correlation between information competencies and numerical intelligence was approximately $r = 0.30$, moderate in magnitude according to guidelines provided by Cohen (1988). Finally, Ando and Ikeda

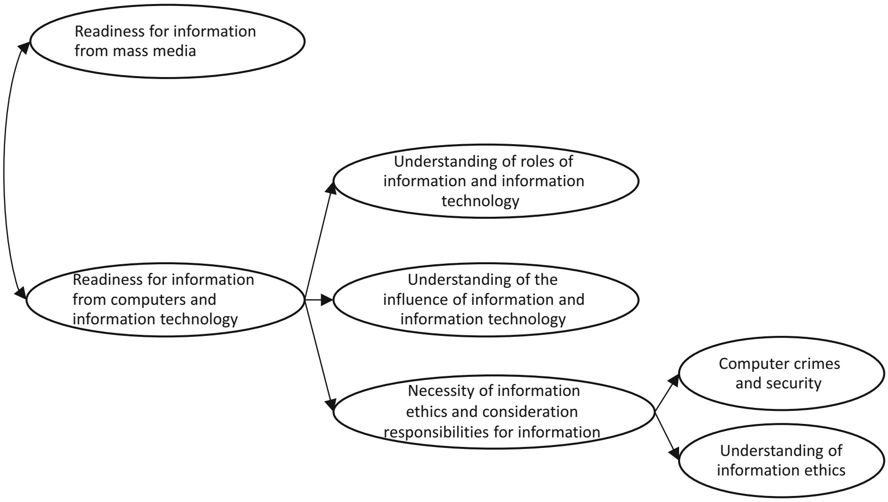


Fig. 2 The structure of the ability to contribute to a desirable information society

(2012) found that high information competencies predicted higher critical thinking skills in follow-up assessments 5 months later.

Empirical Research on the Influence of ICT Use on Information Literacy in Japan

Japanese junior high schools have a technology and home economics class, which includes an information education module. Japanese senior high schools have a class dedicated to information education. These classes are designed to develop students' ability to understand information scientifically, which is a component of information literacy. Meanwhile, students cannot acquire the other two components of information literacy, which are information competencies and the ability to contribute to a desirable information society, through these classes alone; they need hands-on experience with ICT while studying a wide variety of school subjects and engaging in school activities. MEXT has provided detailed examples of activities using ICT, which should be provided in each school subject in order to improve students' information literacy (MEXT 2002). Table 5 shows examples of activities for a science class.

As previously described, the use of ICT is considered important for the development of information literacy. The Japanese government therefore has promoted the introduction and use of ICT in schools, and whether or not ICT use actually improves students' information literacy, information competencies, and the ability to contribute to a desirable information society in particular has become an important research area. The following sections introduce quasi-experiments and panel studies conducted on this theme.

Table 4 Example statements in the scale measuring the ability to contribute to a desirable information society

1. Understanding of roles of information and information technology
I am not interested in studying computer programming [R]
I want to actively use computers to make my daily living more convenient
2. Understanding of the influence of information and information technology
(a) Issues regarding a computer-dependent society
I want to understand issues regarding a computer-dependent society
I am not interested in the influence of computers on the human body [R]
(b) Influence of mass media on society
I try not to let commercials influence my purchasing decisions
I am easily influenced by opinions introduced on TV, in newspapers, and in magazines [R]
3. Necessity of information ethics and consideration of responsibilities for information
(a) Understanding of information ethics
1. Information ethics and manners
I often give information to others even though I am not sure of its correctness [R]
I do not want to post information on the internet that may make viewers uncomfortable
2. Privacy
I disclose my friends' street addresses and phone numbers without their permission [R]
I do not want to view websites containing content that violates someone's privacy
3. Copyrights
If I can copy game software such as video games, I will do so without hesitation [R]
I want to understand the Copyright Act properly
(b) Computer crimes and security
I hope technology that allows safe online information exchanges will develop further
I admire hackers (people who infiltrate others' computers via networks) [R]

Note: Statements marked with [R] are reverse scoring items

Table 5 Examples of science class activities that improve students' information literacy

Tabulation, processing, and drawing graphs of observational or experimental data using a computer and discovering a new rule in the processed data
Quantification of natural events and changes and performance of experiments, including measurement and control, using a computer
Consideration of a causal relationship within an event through simulation
Searching for information on natural events and objects using a computer or the internet
Exchanging information on nature or the environment via the internet

Quasi-experiments

A randomized experiment is a powerful method to determine a causal relationship between independent and dependent variables by controlling extraneous variables. It is however not realistic to implement a randomized experiment to examine the educational effect of ICT use on Japanese primary and secondary school students. In a randomized experiment, participating students are first divided into groups, and each group is subject to a different educational intervention. Should a randomized experiment be conducted, it usually involves a short-term intervention or a small number of participants. It has been pointed out that many studies on the effect of ICT use face this experimental limitation (Pérez-Sanagustín et al. 2016).

A quasi-experiment is an experimental method that overcomes the issues of randomized experiments by sacrificing some control of extraneous variables. Studies on the influence of ICT use on information literacy should examine long-term effects, and their results need to be generalizable to a wide range of student categories. These criteria provide a strong rationale for selecting a quasi-experimental approach. Extraneous variables are not fully controlled in a quasi-experiment, and it is therefore important to discuss and nullify an alternative interpretation that interferes with the determination of a causal relationship between independent and dependent variables.

For example, a quasi-experiment to examine the influence of a use is viable when (a) changes in participants between before and after the diffusion of the subject media tool in one area (treatment condition) are compared to (b) changes in participants in areas where the same media tool has already been or does not take place (control condition) within the same period of time. One of the well-known quasi-experiments is by Harrison and Williams (1986) where researchers measured creative thinking skills, spatial perception skills, and the vocabulary size of children at two different time points in a town with no television (Notel condition), a town with only a single TV channel available (Unitel condition), and a town where all TV channels were available (Multitel condition). TV was introduced to the Notel town between the first and second measurements. Analysis of the obtained data indicated that, although children in the Notel condition had higher creative thinking skills than their counterparts at the first measurement, such skill difference was no longer observed at the second measurement. The study suggested that TV viewing may have been responsible for the decline of creative thinking skills.

In the field of information literacy, Naito et al. (2003) conducted a quasi-experiment to examine whether or not the use of high-speed internet improved students' information competencies. In one region of Japan, high-speed internet was introduced to three schools (treatment condition) and was not introduced to two schools (control condition). These five schools existed in very similar environments, and Naito et al. (2003) compared the changes in students' information competencies between treatment and control schools. The pre-post change score was computed by subtracting the students' information competency score measured before the high-speed internet was introduced from the score after it was introduced. The interval between measurements was 6 months. The data analysis indicated that the change score was significantly more positive for the treatment schools than for the control schools. This result suggests that internet use at school may contribute to improvement of information competency. The result also supports the study by Underwood et al. (2005) on the effectiveness of high-speed internet.

Naito et al. (2003) also compared the six components of information competencies – the ability to collect, evaluate, organize, process, and create information as well as the ability to communicate information appropriately – between schools with and without high-speed internet. Except for the ability to create information, the scores of pre-post change were more positive at the schools with the high-speed internet than those without it.

In a quasi-experiment by Naito et al. (2003), students' information competencies were measured twice, before the high-speed internet was introduced and once after the introduction. The interval between the two pre-introduction measurements was 6 months. These two measurements allowed controlling for the baseline changes between the two conditions (Shadish et al. 2002). As a result of analysis, the information competency score between the two conditions showed no changes in the two pre-introduction measurements. The difference score changed rapidly after the introduction, however, and this difference could not be explained by any changes observed prior to the introduction of high-speed internet. Such nullification of alternative explanations strengthens the argument that the introduction of high-speed internet influenced information competencies in students.

Kashibuchi et al. (2003) conducted a quasi-experiment on the ability to contribute to a desirable information society, one component of information literacy. Similar to the study by Naito et al. (2003), Kashibuchi et al. (2003) measured students' ability to contribute to a desirable information society. These students were from junior high schools with or without high-speed internet. Changes in the ability score difference between the two conditions were compared before and after the introduction of high-speed internet. The result of the analyses indicated no differences between the two groups in their changes over time. Therefore, high-speed internet use was deemed unlikely to have influenced students' ability to contribute to a desirable information society in the Kashibuchi et al. (2003) study.

Panel Studies

In addition to quasi-experiments, panel studies have been used to examine the influence of ICT use on information competencies and the ability to contribute to a desirable information society. A panel study is a type of longitudinal study in which the same set of participants is measured in the same way multiple times with a certain time interval. For example, to examine the influence of media tool use, participants are measured multiple times for their exposure to the subject media tool and the outcome variables, such as cognitive skills or aggressiveness, which may be influenced by the use of the media tool. As with quasi-experiments, panel studies allow estimation of a causal relationship to some degree (Markus 1979; Finkel 1995).

Markus (1979) popularized panel studies by using the technique to address questions such as whether political party membership in the USA tends to influence positions on issues or whether positions on issues tend to influence party membership. As for the research of media impact, the application of similar methodology has been found in earlier periods in research such as the Sesame Street evaluation study which confirmed a positive impact of viewing this young children's television program on school readiness skills (Bogatz and Ball 1971; Searcy and Chapman

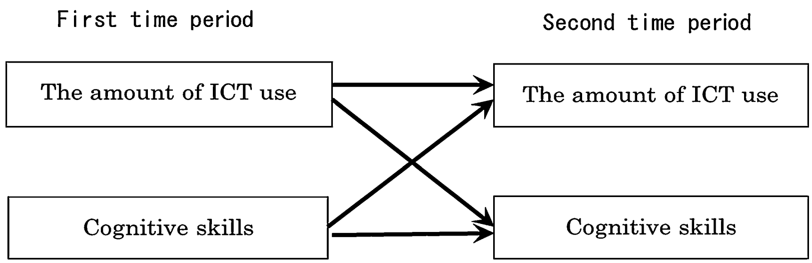


Fig. 3 The cross-lagged effects model of ICT use and cognitive skills

1972). Christensen (2002) gathered and analyzed panel study data to show that needs-based professional development for technology integration in teachers fosters more positive attitudes toward computers in their students. One major advantage of the panel study method is that it allows causal inference without a laboratory-type experimental design. In the field of educational science concerning ICT use, it seems so far that there have been only a small number of studies that examined causal relationships using panel study data.

Figure 3 shows a typical analysis model created for examining the causal relationships between the amount of ICT use and cognitive skills at two different time points. This model is called a cross-lagged effects model. If analysis using this model indicates that the path from the amount of ICT use measured at the first time point to cognitive skills measured at the second time point is significant, a causal relationship of ICT use influencing the cognitive skills is regarded as being supported. Unlike panel studies, on the other hand, cross-sectional correlation studies that require only a single measurement cannot fundamentally determine causal relationships (Prot and Anderson 2013).

Some Japanese panel studies examined the influence of ICT use on information literacy. For example, Takahira et al. (2007) examined the influence of ICT use on information competencies. They measured the amount of daily internet use at school and home and information competencies of 702 students from eight elementary schools. Measurement was performed twice with a 2-month interval, and the two sets of data obtained at different time points were analyzed using the cross-lagged effects model. The result indicated that internet use had a significant effect on improving information competencies of elementary school students, and among the components of information competencies, the ability to collect information improved the most. Internet use also had a positive effect, although weak, on the abilities to evaluate and organize information. The study further indicated that information competencies as a whole and the ability to collect information promoted internet use. The researchers developed and used a scale appropriate for elementary school students based on the scale developed by Takahira et al. (2001) for use by junior and senior high school students.

Another example is a panel study by Takahira et al. (2003) of 675 students from nine junior high schools. This was a two-wave study with a 5-month interval, and researchers measured the amount of internet use at home. Analysis of data indicated that home internet use had a significant effect on improving the ability to collect information but no other information competency components. In addition, as with the case of elementary school students, the researchers found that the ability to process information promoted internet use and the ability to communicate information appropriately promoted email use. Takahira et al. (2002) also conducted another study of 201 senior high school students. Again, they measured the amount of internet use at home. The result of data analysis indicated that home internet use only had a significant effect on improving the ability to evaluate information while it weakened the ability to create information. No significant effect was observed regarding the ability to collect information.

Mouri et al. (2002) conducted a panel study to examine the effect of computer use at school. From 34 senior high schools, 2304 students participated in the study. Measurements were performed with a 6-month interval. The study showed that, while computer use influenced the ability to operate a computer, it had almost no effect on information competencies. The researchers then conducted a survey of teachers of the participating schools. They examined the level of effort that each school put into information education and reanalyzed measurement data for the schools that actively implemented information education and for those that did not. As a result, the students of the schools that actively implemented information education showed the effect of computer use as improving their ability to operate a computer and also the ability to evaluate information.

In the paper reporting the influence of internet use on information competencies of junior high school students described above, Takahira et al. (2003) also reported the influence of internet use on the ability to contribute to a desirable information society. The result indicated almost no significant effect due to internet use. It even had a significant negative effect on readiness for information from mass media. In the study of senior high school students by Takahira et al. (2002) described above,, internet use also showed almost no significant effect on their ability to contribute to a desirable information society.

The Causal Relationship Between ICT Use and Information Literacy

Only a few extensive evaluation studies have recently been conducted to analyze the causal relationship between ICT use and information literacy. This maintains the relevance of earlier evaluation studies. There are some possible reasons for the decline in the number of evaluation studies. First, current educational science thinking places importance on practicability of studies. This may deter researchers from conducting scientific evaluation studies. Second, it has become difficult to obtain the permission of schools to conduct evaluation studies with students due to human rights concerns. However, some studies in other regions of the world have produced findings with causal inference, and at least one large-scale study has been conducted across nations that tends to provide correlational evidence relevant to findings with causal inferences previously reported. For example, the European

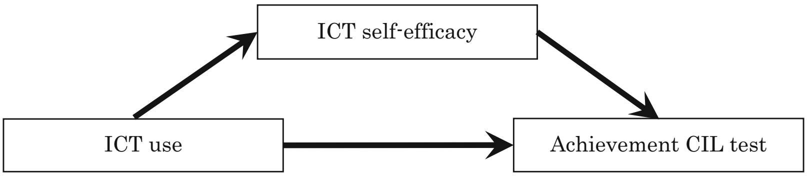


Fig. 4 Indirect effect of ICT use on computer and information literacy (CIL) achievement via ICT self-efficacy (Source: Adapted from Rohatgi et al. 2016, p. 107)

Commission's ET2020 strategy framework identified the innovative use of ICT as a priority and catalyst for achieving transformation in education (Brecko et al. 2014).

In another large-scale analysis, Rohatgi et al. (2016) analyzed Norwegian data obtained from the International Computer and Information Literacy Study (ICILS) in 2013 ($N = 2410$ students in grade level 9) and found through structural equation modeling that there is an indirect effect of ICT use on computer and information literacy (CIL) achievement via ICT self-efficacy (Fig. 4). The indirect effect was significant and positive for students' ICT use for task learning via basic ICT self-efficacy (beta = 0.03, $p < 0.001$), with similar but stronger effects for recreational uses of ICT and basic ICT self-efficacy (beta = 0.07). For students' ICT use for study purposes, the indirect effects were not significant. By way of contrast, none of the direct effects of ICT use on CIL achievement were significant at the $p < 0.05$ level. Rohatgi et al. (2016) viewed these findings as strong support for the indirect effect of ICT use on computer and information literacy achievement, via ICT self-efficacy.

Brecko et al. (2014) polled 149 educational stakeholders to evaluate a set of 60 policy recommendations developed during the "Up-Scaling Creative Classrooms in Europe" (SCALE CCR) project of the European Commission, in order to produce seven clusters of recommendations and a top ten list. Under the infrastructure cluster was the third recommendation, to "ensure that all learners have equal and ubiquitous ICT access, in and out of school" (p. 5). These recommendations by EC educational stakeholders reinforce the implications of the research by Rohatgi et al. (2016) that access to information technology outside of school appears to be critical for fostering high computer and information literacy in many parts of the world.

Summary of Insights Regarding ICT Use and Information Literacy

The results of quasi-experiments and panel studies introduced in this chapter, in the context of relational studies or expert opinion compendiums from other regions of the world, lead to the following insights.

First, both quasi-experiments and panel studies indicate that ICT use can improve information competencies. In particular, the abilities to collect and evaluate information can be improved by even daily internet use, as suggested by the panel study results. To heighten information competencies, therefore, promotion of ICT use should be effective. This could support such recent international frameworks and orientations on information education and recent findings of major research on educational ICT use as previously mentioned. This can also be regarded as providing evidence of causality underlying those frameworks and orientations.

Second, unlike for information competencies, ICT use was not found to improve the ability to contribute to a desirable information society. More frequent ICT use of course tends to cause more information ethics issues and online safety problems. As far as the study results are concerned, however, it is quite unlikely that individuals can naturally acquire high-level information ethics and online safety just because they use ICT. This means that students who start or increase the use of ICT must be provided with education designed to improve their ability to contribute to a desirable information society, with a special emphasis on information ethics and online safety.

Third, quasi-experiments and panel studies produce different results. While the quasi-experiments indicated that ICT use could promote the majority of components of information competencies, the panel studies suggested that ICT had a limited effect. This may be explained by the fact that ICT use measured in the quasi-experiments was a part of class or school activities with an educational purpose. In fact, it has been suggested that giving educational meaning to ICT use is important to heighten its effect (Condie and Munro 2006). On the other hand, positive effects detected by the panel studies existed, even if they were limited. As mentioned in the first section of this chapter, it seems that researchers have documented the positive effects of ICT use not only at school but also at home (Scherer et al. 2017). Actually, the sophistication of ICT use at home has been observed (Biagi and Loi 2012; Steinkuehler and Duncan 2008), and additionally some research results which suggest the importance of home use have been presented (Brecko et al. 2014; Rohatgi et al. 2016). It therefore seems that the results of panel studies do not contradict international expectations and findings on ICT home use. Fraillon et al. (2013b) showed that (a) ICT use was much more frequent at home than any other place, (b) the amount of ICT use at home was positively correlated with CIL, and (c) the amount of ICT use at school was also correlated with CIL. This suggests that if children learn the appropriate use of ICT at school, it could lead to the appropriate use at home, and consequently CIL would be improved. Future studies should examine the types of usage of ICT at home that have positive educational effects and how the effects of home use can be enhanced through school education,

Fourth, according to the results of the panel studies presented in this chapter, the effect of ICT use on information competencies may vary with user age. More specifically, it seems to be the most effective on elementary school students and the least effective on senior high school students. The effect on junior high school students is in the middle. These study results match the traditional argument that the effect of ICT use is strong on elementary school students and weak on secondary school students (Balanskat et al. 2006). Components of information literacy that are influenced by ICT use may also vary with user age. In the panel studies of elementary and junior high school students, ICT use improved their ability to collect information. In similar studies of senior high school students, on the other hand, ICT use improved their ability to evaluate rather than collect information. Generally speaking, if individuals are unable to collect much information, they will have only limited opportunities to evaluate the quality of information, and this may prohibit improvement of the ability to evaluate information. The elementary and junior high school students participating in the panel studies may have shown the effect of ICT use on only the ability to collect information because they had little experience with ICT at the time of study, while the senior high school students may no longer have shown the effect on the ability to collect information but, instead, the ability to evaluate information, which is supported by the ability to collect information, because they already had it established through their earlier experiences.

Fifth, among information competencies, the ability to create information was found unlikely to improve through ICT use. Both the quasi-experiments and panel studies failed to show any improvement. Different studies that measured the ability to create information through tests also failed to find any effect of ICT use (Sakamoto and Sakamoto 1993; Sakamoto et al. 1998). Whether or not ICT use improves the creativity of users has been discussed for a very long time. While optimistic opinions have been presented frequently (Clements 1995; Loveless 2002), some still argue that sufficient testing is necessary (Scherer 2016). As far as the Japanese study results are concerned, it seems to be difficult to have an optimistic view toward the effect of ICT use on creativity. Given that it is not easy to improve creativity, it would seem particularly important to consider educational approaches to improving it.

Finally, the panel studies often indicated a reverse causal relationship in which information competencies promoted ICT use. Students' attitudes toward using ICT and their ICT skills have been found to be important in promotion of ICT use (Knezek and Christensen 2008). The result of Japanese studies suggests that like attitudes toward ICT skills and ICT skills themselves, information competencies could be included in the set of student variables that promote ICT use.

Conclusion

Researchers' interest in the educational impact of ICT use has a long history, and this issue has been studied in Japan as well as other countries. Quasi-experiments and panel studies have often been used in Japan, and these methodologies have strength in the identification of causality. This chapter reported the findings of Japanese research on the impact of ICT use on children's information literacy, while aligning the concept of information literacy in Japan with its major concepts in other countries. Japanese researchers have presented many research results which indicate positive effects of ICT use on information literacy. In particular, positive effects on the ability to collect information from a lot of resources and to appropriately evaluate the authenticity and value of each piece of information have often been identified. Japanese research has also indicated that not only ICT use at school but also the use at home could have positive effects, and therefore home use cannot be ignored. These findings are consistent with current international orientations on the issue of the educational impact of ICT use and also provide strengthened evidence of causality. It seems that research on the impact of home use becomes necessary to be continued worldwide. If so, quasi-experiments and panel studies would be options for the research, and Japanese research studies could also be referred to as a sample of these methodologies.

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The Interaction of Psychological Constructs with Information Technology-Enhanced Teaching and Learning 20

Yaacov J. Katz

Contents

Abstract

Information Technology (IT) has developed into an effective teaching media available to educators. Research evidence clearly indicates that the effective use of IT-based tools by teachers leads to the enhancement of elementary and secondary school students' learning achievement and all-round educational performance.

However, effective utilization of IT-based tools by teachers for the benefit of their students is almost totally dependent on the existence of relevant constructs in teachers' and students' affective arsenals. Constructs that characterize teachers such as teacher change, teacher knowledge, and pedagogical beliefs as well as

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affective constructs that typify both teachers and students such as autonomy, creativity, flexibility, motivation, satisfaction, and self-efficacy (that includes technological self-confidence) are vital tools in the repertoire of teachers and students needed to maximize the positive effect of IT-based tools in the classroom.

Educational administrators need to formulate pre-service as well in-service teacher training programs that include the enhancement of those constructs needed to successfully mediate the efficient use of IT-based tools that will conceivably lead to the promotion of student achievement and all-round performance in the educational process.

Keywords

IT enhanced teaching · IT enhanced learning · Psychological constructs of teachers · Psychological constructs of learners

Introduction

Information Technology (IT) has gradually become an indispensable educational medium. Since the 1960s when the first attempts were made to implement mass IT-based instruction in the educational system, teachers have accumulated valuable experience that has increased the potent use of IT-based tools as a teaching and learning medium. Achievement levels attained by students have gradually and moderately improved as a result of the use of IT-based tools in the teaching and learning processes, and there is increasing evidence that the efficient use of IT-based tools by teachers is related to teaching variables such as teacher change, teacher knowledge, and pedagogical beliefs of teachers as well as to affective variables, such as autonomy, creativity, flexibility, motivation, and self-efficacy (including technological self-confidence) of both teachers and students (Katz 2014a).

This chapter will address the relationship between IT-based tools used in teaching and learning and enhanced educational achievement as well as the mediating contribution of key variables demonstrated in numerous studies to contribute significantly to the effective use of IT-based tools in teaching and learning. The key variables related to effective teaching with IT-based tools include teacher learning and knowledge about educational technology (Riel and Becker 2008) as well as teacher change, teacher self-efficacy, and pedagogical beliefs of teachers (Ertmer and Ottenbreit-Leftwich 2010). In addition, research evidence has indicated the existence of key affective variables associated with effective teaching and learning, such as autonomy, creativity, flexibility, motivation, satisfaction, and self-efficacy (including technological self-confidence) of both teachers and students (Katz 2014a). The different uses of IT-based tools will be addressed as they relate to the development and implementation in the educational system. One needs to bear in mind that teachers utilizing IT-based tools for their teaching usually use a number of IT-based tools, depending on the specific characteristics of the content being taught as well as the specific needs of the students. Thus the evolution of the different types and levels of IT-based tools generally used by teachers will be described in the first section of the chapter. Thereafter the relationship of the aforementioned variables, such as teacher change, teacher knowledge, pedagogical beliefs of teachers, as well as autonomy, creativity, flexibility, motivation, satisfaction, self-efficacy (that includes technological self-confidence), of both teachers and students regarding the use of IT-based tools and the mediating power of these variables and their contribution to the enhancement of students' performance and their positive feelings towards their studies will be examined in the second section of the chapter.

IT-Based Tools

IT-based tools can be divided into two distinct categories. The first category consists of those tools that are confined to predefined and inflexible teaching that is based on offline software packages uploaded onto computers and used by teachers and students in the classroom. These tools deliver subject matter and are based on the software present on the computers at the disposal of teachers and on the ability of teachers to efficiently use the software for their teaching. The second category is characterized by the use of flexible IT-based tools mainly imported via online Internet access where the teachers' role is to facilitate students' use of the Internet delivered content rather than to directly instruct the students. Following are overviews of the two categories of IT-based tools.

Evolution of IT Teaching and Learning Tools

The evolution from inflexible or preset ("closed") or flexible ("open") IT-based tools ran parallel to the introduction of different learning approaches in the educational system (van Rooij 2009). Beginning with the behavioristic approach associated with the use of totally inflexible "closed" IT-based tools, through the introduction of more flexible "open" IT-based tools explained by the constructivist approach to learning, culminating with advanced and totally "open" IT-based tools backed by cognitivist and social learning approaches, the centrality of IT in the educational system was entrenched.

Skinner (1958) was among the first researchers to address the implementation of IT-based tools in education and published a study in which he described teaching machines and cautiously predicted that these machines would make teaching dramatically more efficient. The first computers introduced into the educational systems in the developed world in the 1960s and 1970s were minicomputers with individual terminals available for use by students. These minicomputers utilized software used by teachers in order to assist their students to perform drill and practice as well as for evaluation of students' progress and achievement in language and mathematics (Kuiper and de Pater-Sneep 2014). These systems were totally inflexible, i.e., closed, with teachers unable to effect any changes in the computer software and served as teaching aids that complemented traditional classroom lessons. Teachers diligently followed students' progress in language and mathematics as mapped out by the computer software and planned their traditional language and mathematics lessons accordingly. The minicomputer system with terminals was widely used and popularized the initial use of IT in the educational systems in the developed world.

Drill and Practice

When the first generation of personal computers became commercially available in the developed world, Apple IIs, Ataris, and Commodore CBMs personal computers connected in rudimentary networks, began replacing the minicomputers and terminals in the school systems. Teachers closely followed inflexible computerized syllabi in a limited number of subjects, among them languages, mathematics, and science. This generation of PCs also drew on behavioral theory (Bryant and Hunton 2000) and the software packages offered to the educational systems were used to complement traditional teaching and were considered to be especially advantageous in providing students with a robust platform for revision after learning via traditional teacher-student face-to-face instruction.

Spreadsheets

Educational researchers began questioning the validity of totally behaviorist learning (such as drill and practice) as a valid theoretical source and inspiration for IT use in the educational system. Additional questions were raised that addressed the relative advantages, effectiveness, and cost-efficiency of inflexible "closed" IT-based tools used in drill and practice. Heated debates characterized the educational establishment regarding the direction to be taken in the use of IT-based tools in the educational system and as a result of these debates other theoretical approaches were suggested. Thus, constructivist theory came to the forefront in the developed world, albeit alongside the behaviorist approach (Salomon 1996), and led to the gradual development and adoption of more flexible use of "open" IT-based tools and learning programs that were introduced into the educational systems. For example, in Israel the use of electronic spreadsheets (Dreyfus et al. 1997) was introduced using IT-based tools that, to a certain extent, enhanced students' autonomy and creativity and provided them with sophisticated graphic assistance that contributed to added understanding of complicated subject matter. Databases, which were also developed and incorporated in this stage of development of IT-based tools (Appelberg 1997), provided students with the opportunity of enriching their knowledge and comprehension of subject matter by facilitating the search for sources hitherto available only in libraries and museums. Aydin (2005) noted that the introduction of the use of spreadsheets and databases in the educational process contributed to the introduction of improved IT-based tools in education leading to enhanced teaching and learning.

Simulation

As time passed and IT became more developed and sophisticated, the constructivist learning model almost totally replaced the behaviorist approach and motivated the introduction of simulation software into developed educational systems. For example, Kaufman and Ireland (2016) described simulation technology as a sophisticated and enhanced methodology that utilizes IT-based tools designed to generate situations similar to those that exist in reality and to introduce these situations into the instructional and learning processes. They noted that educational technology simulations are based on dynamic interaction between the learner and the instructional computer program and may be defined as part of a modeling process that involves the execution of the model by the learner. Through the methodology of simulation, teachers were able to provide their students with realistic models of subject matter thereby facilitating students' understanding and mastery of learning. Wang et al. (2014) cited simulation as especially effective for the science and technology subjects where experiments can be conducted using IT-based tools instead of having to prepare and use materials in the traditional science or technology laboratory.

Delialioglu and Yildirim (2007) indicated how the use of IT-based tools contributed to enhanced cognitivist learning and to students' use of higher order thinking skills in the learning process. Baran and Maskan (2013) confirmed that the achievement of students who experienced instruction and learning via simulation with IT-based tools was usually on a par with or even outstripped achievement of students exposed solely to teaching and learning situations that did not simulate reality.

Virtual and Augmented Reality

Additional IT development in educational systems focused on virtual reality and augmented reality technologies, closely associated with cognitivist learning (Lúcia and Rubens 2004). Tiala (2007) defined virtual reality technology as a highly interactive IT-based environment in which the user becomes a fully-fledged partner in a virtual world. When experiencing virtual reality, the user becomes an immersed participant in the technology generated virtual reality program. Psotka (2013) confirmed that upon entry into the virtual world students feel physically immersed in that world and undergo physical, cognitive, and emotional experiences very similar to those that exist in the real world in which they live. He added that the use of virtual reality technology in instruction positively contributes to enhanced cognitive performance of learners. Thus virtual reality with advanced IT-based tools provides both cognitivist learning and understanding that surpass achievement characterized by more traditional approaches (Zinchenko et al. 2010).

Augmented reality was developed as an offshoot of virtual reality (Bacca et al. 2014) and even further enhances cognitivist learning. An augmented reality system allows for combining or supplementing real world objects with virtual objects or superimposed information. As a result virtual objects seem to coexist in the same space with the real world (Azuma et al. 2011). However, augmented reality is not restricted only to the sense of sight; it can be applied to all senses such as hearing, touch, and smell. Augmented reality allows for combining virtual content with the real world, thereby differing from the notion of a virtual reality environment where the user is completely immersed inside a synthetic environment (Azuma et al. 2011). In this sense, augmented reality supplements reality, rather than completely replacing it and is better equipped to enhance constructivist learning where the learners are able to utilize all their physical and cognitive faculties in their thinking processes. According to Azuma et al. (2011), augmented reality has been shown to enhance students' learning and achievement.

Internet-Based Learning

A further breakthrough in the use of IT in educational settings occurred with the development of IT-based tools delivered via the Internet as well as distance learning. Internet-based distance learning provides students in the educational system with new opportunities to study efficiently when the location where teaching originates may be separated by geographical distances from the learning centers. Instructional activity through the medium of Internet-based learning systems was redefined to include and focus on teaching and learning based on teacher-student interaction (Johnson 2006). Interaction through the medium of Internet or Intranet offers one-to-one or one-to-many interaction in which teachers and students are able to communicate synchronously or asynchronously thereby solving key instructional and learning problems.

Tsai (2004) proposed that Internet-based learning provides an adequate context that facilitates the development of evaluative standards by learners. The standards are used to judge the information and knowledge acquired from online environments. Tsai found that students who were exposed to sophisticated Internet-based teaching and learning perceived an increase in their learning potential and an enhancement of their ability to process content and to access valuable learning resources. Abdallah (2009) indicated that the latest Internet-based teaching and learning strategies contribute to improved quality of students' learning and provide students with content and resources that are easily accessible. In summary, research evidence indicates that creating, sharing, and knowledge capitalization are all efficiently and effectively facilitated by Internet-based student-centered teaching and learning packages.

Mobile Learning

Mobile learning, a specific development of Internet-based learning, offers a learning environment that is especially characterized by flexibility offered to the learner as it is not bound by space or time (Katz 2014a). It should be noted that the use of mobile learning provides enhanced technological possibilities on small hand-held devices such as Ipads, tablets, and smartphones which include among other features, text, voice, still-camera, video, paging, and geo-positioning capabilities. These tools provide a rich variety of IT-based delivery strategies that enhance teaching and flexible student-centered learning. Rui-Ting et al. (2014) indicated that mobile learning contributes significantly towards a more comprehensive cognitive educational environment for learning and confirmed that mobile learning has become an appropriate and key student-centered and self-regulatory learning channel in the educational system.

Mobile learning particularly provides opportunities to teach and learn through social networks (Kapuler 2011). Recent studies have indicated the increasing effectiveness of the contribution of social networks to the learning process. Alvarez and Olivera-Smith (2013) concluded that learning via social networking is positively received by students and contributes to an enhancement of student cognitive performance in the learning process. They added that social networks afford ample and potentially effective opportunities to improve student self-regulated learning at both school and university levels. Katz (2014a) indicated the relative efficiency of SMS, Facebook and WhatsApp delivery of learning as well as students' relative preferences regarding the different social network learning delivery platforms.

A number of research studies have indicated that students' academic achievement is positively related to the use of delivery platforms suited to mobile learning. Ituma (2011) confirmed that students who were enrolled in courses where learning was delivered by mobile applications had positive perceptions of the learning process and Chandra and Watters (2012) confirmed that learning physics through the medium of mobile learning delivery enhanced students' understanding of the content matter as well as learning outcomes.

It appears that the different types of IT-based tools that were developed over the years and described above lend themselves to enhance learning processes. As these tools developed and the learning platforms became more sophisticated, learning became more student-centered and led to student self-regulation, which in turn promoted student achievement and learning outcomes.

Interaction of Constructs with IT-Based Learning

After reviewing the literature dealing with evolving aspects of IT-based tools as presented in the previous section of this chapter, this section addresses the relationship between constructs characterizing teachers, on the one hand, and efficient and effective utilization of the IT-based tools mentioned in the previous section on the other. Evidence from research studies that examined the relationships of general and affective constructs and their contribution to the promotion of positive and effective IT-based teaching will be presented. Emphasis will be placed on constructs scientifically known to have significant relationships with the use of IT-based tools. General constructs are defined as those that are related to teaching and pedagogy and affective constructs may be defined as those variables that lend themselves to the enhancement of student cognitive activity and learning (Katz 2014b). Motivation is a typical example of an affective variable that is significantly related to the enhancement of learning. Thus the relationship between constructs and the use of IT in learning will be discussed in this section of the chapter.

Constructs and Learning with IT-Based Tools

Katz (2014a), among others, testified to the existence of constructs characterizing teachers at elementary and secondary school levels that contribute to the efficient utilization of IT for educational purposes. Teachers willing to use IT are typified by quite a large number of general constructs, most especially teacher change, teacher knowledge and pedagogical beliefs (Riel and Becker 2008; Ertmer and Ottenbreit-Leftwich 2010). In addition, Katz (2014a) indicated both teachers and students are characterized by affective constructs such as autonomy, creativity, flexibility, motivation, satisfaction, and self-efficacy (including technological self-confidence). Teachers characterized by positive attitudes toward some or all of these constructs have been more effective and efficient in their use of different IT-based tools than teachers not characterized by affective variables and students typified by the some or all of the affective constructs have reached enhanced learning and achievement levels. A sample of these research studies are presented below.

Teacher Change, Teacher Knowledge and Teacher Pedagogical Beliefs

Drent and Meelissen (2008) confirmed that teachers in elementary and secondary schools, who are characterized by certain constructs, are favorable towards the use of IT-based tools in the teaching process and that positive integration of IT in classroom teaching and learning is highly dependent on the existence of these constructs. Riel and Becker (2008) indicated that teacher knowledge about the use of IT in their teaching as well as ongoing teacher collaboration in developing IT knowledge and skills for effective teaching are necessary preconditions for the efficient utilization of technology in teaching. Ertmer and Ottenbreit-Leftwich (2010) described how teachers' positive attitudinal change towards the use of IT-based tools in their teaching as well as teachers' pedagogical beliefs about the added value of the use of IT in their teaching are essential prerequisites for effective use of IT in the educational process. They added that it is critically important that teachers believe in their own abilities to implement these changes within their classrooms. Teachers who positively strengthen their pedagogical beliefs and adopt the notion that effective teaching includes the use of IT-based tools also need to be reinforced with evidence that student thinking and learning processes as well as achievement are significantly enhanced by the use of IT-based tools in teaching and learning.

Additional research studies have indicated that teachers and students who hold positive perceptions of their autonomy, creativity, flexibility, motivation, satisfaction, self-efficacy (including technological self-confidence) are significantly more positive towards the utilization of IT-based tools in their teaching and learning than those who do not hold similar affective constructs.

Autonomy

Webb and Cox (2004) contended that the move from teacher centered to student centered pedagogy depends significantly on the level of autonomy of the teacher and the ability of the teacher to adapt teaching to the use of IT-based tools. Tijdens and Steijn (2005) found that autonomy of both teachers and learners is one of the key factors contributing to the ability of the learner to master learning material when using IT-based tools. Granic et al. (2009) added that teacher and learner autonomy is a significant factor that contributes to effective use of technology-based mobile learning. Katz (2014a) confirmed the relationship between teacher autonomy and learner autonomy and effective utilization of technology in the teaching and learning processes. Thus autonomy characterizing both teachers and students can be considered as an important construct that serves as a prerequisite for effective and enhanced teaching and learning with IT-based tools.

Creativity

According to Henriksen and Mishra (2015), creative teachers show a willingness to try new things and use innovative educational approaches such as the harnessing of IT-based tools in their teaching. As a result of teachers' creative use of IT, students tend to be enthusiastic in their studies and are able to acquire the skills necessary for success in problem solving and applying knowledge (Zhao 2012). Henriksen et al. (2016) contended that the use of creative approaches by teachers fosters new methods of utilizing IT for pedagogical purposes, and in a reciprocal way, IT in teaching can stimulate and expand teacher and student creativity.

Peterson and Harrison (2005) postulated that the ability of the teacher to foster a creative atmosphere in the classroom contributes significantly to the creativity of students and enhances their effective use of IT-based tools in learning. Hosseini (2014) confirmed that teachers, characterized by their ability to promote a creative atmosphere among their students in their classrooms, contributed significantly to the enhanced and effective use of IT by students in their learning processes.

Thus the use of IT-based instruction and learning in the classroom is highly dependent on the creativity of both teachers and students as well as on the ability of the teacher to foster a creative atmosphere in the classroom. Creativity is a focal affective construct positively related to effective use of IT-based tools in the classroom.

Flexibility

Ravitz and Becker (2000) indicated that teachers who embrace flexible teaching philosophies are more positive towards the use of IT-based tools in their teaching. Himsworth (2007) studied the relationship between the use of IT by teachers in their teaching practices and their pedagogical beliefs. Results of the study indicated that teachers whose pedagogical beliefs were more flexible and democratic in nature use IT-based tools in their teaching more frequently than teachers who have more traditional pedagogical and authoritative beliefs. These results were later confirmed by Ertmer and Ottenbreit-Leftwich (2010). Ying-Shao et al. (2007) reaffirmed that flexibility is a defining factor in teachers' ability to more readily use IT-based tools in their teaching and classroom practice and to enhance the flexibility of their students in the cognitive and learning processes. Malik (2009) described the twenty-first century teacher as one who flexibly imparts education and helps students to adopt flexible learning strategies, especially when using IT-based tools. Hsu (2016) confirmed that teachers who hold flexible pedagogical beliefs as well as positive attitudes toward flexible innovation in students' thinking and learning are highly disposed towards the use of IT-based tools in their teaching and more significantly stimulate the cognitive and learning processes of their students.

Thus the affective flexibility construct is significantly related to teaching with IT and to the enhancement of students' flexibility in the learning process.

Motivation

Katz (2014a) confirmed that the use of IT-based tools by teachers provides them, as well as their students, with teaching and learning opportunities that motivate them to more effectively address the study material than traditional instruction that does not utilize IT-based tools. Both teachers and students involved in teaching and learning via IT-based educational packages indicated higher levels of motivation when involved in the educational process and also felt that they were more in control of the teaching and learning processes than teachers and students who used less IT in their teaching. In addition, the teachers and students exposed to IT-based tools perceived teacher-student interactions to be more positive and intense than in classrooms where teaching did not include significant use of IT.

Ying-Shao et al. (2007) declared that teachers' and students' motivation, beliefs, and attitudes toward IT use in teaching and learning as well as readily available technological resources are major factors that enhanced their efficient use of IT-based tools in teaching and learning. They emphasized that teachers' motivation and beliefs regarding IT are the major predictors of teacher IT preferences as well as enhanced teacher-student interactions and student achievement. Conversely, a lack of motivation or strong beliefs and attitudes toward the use of IT-based tools in teaching contributes significantly to teacher's hesitation to use IT in their teaching as well as to reduced teacher-student classroom interactions.

Katz (2014a) presented a number of studies that indicated that student motivation to utilize IT-based tools in the learning process significantly contributes to the enhancement of learning skills and academic achievement. Thus it appears that motivation is a central affective construct that spurs both teachers and students on to utilize IT-based tools in their teaching and learning and promotes efficient and enhanced learning and achievement.

Satisfaction

In a comprehensive research study, Katz (2014a) found that one of the key constructs that positively affects teacher and student performance is the satisfaction of both teachers and students with the introduction of IT-based tools into the teaching and learning processes. When teachers and students utilize IT-based tools in teaching and learning, the level of their satisfaction with the educational process increases as does student performance. Small et al. (2012), who also addressed the issue of teacher satisfaction with the use of IT-based tools in their teaching, found that teachers who utilize IT in their teaching are more satisfied with their teaching and are better liked and respected by their students. Tsai (2012) confirmed that teacher satisfaction with the use of IT-based tools in the teaching process enhances teaching effectiveness.

Sahin and Mack (2008) demonstrated how student satisfaction with the use of IT in the learning process ultimately leads to higher levels of student engagement, learning, and success. Goyal et al. (2011) confirmed that satisfaction with the use of IT-based tools in the learning process significantly explains the enhancement of students' learning performance. Mayer et al. (2017) confirmed that a student-centered IT-based learning environment fosters student satisfaction with the learning process. The above evidence emphasizes the key relationship between satisfaction of both teachers and students resulting from the use of IT in the teaching and learning processes.

Self-Efficacy (That Includes Technological Self-Confidence)

According to Kumar and Kumar (2003), the positive attitude of science teachers toward the use of IT-based tools in their teaching may be attributed to their positive experiences with the use of IT in teaching and the resulting feelings of self-efficacy and technological self-confidence in their use of IT-based tools in the classroom. Watson (2006) concurred that a feeling of self-efficacy and technological self-efficacy of teachers leads them to permanently use IT-based tools in their classroom teaching, and Anderson and Maninger (2007) found that pre-service teachers' self-efficacy was the best predictor of technology use in the training classroom. Ertmer and Ottenbreit-Leftwich (2010) described how positive teacher change towards the adoption of IT-based tools in their teaching contributes to their feeling of teacher self-efficacy which is of paramount importance in the effective use of IT in teaching. Jarvis et al. (2011) confirmed that self-efficacy and technological self-confidence in the use of student-centered IT-based tools in the teaching of science is a major factor that contributes to the enhancement of learning. Yaprak (2014) observed a significant relationship between teachers' feelings of IT self-efficacy and their willingness to use flexible IT-based tools in their teaching. Hsu (2016) indicated that personal dispositions of teachers, such as openness to change and innovation towards the use of educational technology, lead to an increase in their feelings of self-efficacy and technological self-confidence towards the use of IT-based tools in their teaching.

The results and conclusions of the research studies described above lead to a clear understanding that teachers' perceptions of their self-efficacy is significantly related to their willingness to use IT-based tools in their teaching. Varol (2013) confirmed the existence of a reciprocal relationship between self-efficacy and technological self-confidence of teachers and their use of IT in their teaching. The higher the teachers' level of self-efficacy and technological self-confidence, the more they tend to use IT-based tools in their classrooms.

In summary it may be concluded that self-efficacy that includes technological self-confidence is a key factor motivating teachers to use IT-based tools in their teaching. When teachers perceive themselves to be in command and control of technology then the way is clear for them to employ IT-based tools for the benefit and enhancement of their students' cognitive performance as well as their learning and achievement.

Conclusions

This chapter described the different IT-based tools that have been developed and introduced into elementary and secondary school classrooms since the 1960s. The penetration of IT-based tools began with the use of initial inflexible and closed technologies such as drill and practice software; continued with the use of more flexible and open electronic spreadsheets, student-centered simulation, and virtual and augmented reality technologies; and is now characterized by different facets of Internet-based technologies that allow for the use of totally flexible IT-based tools in their teaching. IT-based tools have contributed to a major change in the art of teaching and have significantly contributed to a situation where teachers have progressed and evolved from classroom managers who directly teach their frequently passive and accepting students into mentors and facilitators who teach indirectly by assisting and prodding their typically active and investigative students into student-centered meaningful cognitive learning experiences.

However, the teaching potential and educational advantages presented by IT can be maximized only by teachers who possess suitable and relevant constructs that over the years have been shown to facilitate and enhance effective and efficient utilization of IT-based tools in school classrooms. Research over the years has clearly indicated that teachers characterized by the positive teacher change, teacher knowledge, and pedagogical beliefs about IT use in the classroom as well teachers and students typified by affective constructs such as creativity, flexibility, motivation, and self-efficacy (that includes technological self-confidence) have a special ability to maximize the use of IT in their teaching in their quest to enhance student learning and all-round performance. Thus it is essential that during both pre-service and in-service teacher training, the relevant constructs that enhance the effective use of IT-based instructional strategies are intensively addressed and strengthened (Katz 2014b).

In light of the evidence pervading the research findings presented in this chapter, IT in general as an educational medium and the use of IT-based tools in particular have the potential to bring about a dramatic and continuous positive change in teaching and learning. However education policy makers as well as teachers and teacher trainers need to be acutely aware of the different constructs needed by teachers to utilize IT-based tools in their teaching. It is imperative that educational authorities allocate the necessary resources to enhance the development, adoption, and intensification of the necessary constructs by teachers so as to ensure effective and efficient use of IT-based tools in teaching and learning.

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Information and Communication Technology Dispositional Factors and Relationship to Information and Communication Technology Practices

21

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Abstract

Teacher dispositions reflect multiple internal factors that contribute to a teacher's decisions/behaviors in any given situation. There have been many studies focused on which dispositional factors lead to teachers' use of information and communications technology (ICT). Teachers' integration of ICT has been assessed in a variety of different ways – as a teacher's intention to use ICT, as the frequency of ICT use in the classroom, and/or as student-centered teaching practices with ICT. If a teacher's dispositions (i.e., attitudes, perceptions, values) are reflected through his or her behaviors, then we need to ask an important question about ICT practices: What specific dispositions do teachers need to use ICT in their classrooms? This chapter reviewed empirical studies that examined four primary dispositions associated with teachers' uses of ICT: self-efficacy, attitudes, pedagogical beliefs, and openness to change. This knowledge provides a robust starting point for answering more challenging and complex questions in the near future, such as: Why does a teacher hold certain dispositions, and how can we capitalize on that information to better support teachers in their actual use of ICT?.

Keywords

ICT · Beliefs · Knowledge · Attitudes · Self-efficacy · Teacher practices · Technology integration

Introduction

What makes a good teacher? This is a difficult question to answer. Oftentimes, it's a gut feeling – "He/she is just a natural teacher." Or it's offering a cliché – "you know it when you see it." Many have referred to this innate quality as a teacher's disposition, which typically encompasses his/her values, attitudes, beliefs, and personality characteristics. Ritchhart (2002) provided the common example of a "friendly disposition" to explain: "we tend to understand a disposition as a tendency toward a general type of action. When we talk about someone having a friendly disposition, we understand that to mean that the person tends to approach situations in a certain way and to display a general set of actions we associate with friendliness. No one action is specified, but rather a whole range of related actions and responses may be evident" (p. 20). Freeman (2007) further asserted that dispositions are closely associated with actual behavior, not just intentions or beliefs, which is why many accrediting institutions are now incorporating dispositions into their assessments of preservice teachers.

According to Wasicsko (2007), teacher dispositions encompass three main constructs: teacher perceptions (e.g., core values and beliefs), teacher characteristics (e.g., attitudes or tendencies consistently demonstrated), and teacher behaviors (e.g., observable activities). In general, these behaviors represent a teacher's internal characteristics and values. For instance, the 2006 standards published by the National Council for Accreditation of Teacher Education (NCATE) defined dispositions as "the values, commitments, and professional ethics that influence behaviors..." (p. 53). These values and commitments have been linked to the reasons teachers initially pursue the teaching profession. Studies have shown that college education majors assigned more importance to altruistic values that aligned with "a world at peace" and "being honest" than business students who selected values related to a "comfortable life" and "social recognition" (Feather and Collins 1974). In a more recent study of 99 student teachers and 125 in-service mentor teachers, Welch and Pitts (2010) found that both populations assigned primary importance to happiness, being loving, earning self-respect, responsibility, and honesty. Furthermore, Welch and Pitts found that the eight NCATE dispositions were promoted by their teacher education program positively with these values. The general idea is that teacher dispositions reflect multiple internal factors that contribute to a teacher's decisions/behaviors in any given situation.

Teachers' Uses of ICT

In the field of educational Information and Communications Technology (ICT), our main goal has been to support one specific behavior – teachers' integration of ICT. In reviewing the literature, we found that teachers' integration of ICT has been assessed in a variety of different ways – as a teacher's intention to use ICT, as the frequency of ICT use in the classroom, and/or as student-centered teaching practices with ICT.

Intention to Use ICT

Intentions to use ICT are often the easiest outcome to measure, but intentions do not always translate into practices (Ertmer et al. 2012). In one example, Teo (2009) surveyed 592 teachers in Singapore. Teo incorporated factors from several models (technology acceptance model, theory of planned behavior, and unified theory of acceptance and use of technology) to measure teachers' self-reported intentions to use ICT. Teachers' perceived usefulness of technology, positive attitudes toward ICT use, and facilitating conditions all directly influenced their intentions to use ICT. Measures of intentions to use ICT are often used with preservice teachers and determined through surveys or interviews (all self-reported). However, despite teachers' good intentions, barriers and other factors can significantly impact teachers' actual technology practices (Ertmer et al. 2012; Sadaf et al. 2012).

Frequency of ICT Use

Frequency of ICT use is another common outcome that can be assessed using surveys, interviews, or observations. Many researchers have examined the impact of different dispositional factors on the frequency of teachers' ICT use. For example, Inan and Lowther (2010a) surveyed 1,382 US teachers to examine which factors were related to self-reported frequency of ICT use. They reported that as a teacher's age and years of teaching experience increased, computer proficiency and self-reported frequency of ICT use tended to decrease.

However, Inan and Lowther (2010a) found that school-level factors (e.g., ICT resources, support) positively influenced computer proficiency. Teacher beliefs, readiness, and computer availability also were positively related to the frequency of teachers' uses of ICT. Still, as Rakes et al. (2006) found, frequency of ICT use, although positively associated with the number of times teachers used ICT, did not predict the use of student-centered ICT practices. The difficulty with this outcome (i.e., frequency of use) is that it is specifically focused on the dispositional factors needed to use ICT frequently. Is our goal to support teachers' *frequent* use of ICT, or is it to promote teachers' student-centered uses of ICT?

Student-Centered ICT Practices

Student-centered ICT practices are often the most difficult outcome to measure. Although this is the outcome posited by researchers and stakeholders (e.g., U.S. Department of Education 2016) as the eventual goal for teachers' ICT use, it is the least commonly measured. The dispositional factors necessary to support student-centered ICT practices may be different than those used to predict the previous two outcomes. For example, Chen (2010) constructed a SEM to examine the outcome of student-centered ICT uses for 206 preservice teachers during their student teaching experiences. Chen found that self-efficacy was the strongest total effect on use among the four factors (value, training, context, self-efficacy). ICT use was measured by survey responses to frequency of uses for students using ICT to (1) gather information or collect data, (2) conduct in-depth projects, and (3) communicate ideas via classroom presentations.

In other examples, researchers have examined the processes by which teachers design ICT lessons and implement them. However, these studies have often focused on the relationship between pedagogical beliefs and practices (Chiu and Churchill 2016; Ertmer et al. 2012; Prestridge 2014). Ertmer et al. (2012) found that teachers who implemented student-centered practices also self-reported high knowledge and attitudes toward ICT. However, the other teachers in the study, who did not implement student-centered practices, self-reported similarly high levels of knowledge and attitudes toward ICT. In Prestridge's (2012) study of eight teachers, she implemented a survey, followed by interviews and document analysis. Of the two teachers who described higher amounts of student-centered practices, Prestridge indicated they possessed "a high level of ICT competence and confidence to try new software and approaches" (p. 457). She suggested that the ICT competency-confidence relationship was important to consider when examining teachers' uses of ICT.

Teacher ICT Dispositions

If a teacher's dispositions (i.e., attitudes, perceptions, values) are reflected through his or her behaviors, then we need to ask an important question about ICT practices: What specific dispositions do teachers need in order to use ICT in their classrooms? Overall, the literature suggests that there are four primary dispositional factors associated with teachers' uses of ICT: self-efficacy, or a belief in one's own capability to use ICT to support teaching/learning; attitudes, or the extent to which teachers value ICT use or find it beneficial; pedagogical beliefs, or beliefs about teaching and learning and the role of technology in the teaching-learning process; and openness to change, or a willingness to incorporate new technologies or try new approaches to teaching with technology. In the sections that follow, we define each disposition and delineate the relationship between the disposition and teachers' ICT practices (i.e., intentions to use, frequency of use, and student centeredness). For each disposition, we also describe how others have successfully increased the factor to lead to more/better ICT practices.

Self-Efficacy

What Is Self-Efficacy?

Self-efficacy has often been referred to as one's belief in his/her capability to do a certain task. Thus, a teacher's self-efficacy refers to his/her belief in his/her capacity to complete teaching tasks. One literature analysis of 165 articles, focused on teacher self-efficacy, found that it has positive relationships with students' academic achievements, classroom quality, and even teachers' feelings of accomplishment, job satisfaction, and commitment (Zee and Koomen 2016). In the case of ICT use with teachers, self-efficacy is often referred to as teachers' belief in their capacity to use ICT for teaching and learning. Sometimes, scholars will also discuss computer self-efficacy, which is basically teachers' belief in their capacity to use computers in general.

Studies have also investigated a similar construct, perceived ease of use (e.g., Holden and Rada 2011), which we have also included within this dispositional factor. With regard to teachers' adoption of ICT, perceived ease of use encompasses how easy the teacher perceives it to be to use a particular ICT tool. Venkatesh and Davis (1996) stated that "an individual's perception of a particular system's ease of use is anchored to her or his general computer self-efficacy at all times" (p. 451). Therefore, although these terms are often mentioned separately, we consider them to be under the same conceptual disposition factor.

Finally, there is an abundance of studies examining teachers' TPACK (or technological pedagogical content knowledge) (Koehler et al. 2014). However, several scholars have suggested that TPACK is a construct that is difficult to measure (Kopcha et al. 2014). The measures typically used to examine TPACK are surveys, such as the Schmidt et al. (2009) survey, which ask teachers to self-report on their perception of their knowledge and/or abilities. When we measure self-efficacy for teachers, we typically use statements asking teachers to assess their capabilities with ICT (e.g., Schmidt et al. 2009). Therefore, scholars have begun to use TPACK surveys as measurements of self-efficacy (e.g., Abbitt 2011; Banas and York 2014; Kazu and Erten 2014) rather than knowledge.

How Does Self-Efficacy Relate to ICT Practices?

Teachers' self-efficacy is important to consider because teachers will tend to avoid activities for which they lack confidence, such as ICT use, and engage instead in activities that lead to success (Pajares and Schunk 2002). Researchers have found that preservice teachers' ICT self-efficacy is positively correlated to their intentions to use ICT in their future classrooms (Banas and York 2014; Celik and Yesilyurt 2013; Lee and Lee 2014; Sang et al. 2010). In addition, studies have found that in-service teachers' ICT self-efficacy can impact teachers' frequency of ICT use (Inan and Lowther 2010a; Pan and Franklin 2011; Turel 2014).

How Does Self-Efficacy Relate to Student-Centered ICT Practices?

While researchers have often measured the link between self-efficacy and intentions to use ICT and/or frequency of ICT use in the classroom, few have investigated the link between self-efficacy and teachers' use of ICT to support student-centered ICT practices. However, Chen (2010) asked 206 preservice teachers to self-report how often they used student-centered ICT practices during their student teaching experiences. Student-centered ICT practices included opportunities for students to use ICT to (1) gather information and/or collect data, (2) conduct in-depth projects, and (3) communicate ideas through classroom presentations. Chen (2010) also asked the preservice teachers to report on the training they had received in their teacher education programs, their skills, teaching beliefs, learning beliefs, computer self-efficacy, ICT integration efficacy, and contextual factors (support, time, access). Based on the results of Chen's survey, measures of preservice teachers' ICT self-efficacy had the strongest relationship to student-centered ICT use. However, this relationship was mediated by their perceived value of teaching and learning with ICT.

Limited research has been conducted on this factor with in-service teachers. However, Minshew and Anderson (2015) examined the 1:1 classroom practices of two middle school science and math teachers to determine how their dispositional factors (knowledge, self-efficacy) impacted those practices. Even when teachers had strong ICT self-efficacy, they still did not use ICT to support student-centered practices: "While Jake exhibited strong self-efficacy with respect to his science knowledge it was not observed in either his technological knowledge or in his pedagogical knowledge with respect to constructivist, inquiry-based practices of science" (p. 357). Dunn and Rakes (2010) also found a significant relationship between in-service teachers' learner-centered beliefs and ICT self-efficacy, but they did not examine teachers' actual practices.

How Can We Increase Self-Efficacy to Lead to More/Better ICT Practices?

Studies have shown that completing educational ICT courses tends to positively impact the ICT self-efficacy of preservice teachers (Albion 2001; Lee and Lee 2014). In addition, when preservice teachers participate in authentic learning experiences with ICT, their ICT self-efficacy has been shown to increase. For example, Lee and Lee (2014) found, in their study of 136 preservice teachers, that ICT self-efficacy was increased via lesson planning practice. Banas and York (2014) also found that authentic learning experiences (such as lesson design and microteaching) increased ICT self-efficacy and intentions to use ICT for 104 preservice teachers. Therefore, in order to increase preservice teachers' intentions to use ICT, teacher education programs should consider incorporating more authentic experiences related to planning lessons with ICT.

Student-teaching experiences may also impact preservice teachers' self-efficacy (Al-Awidi and Alghazo 2012; Flores 2015). Al-Awidi and Alghazo (2012) surveyed 62 preservice teachers before and after their student teaching experiences. The survey results showed an increase in ICT self-efficacy. They also conducted follow-up interviews with 16 of the preservice teachers who rated themselves highest in ICT self-efficacy. These preservice teachers reported that during their teacher education programs, the most influential experiences toward building their ICT self-efficacy were mastery experiences (e.g., self-exploration of tools and resources) and vicarious experiences (e.g., tips from supervisors or peers).

In general, many of the same approaches have been used to positively impact ICT self-efficacy of in-service teachers. Pan and Franklin (2011) found that professional development experiences were critical to increasing teachers' ICT self-efficacy. However, this recommendation is rather vague, stating that merely increasing the amount of time spent in PD will result in stronger self-efficacy, whereas others have suggested that specific approaches to PD (e.g., sustained, contextual, personalized) are needed in order to impact teachers' ICT use (DeSantis 2013; Lawless and Pellegrino 2007). DeSantis (2013) found that by providing ICT professional development experiences that were sustained, collaborative, and scaffolded, he was able to increase teachers' ICT self-efficacy with regard to interactive whiteboards. In order to create change in teachers' self-efficacy and learner-centered beliefs, Dunn and Rakes (2010) recommended that professional development begin by explaining the benefits and relevance of student-centered ICT use, including actual stories of real teachers and students. In addition, they suggested the use of observations and modeling as additional ways to increase in-service teachers' ICT self-efficacy.

Attitudes, Value Beliefs, and Subjective Norms About ICT

What Are Attitudes, Perceived Usefulness, Value Beliefs, and Subject(ive) Norms?

One dispositional factor that researchers indicate influences a teacher's adoption or use of ICT is the extent to which the teacher values ICT. This factor has been defined using many different terms: attitudes (Christensen 2002), perceived usefulness (Teo 2009), value beliefs (Ottenbreit-Leftwich et al. 2010), and even subject(ive) norm beliefs (Hazzan 2003). While all these terms have slight nuances in how they are measured or even conceptualized, we believe they all address the same question: Does the teacher find ICT useful and important for his/her teaching and learning?

How Do Attitudes Relate to ICT Practices?

Some studies have shown a strong relationship between teachers' attitudes (or perceived usefulness) and teachers' ICT practices. At the preservice level, attitudes are commonly tied to intentions to use ICT (e.g., Sadaf et al. 2012). For example, Sadaf et al. surveyed 286 preservice teachers in the United States to examine which factors predicted their intentions to use Web 2.0 tools in their future classrooms. They triangulated the survey findings with seven interviews. The two most significant predictors of preservice teachers' intentions to use Web 2.0 technologies were positive attitudes and perceptions of perceived usefulness. Furthermore, in their interviews, preservice teachers indicated that their intentions to use Web 2.0 technologies depended on the subjects and grade levels being taught. In another study, Yusop (2015) surveyed 100 preservice teachers to examine their intentions to use Web 2.0 technologies and to determine which factors predicted those intentions. Similar to Sadaf et al., Yusop found that attitudes were the most influential factor in determining preservice teachers' intentions to use Web 2.0 in their future classrooms. In another survey of 727 Chinese preservice teachers, Sang et al. (2010) also found that computer attitudes correlated with intentions to use ICT in their future classrooms.

Studies at the in-service level have also identified a relationship between teachers' attitudes and their ICT practices. In one survey of 242 Taiwanese secondary science teachers, Shiue (2007) found that teachers' attitudes and perceived usefulness impacted teachers' intentions and self-reported frequency of ICT use. Another survey of 460 Jordanian secondary teachers (Al-Zaidiyeen et al. 2010) found a significant correlation between teachers' attitudes about ICT for educational purposes and their self-reported frequency of ICT use. In another example, Chiu and Churchill (2016) examined how beliefs, attitudes, and anxiety levels of 62 secondary in-service teachers changed during the implementation of mobile devices in teaching. Half of the teachers were math and science teachers, while the other half taught language and humanities. Chiu and Churchill found that the mathematics and science teacher group significantly improved their views on the usefulness of ICT, but the language and humanities group did not experience similar changes. The authors suggested: "These changes appear to be influenced by subject matter culture and learning objectives in different subject areas. The mathematics and science group in this study found that the adoption of mobile technologies can help them achieve their teaching goals; the language and humanities group in this study found that mobile devices were not especially appropriate teaching and learning tools although they managed to make use of those devices" (p. 324).

How Do Attitudes Relate to Student-Centered ICT Practices?

How do teachers' attitudes relate to student-centered ICT practices? In other words, what do teachers' attitudes need to look like in order to support student-centered ICT practices? There are few studies that examine how teachers' attitudes influence, or are related to, student-centered ICT practices. Yagci (2016) surveyed 186 preservice Turkish teachers and found that their attitudes about ICT were related to their pedagogical beliefs. In other words, if a preservice teacher had positive attitudes toward ICT, they were more likely to have student-centered pedagogical beliefs (Yagci 2016). In another preservice survey of 727 Chinese teachers, Sang et al. (2010) found that computer attitudes were correlated with student-centered teaching beliefs.

In an example with in-service teachers, McKnight et al. (2016) examined a team of four teachers who reported strongly valuing ICT and using it in student-centered ways. However, the principal described being surprised that the ideals and attitudes shared by this small group of teachers had not spread to the rest of the school. Although it is plausible that teachers need positive attitudes about ICT to support student-centered ICT practices, the exact nature of those attitudes, as well as teachers' perceptions about what's valuable, still need to be investigated.

How Can We Increase Attitudes to Lead to More/Better ICT Practices?

In order to facilitate more positive teacher attitudes toward ICT, scholars have recommended ongoing PD support and collaboration with other teachers. For example, Christensen (2002) found that her ICT professional development impacted teachers' attitudes. Christensen (2002) examined three sites and the impact of ICT PD on teachers' attitudes and ICT practices: two sites provided district-determined ICT PD, while one site received needs-based ICT PD. The needs-based ICT PD included 2 intensive training days at the beginning of the school year with follow-up training every 6 weeks for the remainder of the year. Christensen found that the needs-based ICT PD had a "rapid, positive effect on teacher attitudes, such as computer anxiety, perceived importance of computers, and computer enjoyment" (p. 411), as well as increased self-reported frequency of computer use. Christensen recommended that ongoing and customized PD was critical to improving teachers' attitudes toward ICT, as well as frequency of use.

Context, such as school support and policies, can also influence teachers' attitudes (Blackwell et al. 2014; Teo 2009). Chiu and Churchill (2016) suggested that teachers may be worried about how ICT will impact their workload or evaluation. In another study of novice high school mathematics teachers' attitudes toward integrating ICT into their instruction, Hazzan (2003) found that perceptions of a negative undercurrent from veteran teachers discouraged novices from using ICT in their lessons. Therefore, schools and teacher education programs might consider creating communities that support the development of positive attitudes toward ICT use in education.

Drent and Meelissen (2008) found that one of the most critical factors for ICT use was "personal entrepreneurship," which directly influenced ICT attitude. The authors operationalized personal entrepreneurship as the number of contacts teachers have available for their own ICT professional growth. Schools and teacher education programs can support the development of personal entrepreneurship through learning communities and reflection activities (Drent and Meelissen 2008). In addition, Sang et al. (2010) recommended that in order to increase preservice teachers' positive attitudes toward ICT, teacher education programs should incorporate more real-life experiences within actual classroom settings.

Openness to Change

What Is Openness to Change?

A teacher's openness to change plays a key role in his/her decision to integrate technology. The characteristics of this disposition have been described in several ways – as a willingness to "try new instructional innovations" and "take risks in teaching" (Baylor and Ritchie 2002, p. 399) as well as "a willingness to commit one's time 'above and beyond the call of duty' and a risk-taking attitude" (Vanatta and Fordham 2004, p. 261). Of course, many teachers are apprehensive of integrating new technologies and practices in the classroom. This has led researchers to examine a teacher's lack of openness, often described as their resistance to change (Mathipa and Mukhari 2014) or anxieties (Chiu and Churchill 2016) over integrating technology. These characteristics of openness are highly related between and among each other and, overall, address the same overarching question: *Is the teacher willing to incorporate new technologies and new approaches to teaching with that technology in the classroom*?

What Evidence Supports the Relationship Between Openness to Change and Technology Practices?

The relationship between a teacher's openness to change and use of technology in the classroom was established over a decade ago. Overall, teachers who are more open to change tend to use ICT more frequently. In a study of 94 classrooms across four states, Baylor and Ritchie (2002) examined the relationships among 15 different predictors of technology use in the classroom (e.g., openness to change, level of planning, instructional use) and technology-related outcomes (e.g., frequency of use, qualities of use). The authors found that a teacher's openness to change was a statistically significant predictor of his/her ability to integrate technology in the classroom, as well as his/her plans to use technology to address higher-order thinking skills. Openness to change, when combined with strong technology leadership, was also a strong predictor of teachers' perceptions of, and plans to use, technology for students' acquisition of content. Vanatta and Fordham (2004) surveyed 170 teachers from 4 schools who were involved in a 3-year professional development project as part of a Preparing Tomorrow's Teachers to Use Technology (PT3) grant. Similar to Baylor and Ritchie, the authors found that openness to change and a willingness to invest additional time predicted teachers' uses of technology (e.g., presentations, email, Internet) when coupled with training. In both studies, openness to change was found to make a unique contribution to the predictive model when compared with related factors such as overall competency and ICT self-efficacy.

More recently, Blau and Peled (2012) surveyed 97 Israeli middle school teachers and found that both their openness to change and overall attitudes toward ICT implementation were significant predictors of teachers' uses of the Internet for professional purposes. In that same study, there was a strong relationship between teachers who volunteered to participate in a one-to-one laptop program and their openness to change. Among 527 teachers from 68 primary schools in Belgium, Tondeur et al. (2008) found that a school's willingness to be innovative was positively related with teachers' uses of technology for learning. Although the presence and capacity of classroom technology has changed dramatically over the past decade, these studies suggest that the relationship between a teacher's openness to change and his/her decision to integrate technology into teaching and learning has not.

Related to openness to change is the concept of resistance to change – that is, an attitude whereby teachers are resistant or unwilling to try new technologies or to use technology in their existing practices (Mathipa and Mukhari 2014). This resistance often stems from a teacher's perception that technology is not useful for teaching and learning and may represent a risk to his/her ability to teach successfully (Howard 2013; Mathipa and Mukhari 2014). Among 157 pre- and in-service teachers, Kimmons and Hall (2016) found that a teacher's decision to integrate technology is based largely on whether he/she thinks that technology will improve what he/she does as a teacher. The authors concluded that teachers who are resistant to change may not be reacting to the technology itself but rather to their perceptions of whether that technology is useful to them and their goals for student learning. This position on resistance to change is not new – other scholars have noted how teachers who resist technology often struggle to see how it improves teaching and learning (Becta 2004; Levin and Wadmany 2008).

What Evidence Supports the Relationship Between Openness to Change and Student-Centered Technology Practices?

The relationship between openness to change and student-centered technology practices is complex, demanding openness both epistemologically and technologically. While many studies have examined teachers' openness to change and overall technology use, far fewer have examined how openness to change impacts student-centered teaching practices. Those that have, however, suggest that an openness to change may be related to a teacher's use of student-centered practices with technology. For example, Baylor and Ritchie (2002) found that openness to change predicted both overall technology use as well as teachers' uses of technology for higher-order thinking, which included activities commonly associated with student-centered practices (e.g., analyze, compare, contrast, or evaluate resources). Tondeur et al. (2008) found that teachers were more likely to use technology for student-centered learning when their school was more willing to support innovative approaches to instruction. Likewise, Aldunate and Nussbaum (2013) found that teachers who were less willing to integrate technology were more likely to abandon their integration efforts when the technology became too complex to use. These studies suggest that the relationship between openness to change and teachers' uses of technology for student-centered learning is likely to be consistent with, if not more pronounced than, their uses of technology more broadly.

What Studies Show How We Can Increase Openness to Change to Lead to More/Better Technology Practices?

One way to improve a teacher's openness to change may be through professional development. In a detailed account of three teachers learning to integrate technology, Levin and Wadmany (2008) found that a teacher's openness to changes varied over time. In particular, they found that a teacher's level of openness increased as they adopt student-centered approaches and that these were associated with overall attitudes and beliefs about technology. The authors suggested that openness and centeredness represent a spectrum that teachers move through as they learn to integrate technology. Howard and Gigliotti (2016 detailed how one teacher developed specific coping strategies (e.g., relying on students to resolve technology issues, reverting to non-digital approaches as needed, developing a core set of teaching activities) over a 3-year one-to-one laptop initiative. The coping strategies addressed more complex uses of technology over time and played a key role in alleviating anxiety and improving the teacher's willingness to take risks and try new practices with technology. Other studies suggest that there is a relationship between a teacher's knowledge of integrating technology and willingness or interest in integrating technology into classroom practices (see Baylor and Ritchie 2002; Bingimlas 2009; Sang et al. 2010).

Another way to improve a teacher's openness to change may be through school culture. Recent studies suggest that teachers are more likely to integrate technology when the school offers a supportive environment. In a study of 1,030 Turkish teachers, Karaca et al. (2013) found that both principal and peer support are important factors that contribute to a teacher's overall attitude toward technology and, in turn, his/her decision to integrate technology in the classroom. Similarly, Tondeur et al. (2008) found that teachers who used technology in student-centered ways more often came from schools that supported innovative approaches to learning. Others have similarly found that school-related factors and support can contribute positively to a teacher's decision to integrate ICT in the classroom (Inan and Lowther 2010a, b; Tondeur et al. 2009).

Pedagogical Beliefs

What Are Pedagogical Beliefs?

Pedagogical beliefs, as they relate to ICT, typically include "teachers' educational beliefs about teaching and learning (referred to here as pedagogical beliefs)" (Ertmer 2005, p. 28). Many have often described pedagogical beliefs on a continuum, from teacher-centered to student-centered (Levin and Wadmany 2008). Teacher-centered beliefs with ICT typically support lower-level uses (e.g., drill and practice, lecturing, information presentation, etc.), while student-centered pedagogical beliefs typically support higher-order thinking skills (Dwyer et al. 1994). Others have suggested that a teacher may possess multiple beliefs with regard to ICT (Ertmer et al. 2015; Hsu 2016; Tondeur et al. 2016). Dwyer et al. (1994) described these pedagogical beliefs as "beliefs about classroom management, curriculum, collaborative learning, and other such issues" (p. 1).

Although most researchers have categorized beliefs on a continuum from teacher-centered/traditional to student-centered/constructivist, some researchers have attempted to create other categories to classify pedagogical beliefs. For example, based on her survey of 48 Australian teachers, Prestridge (2012) identified 4 categories of ICT beliefs and practices: foundational (general statements about using ICT in all subjects), developing (curriculum implications of ICT), skill-based (students need to develop ICT skills), and digital pedagogical practices (ICT promotes student-centered learning). Ertmer et al. (2012) also suggested terms focused on the role of technology in teachers' ICT practices: ICT to deliver content and reinforce skills, ICT to complement or enrich the curriculum, or ICT to transform teaching and learning.

What Evidence Supports the Relationship Between Pedagogical Beliefs and ICT Practices?

Some researchers have shown that teachers' espoused pedagogical beliefs do not align with their ICT practices (e.g., Liu 2011; Shifflet and Weilbacher 2015). For example, Liu (2011) surveyed 1,120 Taiwanese elementary teachers about their pedagogical beliefs and reported practices. Although most teachers ($n = 888$) reported constructivist beliefs, only 28.2% of these teachers reported implementing constructivist activities with ICT. However, of the teachers who reported traditional beliefs ($n = 232$), 80.2% of these teachers reported implementing traditional or lecture-based activities with ICT. Liu concluded that although most of the Taiwanese teachers expressed constructivist beliefs, their reported practices with ICT were typically traditional. However, these results were based on self-reported data.

Other studies have shown mixed results. In one survey with 1,230 Singaporean preservice teachers, Chai (2010) found that although those with traditional beliefs intended to use ICT in traditional ways, those with constructivist beliefs had broader intentions. Teachers who reported constructivist beliefs also reported intentions to use ICT to support both constructivist and traditional practices. In another survey of 152 US elementary teachers, Hsu (2016) compared teachers' self-reported pedagogical beliefs with their self-reported ICT practices. Among the teachers who participated, most identified their pedagogical beliefs as constructivist ($n = 120$), while some identified as traditional ($n = 32$). Of those teachers with constructivist pedagogical beliefs, 85% self-reported technology integration practices that contained eclectic instances (McCrory's (2006) framework of ICT's affordances for students to engage in high-level learning. McCrory classified these affordances as representation (illustrating ideas and processes that were difficult to represent without ICT), information (providing access to data or content), transformation (changing the tasks students engage in), and collaboration (ICT helps students communicate with peers/experts). For those teachers with traditional pedagogical beliefs, 68% reported using only information practices (e.g., Google searches) with ICT. Hsu then conducted follow-up interviews and observations with eight teachers representing a maximum range of grade levels, locations, and years of teaching experience. Similar results were found when actual practices were observed. Those teachers with constructivist pedagogical beliefs used two or more practices of high-level learning in their lessons, while those with traditional pedagogical beliefs utilized high-level learning practices.

Many researchers examining pedagogical beliefs and technology practices have used interviews and observations. These studies have typically found that pedagogical beliefs and technology practices did align (Kim et al. 2013; Prestridge 2012). In one example, Ertmer et al. (2012) examined the beliefs and practices of 12 US award-winning ICT-using teachers. Ertmer and colleagues found that in most instances, teachers' beliefs aligned with their actual practices. For those that expressed more traditional pedagogical beliefs in their interviews, their implementation of ICT usually supported the achievement of skills. For the teachers who held more constructivist beliefs, their implementation of ICT tended to support higher-order thinking skills. For the remaining two teachers who showed differences in their beliefs and practices, Ertmer and colleagues suggested this might have been due, in part, to contextual barriers (e.g., lack of resources). In another survey of 474 US teachers involved in a pilot study using technology, Overbay et al. (2010) found that those with constructivist beliefs were more likely to use technology and that there was a relationship between their beliefs and practices. Teachers who identified ICT as a useful tool to support student-centered learning were more likely to use technology.

What Studies Show How We Can Increase Pedagogical Beliefs to Lead to More/Better Technology Practices?

Lim and Chan (2007) implemented ICT experiences for 19 Singaporean preservice teachers, with the intent of changing their pedagogical beliefs to be more constructivist. After 8 weeks in a local school practicum, preservice teachers were asked to design an individualized ICT lesson. For the remaining 5 weeks of the course, preservice teachers were introduced to constructivist-based learning experiences with ICT and asked to design a collaborative lesson with others in the course. Lim and Chan collected the two lesson plans, conducted weekly beliefs surveys, and conducted three interviews (the preservice teacher with the largest increase in belief survey scores, smallest change, and largest decrease). Holistically, all individual ICT lessons used traditional instructional practices, whereas the collaborative lessons all used constructivist instructional practices. Lim and Chan suggest that this change indicates a change in preservice teachers' pedagogical beliefs. However, they concluded that merely providing exposure to constructivist theories was insufficient to change preservice teachers' pedagogical beliefs. In addition, they suggest that asking preservice teachers to reflect on their dissatisfaction with traditional instructional approaches, as well as helping preservice teachers to identify their perceived barriers to implementing constructivist instruction, may help change beliefs and practices.

Prestridge (2014) followed 16 teachers through an action research professional development program with ICT, wherein teachers were asked to reflectively blog. For the one teacher who consistently blogged, Prestridge was able to observe strong pedagogical changes. Prestridge suggests that the reasons the other teachers did not blog as often was because they did not find value in the reflection activity. However, she reasoned that if teachers received more guidance and support, they might see the value and reflective blogging has the potential to be more transformational for teachers' ICT pedagogical beliefs.

One of the earliest transformative stories emerged from the Apple Classrooms of Tomorrow (ACOT) research. In ACOT, Apple provided 32 US teachers with resources and support to integrate ICT in the late 1980s. Results showed that all 32 teachers moved through 5 stages of ICT integration, toward more constructivist learning experiences. After 4 years, Dwyer et al. (1994) described how teachers' beliefs need to be confronted: "Before teachers can reflect on their beliefs, then, they must somehow bring them to a conscious level, and they must see and understand the connection between their beliefs and their actions. They must also be aware of alternative belief systems and have experienced the consequences of those beliefs" (p. 37).

Connecting Dispositions to Knowledge

Knowledge in and of itself is not a teacher disposition. Dispositions are typically the attitudes and values that a person holds that help explain his/her behaviors. However, knowledge plays an important role in shaping a teacher's dispositions as well as predicting a teacher's use of ICT technologies. For example, teachers' pedagogical beliefs may grow as that they become more knowledgeable about using ICT to support student-centered approaches to learning (Ertmer and Ottenbreit-Leftwich 2010). This may, in turn, improve their attitudes about the value of ICT in the classroom (Ottenbreit-Leftwich et al. 2010). Similarly, teachers' pedagogical beliefs and attitudes toward ICT may grow more positive as they become more knowledgeable about using ICT to support student-centered approaches to learning (Howard and Gigliotti 2016; Levin and Wadmany 2008; Vanatta and Fordham 2004). Both self-efficacy and openness to change play a role in a teacher's decision to integrate ICT in the classroom, and this relationship is stronger when teachers receive professional development that addresses their knowledge of ICT integration (Baylor and Ritchie 2002; van Braak et al. 2004). Thus, a teacher's knowledge is an important piece of a teacher's dispositions, even if it is not a disposition itself.

Several recent studies suggest that knowledge and dispositions each play a unique role in a teacher's decision to use ICT in the classroom. Inan and Lowther (2010a, b) used path analysis to evaluate the influence of both primary (e.g., teacher readiness with and attitudes toward ICT) and secondary (e.g., professional development, school support) factors. In both papers, a teacher's readiness to use computers and beliefs about integrating ICT were significant predictors of their ICT use; readiness was strongly influenced by a teacher's knowledge of and proficiency with computers, whereas beliefs were strongly influenced by overall support from the school. Agyei and Voogt (2011) explored how knowledge and dispositions influenced the ICT use of 120 math teachers in Ghana. Teacher attitudes were measured on several dimensions, including anxiety/willingness to integrate, perceived benefit and enjoyment, and professional enhancement. The authors found that teacher attitudes toward computers and teacher competence with computers together accounted for the largest percent of variance when predicting teachers' level of ICT use. In a study of 357 Swedish teachers, Petko (2012) similarly found that teachers more often incorporated computers and Internet for learning when they felt more competent, expressed constructivist beliefs about learning, and perceived ICT as a benefit in the classroom. Karaca et al. (2013) similarly found that computer competence and teacher attitudes were significant predictors of a teacher's ICT use. Overall, these studies suggest that both knowledge and dispositions work together to influence a teacher's use of ICT in the classroom.

Current Issues in ICT Dispositions Research

Based on the current research, it is difficult to determine how dispositions independently influence a teacher's ICT use. One reason for this difficulty is that the outcome variable differs across studies. For example, many studies examine a teacher's ICT use in terms of both instructional and noninstructional uses. When ICT is examined broadly, computer competency or proficiency (i.e., knowledge) is more strongly associated with ICT use than dispositions such as attitudes and beliefs (e.g., Inan and Lowther 2010a; Karaca et al. 2013; van Braak et al. 2004). However, when Inan and Lowther (2010b) assessed teachers' uses of laptops with students, specifically, knowledge and dispositions were similarly strong predictors. Tondeur et al. (2008) found that a teacher's use of ICT for learning was strongly influenced by his/her level of constructivist beliefs about learning; this was additionally influenced by school-related factors (e.g., levels and types of support, willingness to innovate, availability of ICT). Thus, the influence of knowledge and dispositions on a teacher's ICT use is likely to differ depending on the ICT practice that is assessed.

Another challenge concerns the nature of our current measures. Current predictive models typically rely on teachers' self-reports of dispositions (e.g., attitudes, self-efficacy, beliefs), knowledge, and ICT use (see Baylor and Ritchie 2002; Inan and Lowther 2010a, b; Karaca et al. 2013; Sang et al. 2011; Tondeur et al. 2008). While self-reports are valuable tools for measuring beliefs and attitudes, they become more problematic with regard to knowledge and actual ICT use. Scholars have argued that self-reported knowledge may actually reflect one's self-efficacy (Banas and York 2014). This is particularly a concern when the items ask a teacher to report on his or her perceived ability as a reflection of that knowledge (e.g., "I can do *this*" or "I know how to do *that*"). Similarly, teachers' self-reports of their practices are susceptible to bias and may reflect what is socially desirable more than what is actually happening in the classroom (Desimone 2009; Kopcha and Sullivan 2007). The problem that self-reports create concerns the manner in which the results are discussed, often as if a teacher's *actual* knowledge predicts his/her *actual* ICT use. A more accurate portrayal would be that a teacher's *perception* of his/her knowledge predicts his/her *perception* of ICT use in the classroom. The gap between perceived and actual ICT use makes it difficult to see what practices best to support teachers' actual ICT use in the classroom.

A third challenge concerns the manner in which dispositions are defined and measured. In some studies, beliefs reflect one's value beliefs (see Ottenbreit-Leftwich et al. 2010), while in other studies beliefs represent pedagogical beliefs about teacher- and/or student-centered instruction (see Ertmer et al. 1999; Sang et al. 2010). Further complicating this issue is that value beliefs and attitudes are often conflated. This conflation stems from the nature of the items used to assess those construct. Scholars have drawn on the technology acceptance model (TAM; e.g., Davis 1989) to assess a teacher's perception of the usefulness of ICT in the classroom or ease of use with ICT. In some studies, those perceptions are taken to reflect beliefs (Baylor and Ritchie 2002; Kimmons and Hall 2016), while in other studies they are defined as attitudes (Agyei and Voogt 2011); still other studies combine multiple components into the single construct of "attitudes and beliefs" (e.g., Karaca et al. 2013). Similarly, teacher knowledge is often conflated with computer competency or proficiency (see Baylor and Ritchie 2002; Karaca et al. 2013), while other studies focus on competency but not a broader perspective on the knowledge associated with ICT integration (e.g., Inan and Lowther 2010a, b). Computer competency inherently reflects knowledge – however, other forms of knowledge are important when integrating ICT in the classroom (e.g., knowledge of pedagogy with ICT, classroom management; Ertmer 1999). Likewise, a teacher's willingness to integrate ICT is sometimes measured in a positive light (i.e., openness to change; see Baylor and Ritchie 2002), while in other cases it is measured in a negative light (i.e., resistance to change or anxiety; see Agyei and Voogt 2011). These issues make it difficult to look across studies and generate research-based recommendations regarding how best to support teachers as they adopt ICT for teaching and learning.

Dispositions: Proceed with Caution

In the past decade, research on the relationship between teachers' dispositions and ICT use in the classroom has risen dramatically. Much of that research is detailed in this chapter and suggests that dispositions play an important role in a teacher's decision to integrate ICT (see also Knezek and Christensen 2008). However, making sense of that relationship is anything but straightforward. Much of the current research uses predictive models to explore teachers' uses of ICT. Predictive models are effective for determining *if* a relationship exists between ICT use and dispositions but do little to reveal what the relationship is or why it exists (Christensen and Knezek 2008; Inan and Lowther 2010a, b). An important caution about that research, then, is to avoid treating any correlative results as causal. For example, several models suggest that computer competency and self-efficacy are related to ICT use. However, this does not mean that ICT use will improve just because teachers participate in stand-alone workshops that aim to improve competency – in fact, such workshops are often least likely to promote ICT use in the classroom (Mouza 2009; Wells 2007). Integrating ICT in the classroom is complex and multifaceted

(Ertmer et al. 2012; Kopcha 2010); knowing *if* dispositions and ICT use are related is far different than knowing *why* they are related and *how* to capitalize on those relationships to better support teachers.

With that in mind, there are several possibilities for future research on dispositions in the context of ICT that would help establish the *why* and *how*. One suggestion is to refine the manner in which dispositions are defined and measured. At this point in time, there are a number of validated instruments for measuring each dispositional factor. These measures, however, differ in subtle but critical ways. For example, the disposition of openness to change has also been studied as a willingness to integrate ICT or even a resistance to ICT. Beliefs and attitudes are often interchanged. While each aspect of these dispositions is undoubtedly related, it is not clear that they reflect the same internal state or construct. Rather than creating new instruments for measuring these potentially related aspects of dispositions, it may be more beneficial to establish if and how these measures converge to reflect the larger construct they seek to represent. Such research would not only help to solidify our definitions of these dispositions but also improve the conclusions that can be drawn across studies (Trochim and Donnelly 2008).

It is also important to note that no single dispositional factor can fully account for a teacher's use of ICT in the classroom – nor should it be the goal of dispositions research to isolate and account for each dispositional factor. Dispositions reflect a complex set of interrelated internal constructs that work together, with knowledge, to form and manifest specific behaviors. Our current measures and models have provided ample evidence of *if* those dispositions influence ICT use. In looking forward, then, research in ICT could build on prior studies to ask more complex questions about dispositions, such as how they form, how they influence actual ICT use, and how they can help scholars and educators support teachers as they learn to integrate ICT into student learning. In other words, how can scholars and educators better understand *why* a teacher holds certain dispositions, and *how* can we capitalize on that information to better support teachers in their actual use of ICT?

This focus on *why* and *how* would help move us past the current issues with ICT dispositions research in several ways. To begin, it would focus less on the specific nature of the disposition as it is measured (e.g., openness/willingness to change vs. resistance) and more on how each disposition reflects the teacher, more holistically. From a holistic point of view, it would be far less important to accurately measure a specific disposition (e.g., resistance) than understand it as it relates to his/her use (or disuse) of ICT due to the disposition. The latter would help determine *how* to capitalize on teacher dispositions as they learn to integrate ICT.

Additionally, a focus on *why* and *how* has the potential to focus more on teachers' actual use of ICT in the classroom. While some argue that existing self-report surveys are valid and reliable measures of a teacher's dispositions and ICT use (Christensen and Knezek 2008), others have shown how triangulating self-reports with observations adds richness and detail to the complex relationships involved in a teacher's decision to integrate ICT (Shulz-Zander et al. 2008). Surveys are undoubtedly useful in collecting large quantities of data, which can improve the generalizability of the findings. However, the focus on generalizability risks losing the specificity needed to better understand how scholars and educators can better support teachers in their use of ICT in the classroom. The relationship between dispositions and ICT use is personal and contextual, often changing over time – teachers may hold similar attitudes and beliefs about computers and learning yet arrive at different levels of ICT use over time (Levin and Wadmany 2008). Triangulating multiple sources (i.e., self-report with objective measures) would better account for the complex relationships between a teacher's dispositions and ICT use and the contextual factors that influence those dispositions.

Conclusion

In this chapter, we reviewed a variety of research that answers an important question: *What specific dispositions do teachers need in order to use ICT in their classrooms?* Overall, that research suggests that a teacher's self-efficacy, attitudes, openness to change, and pedagogical beliefs each have a relationship with a teacher's use of ICT for teaching and learning. This knowledge provides a robust starting point for answering more challenging and complex questions in the near future, such as: *Why does a teacher hold certain dispositions, and how can we capitalize on that information to better support teachers in their actual use of ICT?* If the goal of ICT research is to support teachers in adopting a range of teacher- and student-centered ICT practices, then knowing *why* a teacher holds a disposition may be as, or more, important than measuring the disposition factor in and of itself. As the quantity and capacity of ICT in schools continues to increase, it will be important to explore the practical strategies that best support teachers in articulating their dispositions and addressing them when they interfere with their efforts to use ICT for teaching and learning.

Cross-References

- ▶ Information and Communication Technology and Education: Meaningful Change Through Teacher Agency
- ▶ Instructional Technology Integration Models and Frameworks: Diffusion, Competencies, Attitudes, and Dispositions
- ▶ Knowledge Base for Information and Communication Technology in Education
- ▶ Measuring Teacher Attitudes, Competencies, and Pedagogical Practices in Support of Student Learning and Classroom Technology Integration
- ▶ Section Introduction: Attitudes, Competencies, and Dispositions for Teaching and Learning with Information Technology
- ▶ The Interaction of Psychological Constructs with Information Technology-Enhanced Teaching and Learning

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22 Instructional Technology Integration Models and Frameworks: Diffusion, Competencies, Attitudes, and Dispositions

Dale S. Niederhauser and Denise L. Lindstrom

Contents

Abstract

Models and frameworks help us better understand complex ideas and processes by providing a simplified explication of a concept, phenomenon, relationship, structure, system, or aspect of the real-world that allows us to focus on essential aspects of that which is being modeled. Relative to classroom technology integration, models can be useful in helping us understand and explain how

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technology integration occurs, allow us to better make decisions about how to effectively utilize technology resources, and provide insights that support development of strategies to more effectively and efficiently promote the kinds of pedagogical reforms that reformers hope to see in schools. The purpose of this chapter is to provide an overview of current models and frameworks that inform teacher adoption of technologies that support the integration of technology into student learning experiences in K-12 school settings, and to link them to theories of diffusion, adoption and change that underpin them.

Keywords
Models · Frameworks · CIT · Diffusion · Competency · Attitudes · Dispositions

Introduction

Despite a massive 30-year infusion of technology into school systems across the USA, current reports on levels of schoolteachers' technology integration indicate that instructional uses of technology with students remain relatively low and that traditional transmission-oriented pedagogical approaches continue to dominate teachers' practice. For example, in a recent Pew Research Center survey, less than half (40%) of teachers allowed students to develop, share, or post work on a website, wiki, or blog. Only 39% of teachers allowed students to participate in online discussions, and only 22% of teachers allowed students to post projects online where someone other than their teachers or classmates could see it (Purcell et al. 2013). These findings are disappointing given early claims about the transformational potential of instructional technologies (c.f., Sandholtz et al. 1992; Sheingold 1991).

According to Webb and Cox (2004), integrating technology into classroom learning requires teachers to engage in complex pedagogical reasoning. However, numerous studies and reports have demonstrated the difficulties involved in prompting teachers to adapt their pedagogical reasoning in ways that take advantage of the learning opportunities provided by digital technologies (Bauer and Kenton 2005; Hutchinson and Reinking 2011). In the 1980s, efforts to infuse technology into schools largely ignored the teacher factor and embraced a "build it and they will come" mentality. Millions of dollars were spent under the assumption that simply installing computers and related technologies and infrastructure in schools would transform education and support the use of constructivist approaches to teaching and learning advocated by the pedagogical reform movement of the day (Niederhauser and Stoddart 2001). Success was measured by counting the ever-increasing numbers of computers, printers, and network connections available in schools. Major issues under discussion at the time included whether computers should be installed in labs or classrooms and whether students should be allowed to access the Internet or be confined to a safer within-school intranet.

While reaching a critical mass of hardware, software, and infrastructure was necessary to provide a fertile environment for technology integration to occur, the lack of teacher behavioral change made it clear that simply providing access was not sufficient to address the kinds of transformational pedagogical change hoped for by reformers. Over time, educators, researchers, and policy-makers began to recognize that the integration of technology was an extremely complex process with multiple interacting factors including environmental, technological, individual, organizational, and pedagogical considerations (Sherry 1998). With the realization that the teacher factor was to play a critical role in the process, new models that addressed teacher knowledge and developmental change were needed to improve instructional integration of technology into the classroom environment.

Models and frameworks help us better understand complex ideas and processes by providing a simplified explication of a concept, phenomenon, relationship, structure, system, or aspect of the real-world that allows us to focus on essential aspects of that which is being modeled. Relative to classroom technology integration, models can be useful in helping us understand and explain how technology integration occurs, allow us to better make decisions about how to effectively utilize technology resources, and provide insights that support development of strategies to more effectively and efficiently promote the kinds of pedagogical pedagogical practices identified as essential to transforming learning in schools. The purpose of this chapter is to provide an overview of current models and frameworks that inform teacher adoption of technologies that support the integration of technology into student learning experiences in K-12 school settings and to link them to theories of diffusion, adoption, and change that underpin them.

Theories of Innovation Diffusion and Adoption

Diffusion theories help explain how an innovation spreads through a population; while adoption theories help us understand the intrapersonal factors and social processes that lead individuals to accept or reject a particular innovation (Straub 2009). The result of engaging in diffusion and adoption processes is change; however, there is no unified model for understanding the processes teachers go through when adopting instructional technologies. Three theoretical orientations underpin models of how and why teachers come to integrate information technology into their pedagogy.

The broadly applicable *Diffusion of Innovations* (DOI) theory (Rogers 2003) helps explain factors that influence individuals' uptake of new technological tools and innovative practices and the developmental stages that adopters pass through, within a community of practice – or within the larger society. Two sociopsychological theories, the *Theory of Planned Behavior* (TPB; Ajzen and Fishbein 1980; Ajzen 2012) and *Social Cognitive Theory* (SCT; Bandura 1986), have been useful in helping us understand the intrapersonal factors that govern developmental change in human behavior.

Diffusion of Innovations

DoI was developed to explain how new ideas and technologies spread within a society and addresses *attributes of the innovation* (relative advantage, compatibility, complexity, trialability, and observability; Rogers 2003, pp. 15–16) and *characteristics of adopters* relative to their stage in the adoption process:

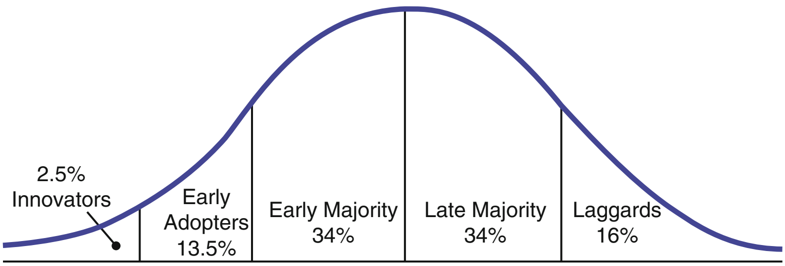

Fig. 1 Characteristics of adopters (Rogers 2003)

Innovators: Interest and initiative drive them to seek new ideas and ways of doing things. Tend to be viewed as risk-takers by the peer group.
Early adopters: Respected by peers. Known for judicious, successful, and discrete use of new ideas and technologies. Often serve as opinion leaders and innovation champions.
Early Majority: Tend to be more deliberate in their adoption. Follow innovators and early adopters willingly but seldom lead.
Late Majority: Innovations are approached with skepticism and caution. Peer pressure and norms drive the innovation-decision process.
Laggards: The last group to adopt an innovation. Tend to be suspicious and delay adoption decisions to see whether the innovation is successfully adopted by others.

As can be seen in Fig. 1, Rogers portrays these adoption categories as arrayed across a bell-shaped distribution.

Also addressed are the stages individuals typically go through when engaged in the *innovation-decision process*:

Knowledge: Becoming aware of the innovation
Persuasion: Becoming knowledgeable about the characteristics of the innovation
Decision: Deciding to adopt or reject the innovation
Implementation: Putting the new idea or technology into practice
Confirmation: Reflecting on the decision and implementation experience to decide whether to continue or discontinue adoption of the innovation

Finally, *diffusion networks* (Rogers 2003, p. 300) help explain how interpersonal connections among community of practice members drive the innovation diffusion process. Diffusion networks provide insights into social norms, capital, and relationships which play a central role in the innovation diffusion process. The literature on diffusion of instructional technology use within the P-12 teacher community of practice provides insights into factors that may influence an educator's likelihood of utilizing a new technology for instructional purposes. Foulger and her colleagues (2013) used DoI as a theoretical framework for examining university faculty use of mobile technologies and found that communication channels within and among institutions of higher education were not substantial enough to initiate widespread use. While DoI may provide a good foundation for understanding how innovations diffuse within a society, it is not easily applied in complex and interconnected processes associated with teacher adoption of technology, which includes numerous variables like characteristics of adopters, characteristics of the innovation, and characteristics of the context, making it difficult to determine the causes of the eventual adoption of an innovation (Damanpour 1996).

Theory of Planned Behavior

The theory of planned behavior (PPB) is useful for explaining, predicting, and guiding change in human social behavior. According to the theory, intention is the immediate antecedent of behavior and is itself a function of attitude toward the behavior, subjective norms, and perceived behavioral control. These determinants follow, respectively, from beliefs about the behavior's likely consequences, from normative expectations of important others, and the presence of factors that control behavioral performance (Ajzen 2012). TPB is grounded in expectancy-value theory. Expectancy-value theory posits that:

1. An individual holds many beliefs about any given object, that is many different characteristics, attributes, values, goals, and concepts are positively or negatively associated with any given object;
2. Associated with each of these "related objects" is a mediating evaluative response – an attitude.
3. These evaluative responses summate;
4. Through the mediation process, the summated evaluative response is associated with the attitude object, and thus;
5. On future occasions the attitude object will elicit this summated evaluative response – this attitude (Fishbein 1965, p. 117).

Thus, an individual's attitude toward any object is a function of the strength of his/her beliefs about the object and the evaluative aspect of those beliefs.

These principles were extended into the TPB, in which performance of a behavior is a joint function of intentions and perceived behavioral control. Specific attitudes toward a behavior, coupled with an individual's beliefs about how people he or she cares about will view the behavior in question, can be expected to predict the individual's intent to engage in that behavior. Further, perceived behavioral control, or people's perceptions of their ability to perform a given behavior, influences intentions (see Fig. 2). In general, more favorable attitudes and subjective norms promote greater perceived control, positively influencing the person's intention to perform the behavior in question (Ajzen 2012).

Research that draws on the TPB tends to focus on the relationships among teachers' beliefs, expectations, intended use, and use of technology in the classroom. For example, in a longitudinal study, researchers found a connection between

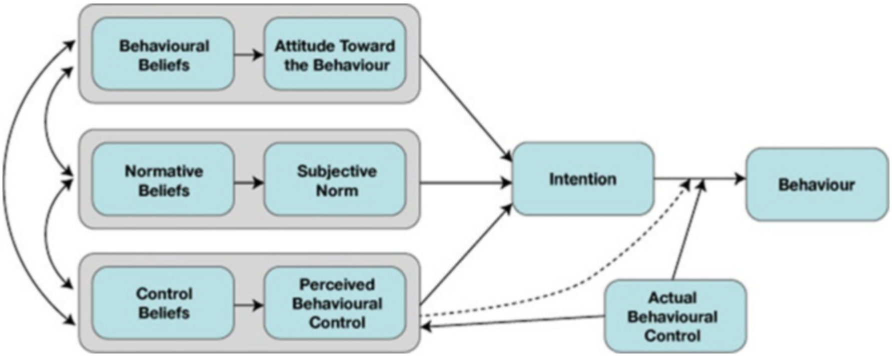

Fig. 2 Graphic representation of the theory of planned behavior (Ajzen 2006)

perceived relevance, perceived usefulness, and technology acceptance for teachers who participated in professional development for using a presentation technology in the classroom (Hu et al. 2003). Teo and his colleagues then showed that perceived usefulness, perceived ease of use, and subjective norms were strong predictors of preservice teachers' computer attitudes (Teo et al. 2008). However, other researchers suggested that only perceived usefulness had a direct significant effect on a group of preservice teachers' intentions to use computer technologies with their future students (Ma et al. 2005). This research has demonstrated that intrapersonal beliefs have a powerful influence on teachers' technology acceptance and intentions.

Social Cognitive Theory

In developing social cognitive theory, Bandura (1986) acknowledged that observation and vicarious reinforcement play key roles in human learning and behavior; however, breaking with the pervasive behavioral paradigm of the time, he also recognized that cognitive, self-regulatory, and self-reflective processes were essential in explaining human adaptation and change. According to Pajares (2002), Bandura viewed people as self-organizing, proactive, self-reflecting, and self-regulating rather than as reactive organisms shaped by environmental forces or driven by concealed inner impulses. He viewed human functioning as the product of a dynamic interplay of personal, behavioral, and environmental influences, with the results of one's own behavior informing and altering their environments and intrapersonal factors which, in turn, inform and alter subsequent behavior. This *reciprocal determinism* is grounded in the idea that (a) cognitive factors in the form of cognition, affect, and biological events; (b) behavior; and (c) environmental influences create interactions that result in a *triadic reciprocality* (see Fig. 3).

Environmental factors clearly play an important role in the technology integration process. Both the social environment and physical environment shape, and are shaped by, teachers' decisions to use technology with their students. As mentioned

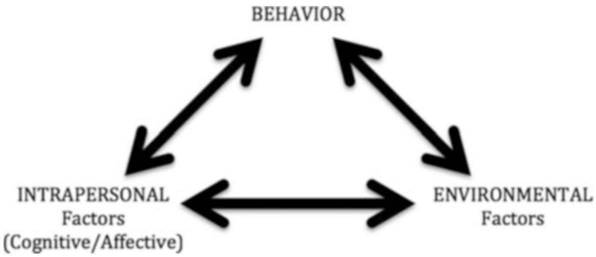

Fig. 3 Graphic representation of social cognitive theory (Adapted from Pajares 2002)

previously, access to technology is a necessary, but not sufficient, condition for technology integration to occur. Thus, access to technology (coupled with the nature of the technology and nature of the access) influences a teacher's ability and willingness to integrate technology into his or her pedagogy, and a teacher's willingness to use technology with students shapes the technology that is available in the environment as he or she requests access to certain technologies and develops pedagogical reasoning to take advantage of the affordances of the available technologies.

In a body of research which examined the Apple Classrooms of Tomorrow initiative – an early attempt to bring the reforming power of computers into K-12 classrooms during the 1980s and 1990s – the initial focus of the project was on providing a technology-rich environment for students and teachers (see Sandholtz et al. 1997). However, ". . .ACOT researchers learned soon enough that a *saturation strategy* failed to alter how teachers taught. . ." [emphasis added] (p. xiii). Noticing that teachers in ACOT classrooms appeared to be moving through developmental stages, they shifted their attention to focus more directly on teachers and identified three stages that teachers moved through as they became increasingly sophisticated in their use of technology for teaching and learning in their classrooms:

1. *Survival:* Feelings of being overwhelmed by an inability to anticipate problems, and make necessary changes;
2. *Mastery*: Beginning to anticipate problems and develop strategies for solving and avoiding problems related to teaching and learning with computers;
3. *Impact*: The ability to use technology to enhance student motivation, interest, and learning (Sandholtz et al. 1992).

The realization that we needed to look beyond student access to technology and examine teachers' feelings, beliefs and attitudes played a central role in shaping the technology integration effort that became widespread during the 1990s and prompted increased attention to professional development efforts and the conceptualization and application of models that focused more directly on intrapersonal factors that shaped teacher behavior. Thus, given that technology has become more available to teachers within a particular *environment* (classroom computers, computer labs, media centers, 1-1 device initiatives, etc.), *intrapersonal factors* have increasingly been recognized as playing a central role in teachers' integration of technology into their practice and the nature of that integration (*behavior*).

Key intrapersonal factors from social cognitive theory include self-efficacy (SE), outcome expectations (OE), and knowledge. Social cognitive career theory (SCCT; Lent et al. 1994, 2002) is an application of social cognitive theory that seeks to explain and predict academic and career-related behaviors. SCCT has been used to examine the role of SE and OE across a variety of career options – particularly in areas of information management and in information technology-related fields (Niederhauser and Perkmen 2008). Of these, self-efficacy has captured the most attention in the literature and is considered the critical factor in the SCCT model (Lent et al. 1994).

Self-efficacy is essentially an individual's level of confidence that he or she can accomplish a given goal. SE addresses ". . .people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances. It is concerned not with the skills one has but with judgments of what one can do with whatever skills one possesses" (Bandura 1986, p. 391). SE is the belief that one can successfully produce a desired outcome and appears to be an important determinant of human behavior because it influences motivation. Those who judge themselves inefficacious may avoid engaging in certain tasks, whereas those with higher SE may participate more enthusiastically (Schunk 2001).

Outcome expectations address one's motivation to complete a task. OE involves the anticipated outcomes of an action ("If I do X, Y will happen") (Lent et al. 1994). According to Bandura (1986), OE rewards take three major forms: *physical* (external rewards like money or grades), *self-evaluative* (self-satisfaction), and *social* (respect from others). Schunk (2001) addressed the importance of OE in human behavior: "Expectancies are important because they help people form cognitive maps, or internal plans comprising expectancies of which actions are needed to attain goals. People follow signs to a goal; they learn meanings rather than discrete responses. People use their cognitive maps to determine the best course of action to attain a goal." (p. 106) Like SE, OE also plays an important role in motivation: "Unless people believe that their actions will have the desired consequences, they have little incentive to engage in those actions" (Pajares 2002, p. 6). Further, outcome expectations may drive individuals to sustain behaviors over long periods of time if they believe their actions will eventually generate the desired outcome.

Teachers' self-efficacy has been widely addressed in the instructional technology integration literature. When computers were first introduced as an instructional tool for classroom teachers in the 1980s, most teachers had little or no experience with these technologies in their personal or professional lives. Teachers' self-efficacy, with regard to using these new technologies with students, played an important role in determining whether they were willing to integrate the new tools into their teaching repertoires (Brinkerhoff 2006; Ertmer et al. 1994).

Aside from the fact that access was limited, hardware and software was rudimentary, and pedagogical awareness of what was available and possible was minimal; many teachers lacked confidence in their ability to use technology with students (Rosen and Weil 1995). As time has passed, and new technology-savvy teachers have joined the workforce, their knowledge of (and facility with) technology has steadily increased – prompting commensurate improvement in self-efficacy. These developments have brought outcome expectations to the forefront (see Niederhauser and Perkmen 2010). Since access to technology has improved dramatically, hardware and software has become much more sophisticated, and teachers becoming increasingly knowledgeable and confident in their ability to use technology (Wang et al. 2014), outcome expectations will likely be a fruitful research area in the future.

Instructional Technology Adoption Models

The theories of innovation, diffusion, and adoption presented above underpin the instructional technology adoption models that are addressed in the remainder of this chapter. These models and frameworks help us better understand the complex ideas and processes that are in play when teachers integrate technology into their pedagogical practices.

The first model, *The Concerns-Based Adoption Model (CBAM)*, is a developmental model that addresses concerns teachers progress through when adopting an innovation and the increasingly sophisticated ways that teachers use technology with their students. Next, we address the *Technological, Pedagogical, and Content Knowledge (TPACK)* framework and *Substitution, Augmentation, Modification, Redefinition (SAMR)* model, which address overlapping areas of knowledge that frame teachers' technology using decision-making and behavior, and the ways that technology can be used to enhance and transform instructional practices, respectively. The *technology acceptance model (TAM)* and *unified theory of acceptance and use of technology (UTAUT)* draw on the psychosocial theories presented earlier. The TAM speaks to technology adoption in the general population, while UTAUT applies TAM in educational settings with teachers and learners. *Will, Skill, Tool, Pedagogy (WSTP)* is the most comprehensive model to date for examining instructional technology integration. In this model the Will construct addresses attitudes and motivation; Skill addresses ability, experience, knowledge, and confidence; Tool addresses availability, accessibility, and environment; and Pedagogy addresses teaching style, knowledge, and practices. Together, these models provide a multifaceted view of the complex processes involved in the integration of technology into teachers' practices and the culture of classrooms and schools.

The Concerns-Based Adoption Model

Grounded in educational change theories and conceptual work on the influence of teachers' concerns in their willingness and likelihood to change (Fuller 1969), CBAM was developed to model teacher change as an individual process undergone by those seeking to – or required to – change their teaching behaviors (Hall 1974). Although it was originally designed for the study of the adoption of any new educational innovation, the Stages of Concern (SoC) and Level of Use (LoU) constructs have been extensively used to directly address adoption of information technology innovations, serving as a theoretical lens for researchers worldwide over the past four decades (Hancock et al. 2007). CBAM proposes a predictable order of the emergence and progression of concerns about innovations that are developmental in nature. In general, initial teacher concerns will subside in intensity before later, higher-stage concerns are internalized and expressed (Wesley and Franks 1996). However, if the lower stages of concern are not resolved or addressed, then higher stages of concern are not likely to emerge. The Stages of Concern dimension provides a sequence of stages that teachers pass through based on their level of concerns about the innovation:

Unconcerned: Little concern or involvement;
Informational: General awareness of, and interest in, the innovation. No worry about the innovation;
Personal: Uncertain about demands of the innovation. Worried about his or her adequacy and role in implementation. Analyzing potential rewards, role, conflicts and commitment;
Management: Focus on process and tasks of using the innovation. Concerns are about efficiency, organizing, managing and scheduling;
Consequence: Focus on the innovation's impact on his or her students. Concerns are about relevance, for students, evaluation of student outcomes, and changes needed to improve those outcomes;
Collaboration: Focuses on coordinating and cooperating with others regarding use of the innovation;
Refocusing: focuses on exploring ways to reap more universal benefits from the innovation, including the possibility of making major changes to it or replacing it with a more powerful alternative (George et al. 2006).

The second dimension of the CBAM, Levels of Use, focuses on how performance and activities change as the individual becomes more familiar with the innovation and more skillful at using it (Loucks and Hall 1979). Like Stages of Concern, LoUs are developmental in nature. The general LoU model includes eight phases: Nonuse, Orientation, Preparation, Mechanical Use, Routine Use, Refinement, Integration, and Renewal (Hall et al. 2006); however, a Level of Technology Integration framework (LoTI) was developed to specifically address teachers' instructional technology integration levels:

Nonuse: Perceived or actual lack of access to technology-based tools, or a lack of time to pursue electronic technology implementation;
Awareness: The use of computers is generally one step removed from the classroom teacher (e.g., integrated learning system labs). Computer-based applications have little or no relevance to the individual teacher's instructional program;
Exploration: Technology-based tools serve as a supplement to existing instructional program (e.g., tutorials, educational games, simulations). The electronic technology is employed either as extension activities or as enrichment exercises;

Infusion: Technology-based tools (e.g., databases, spreadsheets, calculators, and desktop publishing applications) are used to augment isolated instructional events (e.g., a science-kit experiment that utilizes spreadsheets to analyze results or desktop publishing to produce a school newsletter);

Integration: Technology-based tools are integrated in a manner that provides a rich context for students' understanding of concepts, themes, and processes. These tools enhance students' opportunities to identify and solve authentic problems relating to an overall theme/concept;

Expansion: Technology access is extended beyond the classroom. Classroom teachers actively elicit technology applications and networking from business enterprises, governmental agencies and other sources (e.g., contacting NASA to establish a link to an orbiting space shuttle via the Internet) to provide expanded student problem solving, issue resolution, and activism experiences;

Refinement: Technology is perceived as a process, product (e.g., invention, patent, new software design), and tool to help students solve authentic problems related to an identified real-world problem or issue. (Moersch 1995)

Lower levels in the taxonomy are representative of issues like access and ease of use; while higher levels tend to reflect higher-order reform-oriented instructional practices.

Research grounded in CBAM indicates that higher CBAM levels are linked to enhanced pedagogical change and increased positive attitudes for teachers (Hao and Lee 2015), as well as collaborative classrooms and more effective instructional strategy-use by teachers (Hall et al. 1975). A strength of the CBAM model is that change is addressed through a developmental perspective – that individual's progress through the stages involves increased sophistication in the use of the innovation (Straub 2009); however, there are some limitations when applying the CBAM model to examine technology integration.

Because CBAM primarily deals with top-down imposed change, it presupposes that teachers will resist change and have negative perceptions (concerns) about the innovation. Therefore, it is not as effective in explaining the role of teacher leaders who tend to embrace change and favor a more bottom-up adoption process. Some teachers may be resistant to change – but may also have positive attitudes toward a particular innovation that may coincide with the existence of the concerns. Straub (2009) cautions against ignoring teachers who may have positive dispositions toward an innovation, as CBAM may sell teachers short by portraying them as resistant luddites.

Technological, Pedagogical, and Content Knowledge

TPACK provides a framework for capturing the dynamic and complex relationships among content, technology, pedagogy, and context (see Fig. 4). The framework highlights what teachers need to know to teach in an information age and supports the design of faculty-based professional development that pushes them to change the

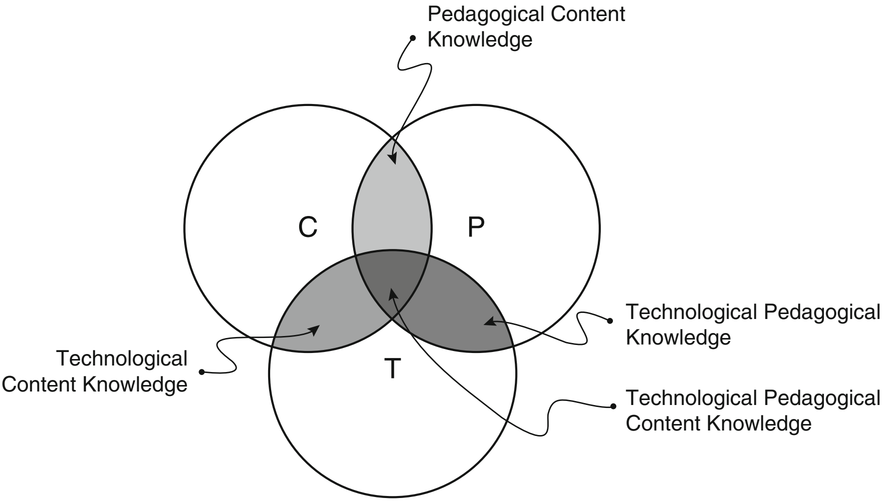

Fig. 4 Graphic representation of the TPACK framework (Mishra and Koehler 2006)

way they teach. The intersection of these three knowledge types represents the interplay among teaching content, pedagogical methods, and use of technologies (Mishra and Koehler 2006). Seven components comprise the framework:

1. Technological knowledge (TK): Knowledge about various technologies, ranging from low-tech technologies like pencil and paper to digital technologies like computers, the Internet, and interactive whiteboards
2. Pedagogical knowledge (PK): Knowledge about methods and processes of teaching including instructional strategies, sequencing instructional events, assessment, classroom management, etc.
3. Content knowledge (CK): Knowledge about the subject matter that is to be taught
4. Technological Pedagogical Knowledge (TPK): Knowledge about how technologies can be used to enhance teaching
5. Technological content knowledge (TCK): Knowledge about using appropriate technologies to teach a specific content area (e.g., the Internet can be used to find original sources when teaching history)
6. Pedagogical content knowledge (PCK): Knowledge of appropriate pedagogy in a given content area (e.g., knowing how to teach literature analysis versus knowing how to teach students to solve differential equations)
7. Technological pedagogical content knowledge (TPACK): Knowing how to effectively integrate technology into one's teaching within a particular content area

The TPACK framework is an important tool for helping teachers reflect on how their technological, pedagogical, and content knowledge shapes their practice and offers teacher educators and professional development providers ways to assess teachers' knowledge and strategically target their knowledge-building efforts.

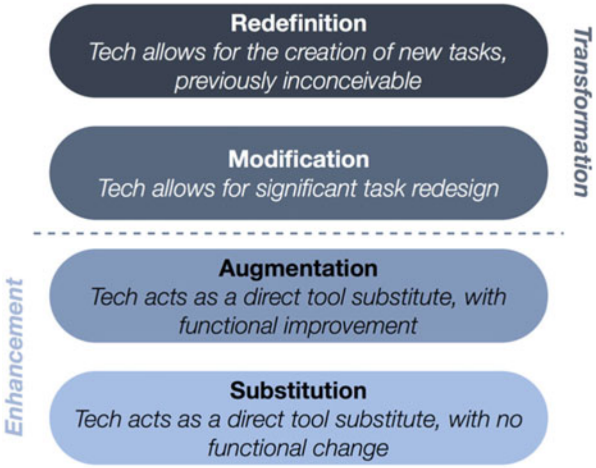

Fig. 5 Graphic representation of the *Substitution, Augmentation, Modification, Redefinition* model (Puentedura 2012)

Substitution, Augmentation, Modification, Redefinition

Focused on promoting the potential for technology to transform instructional practice, the Substitution, Augmentation, Modification, Redefinition model provides a scale for examining the degree to which teachers' technology use enhances and/or transforms the instructional context (see Fig. 5). The goal is to transform learning experiences so they result in higher achievement levels for students.

While the TPACK framework has had a major influence on the technology-using teacher preparation field, the pragmatic focus of the SAMR model has made it particularly appealing to the professional development community.

Technology Acceptance Model

The TAM was developed to help us understand all forms of technology adoption in the general population. TAM is grounded theoretically in the theory of planned behavior (Ajzen and Fishbein 1980; Ajzen 2012) and was among the first models to include social-psychological factors to examine technology acceptance. TAM specifies the relationships between perceived usefulness, perceived ease of use, attitude toward computer use, and behavioral intention to use technology. TAM proposes that perceived ease of use and perceived usefulness of a technology are fundamental determinants in computer use. Perceived usefulness is the degree to which a person believes that using a particular technology will enhance his or her job performance (Davis et al. 1989), while perceived ease of use refers to the degree to which a person believes that using a particular technology will require little effort. As can be seen in see Fig. 6, these two mediating factors significantly influence attitude toward computer use, which in turns affects the behavioral intention to use technology (Liaw and Huang 2003).

Results from research using TAM in educational settings suggest that teachers tended to consider the limitations and effectiveness of technology tools in the

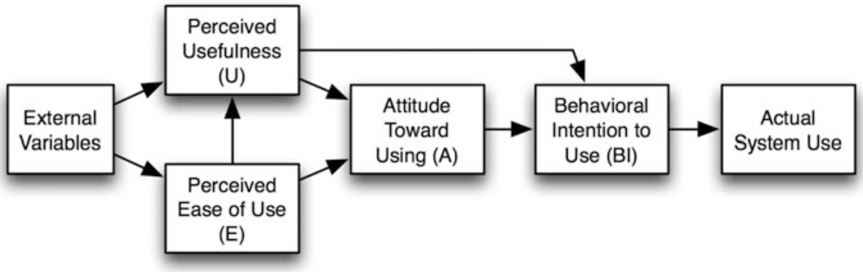

Fig. 6 Graphic representation of the TAM model (Davis et al. 1989)

context of teaching, that positive attitudes tended to lead teachers to incorporate technology into their teaching practices, and that the relationship between attitudes and beliefs was bidirectional (Smarkola 2008; Zacharia 2003).

However, because TAM and related models focus on the explanation of how characteristics of a specific technology affect user acceptance (Davis 1993), TAM draws on only two personal belief systems and excludes other independent variables which might influence perceived usefulness and ease of use (Bagozzi 2007). Thus, TAM may not be comprehensive enough to capture the effects of external variables or social factors (Bagozzi 2007; Smarkola 2008). Additionally, TAM has been largely used and tested in contexts in which technology use is voluntary (e.g., Benbasat and Barki 2007) and may have limited explanatory power in contexts like schools – where technology use is often mandated.

Unified Theory of Acceptance and Use of Technology

The unified theory of acceptance and use of technology (Venkatesh et al. 2003) builds on the TAM and has been widely applied and tested in educational contexts with students and teachers (Teo 2015). UTAUT is comprised of three constructs which together seek to determine an individual's intention to use a specific information technology (see Fig. 7). The three constructs are:

Performance expectancy: The degree to which the user expects that using the system will help him or her improve job performance;

Effort expectancy: How easy or difficult the user believes it will be to implement the innovation;

Social influence: The degree to which an individual perceives that others (whose opinions are valued) believe that he or she should implement the innovation. (Teo 2015)

As we saw with other models, researchers have identified limitations with the UTAUT model. UTAUT does not address knowledge factors like prior experience,

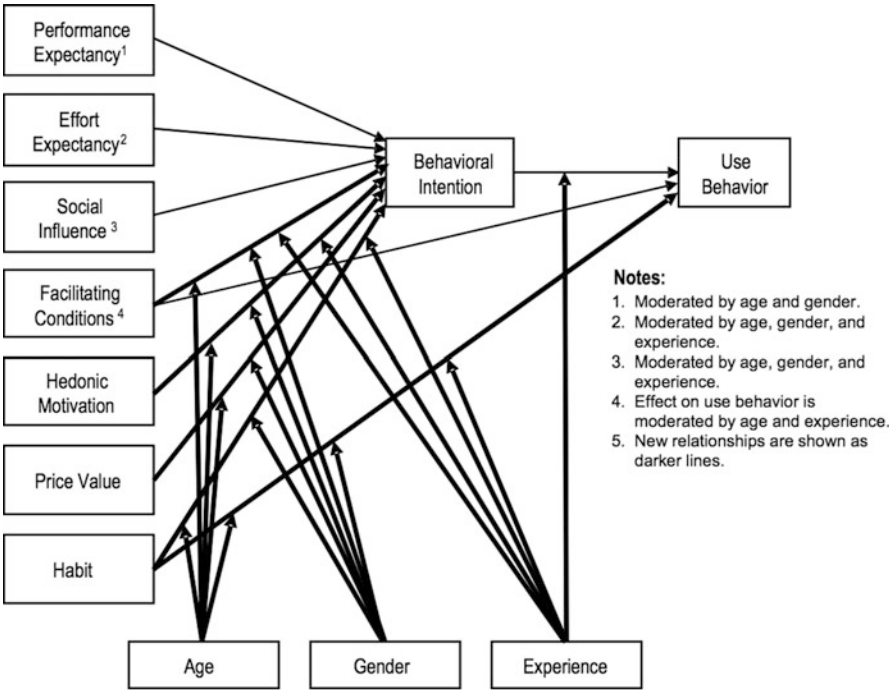

Fig. 7 Graphic representation of the UTAUT model (Venkatesh et al. 2012)

affective factors like perceived interest or enjoyment, or external facilitating conditions; and, like TPACK, assessing constructs typically relies on self-report as the primary data source. UTAUT has also been criticized as being overly complex, not parsimonious in its approach, and not well-suited to explaining individual behavior (Bagozzi 2007; Casey and Wilson-Evered 2012).

Will, Skill, Tool, Pedagogy

Will, Skill, Tool, Pedagogy provides a proficiency model that, in its original form, included three constructs relevant to classroom teaching selected from more than 30 variables that have been recognized as essential for student learning (Knezek and Christensen 2016). WST was initially designed to focus specifically on the school environment and the contribution of classroom technology integration to student learning (Knezek et al. 2000). Findings from some of the early WST research indicated that constructivist pedagogical practices lead to more effective technology integration (Petko 2012), which prompted the addition of teaching style (or pedagogical practice) to form the WSTP model (see Knezek and Christensen 2016). The WSTP constructs that influence the integration of technology in the classroom include:

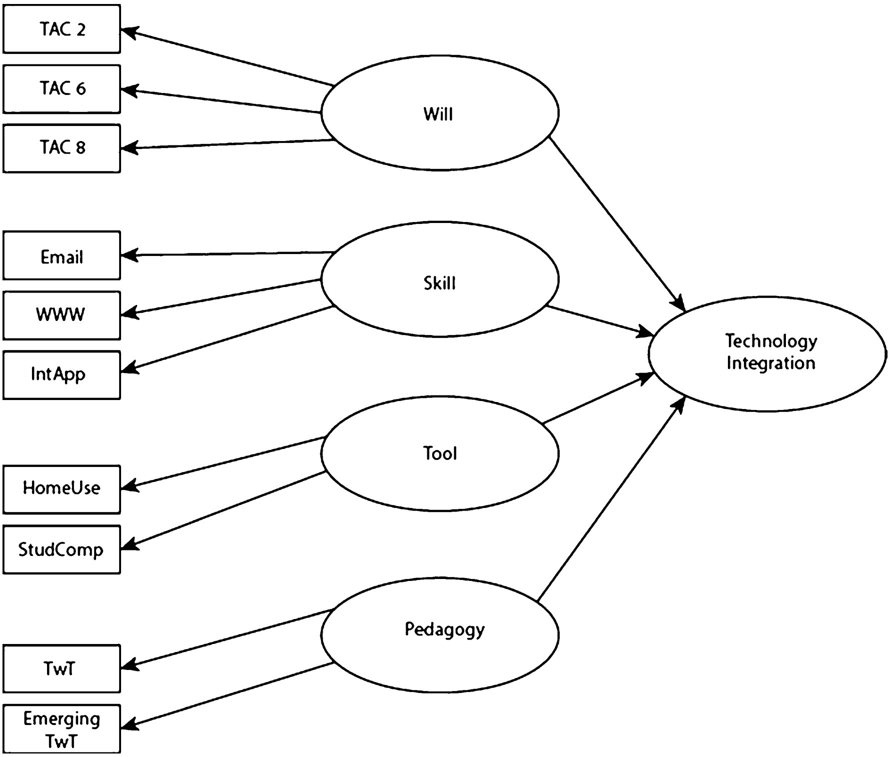

Fig. 8 Expanded Will, Skill, Tool, Pedagogy model of technology integration (Knezek and Christensen 2016)

Will: Holding a positive attitude toward instructional use of technology;
Skill: The ability to use and experience technology, as well as perceived confidence (self-efficacy) and readiness;
Tool: Availability, accessibility, and nature of the use of a given technology;
Pedagogy: Teaching style; pedagogical practice. (Knezek and Christensen 2016)

The main purpose of the WSTP model is to help educational leaders make informed decisions for teacher professional development to enhance teaching and learning. However, studies using WST and WSTP models support claims that the presence of technology does not guarantee effective classroom use. Results have indicated that 40–90% of a teacher's level of technology integration can be explained using Will, Skill, Tool and Pedagogy data (Agyei and Voogt 2011). The complete model has a second stage in which level of technology integration is used to predict student learning and achievement. The technology integration portion of the WSTP model is shown in Fig. 8.

Conclusion

Findings from studies using the models and frameworks described above seem to point toward a need for pedagogical change if teachers are to adopt technology and use technology meaningfully in educational settings. It also seems that teacher technology adoption processes are strongly influenced by interpersonal characteristics, like predisposition to embrace or avoid change, and their attitudes and beliefs about the usefulness of digital technologies for learning in school (Ertmer 2005; Hew and Brush 2007). However, research on teacher technology integration tends to focus on teachers' self-reported perceptions of their knowledge (e.g., Schmidt et al. 2009), and beliefs about the value of technology for learning and/or self-efficacy beliefs, even though these conceptions alone appear to be too narrow for determining why there are differences in whether and how teachers integrate technology (Kim et al. 2013).

For example, characterizing Will as a positive attitude toward the use of technology in instruction (as measured by subscales from the Teachers' Attitudes toward Computers (TAC) and Teachers' Attitudes Toward Information Technology (TAT)) represents a techno-centric view that, in general, technology use is good. This techno-centric view that technology is good fails to explain how two teachers could have strong positive beliefs about the value of technology for student learning; with one teacher only using technology to present content to students, while the other consistently uses technology to create interactive learning experiences (Kim et al. 2013).

Additionally teacher beliefs, as currently conceptualized in models of technology integration, do not appear to account for the "new mindsets" needed for the adoption of new technology tools that have fundamentally changed the way knowledge is constructed and distributed (Lankshear and Knobel 2007). For example, researchers found that Advanced Placement (AP) teachers and National Writing Project (NWP) teachers use Wikipedia at much higher rates than US adult Internet users as a whole (87% vs. 53%) in their personal lives (Purcell et al. 2013). However, these same teachers reported that they discourage or bar students from using Wikipedia because of concerns about the reliability of its content. Additionally 77% of AP and NWP teachers say the impact of using the internet and other digital technologies on students has been "mostly positive," and 76% of teachers surveyed "strongly agree" with the notion that the Internet "enables students to find and use resources that would otherwise not be available to them yet (76%) complain that "search engines have conditioned students to expect to be able to find information quickly and easily" (Purcell et al. 2013, p. 16).

Findings like these seem to contradict models for technology integration that suggest the ability to use a particular technology (Skill) is a strong predictor of technology integration in the USA (Velazquez 2007) or because there is a perception that a particular technology is easy to use, as TAM and UTAUT models suggest. Although teachers' TPACK may be a strong enabler for effective technology integration, it does not explain why teachers with sufficient knowledge utilize technology differently (Hall 2010).

Lankshear and Knobel (2007) suggest that "new mindsets" may be needed for more meaningful uses of technology in school. For example, teachers who make rules against using Wikipedia for learning in school reflect a *physical-industrial* mindset where expertise and authority are *located* in individuals and institutions. However, teachers who ask students to become editors of Wikipedia articles represent a *cyberspatial postindustrial* mindset where Wikipedia is not suspect but valued because it provides a space where individuals with diverse points of view can collaboratively construct knowledge.

Models and frameworks that can help capture and support the development of the cyberspatial postindustrial mindset may help educators adopt technologies in ways that better prepare students for the realities of twenty-first-century work and learning. To address these issues, current models and frameworks may need to expand to more directly address the kinds of learning that are currently valued in school (Kim et al. 2013).

As society adapts to the new-world-order prompted by the rapidly increasing progression of technological innovation, it is essential that we continue to develop and refine our models. Thoughtful progress in promoting meaningful instructional technology integration is predicated on a deep understanding of how teachers continuously adapt to an ever-changing school culture in an increasingly technological world. It is through ongoing development of these theories and models that we will better understand the complex dynamic processes involved in technology-using teacher development. The models discussed in this chapter provide teacher educators, school administrators, and educational policy-makers with powerful tools that help explain how technology integration occurs, allow us to make informed decisions about how to use technology resources, and provide insights that can support effective ways to diffuse effective and meaningful technology integration that can transform schools.

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23 Measuring Teacher Attitudes, Competencies, and Pedagogical Practices in Support of Student Learning and Classroom Technology Integration

Rhonda Christensen and Gerald Knezek

Contents

Abstract

In this chapter we feature instruments to measure teacher attitudes, competencies, and pedagogical practices judged to be important for effectively integrating technology into the classroom learning environment. The ability to assess a teacher's level on these attributes is important because positive attitudes, proficiency, and effective pedagogical strategies are necessary to foster quality student learning. Specific instruments that serve as exemplars for teacher appraisal are introduced. The importance of including more than one type of measure to comprehensively assess teacher needs and prescribe appropriate professional development is discussed.

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Teacher attitudes · Technology competencies · Technology integration · Attitudinal measures · Competency measures · Pedagogical practices

Introduction

Teacher attitudes, beliefs, and practices are important to investigate and understand in advancing effective instruction. Most teacher attributes related to effective teaching can be assessed in multiple ways that include self-report, interviews, artifacts, lesson plan reviews, observation techniques, and a combination of these techniques. However, not all assessment techniques result in measurements as defined in the following quote.

> Measurement is the assignment of scores to individuals so that the scores represent some characteristic of the individuals. [Measurement requires] . . . some systematic procedure for assigning scores to individuals or objects so that those scores represent the characteristic of interest. Psychological measurement is often referred to as psychometrics. (Price et al. 2015, Chap. 5, p. 1)

In this chapter we will restrict discussion to instruments that assign scores to individuals.

Over the decade that has passed since the publication of the first edition of this International Handbook in 2008, perspectives on the measurement of teacher attitudes, competencies, and pedagogical practices for teaching with technology have evolved from being viewed as unique domains to components of an integrated whole. Especially beginning with the broad-scale acceptance of Bandura's thoughts on self-efficacy (Bandura 1993), and continuing until the current day's recognition of the significance of TPACK (Technological Pedagogical Content Knowledge) as an important conceptual framework for technology integration – we must acknowledge that technology integration proficiency is a multifaceted attribute of an individual teacher that involves not only technology knowledge and skills but also pedagogical expertise, merged together with content knowledge in a discipline. But even this framework is incomplete as we also recognize that positive attitudes and long-standing positive dispositions are necessary for teaching with technology to flourish in any teacher's classroom.

Researchers have developed models with necessary components for successful integration of technology into the classroom (e.g., Rogers 1999). Many of these are described in a different chapter in this handbook (▶ Chap. 22, "Instructional Technology Integration Models and Frameworks: Diffusion, Competencies, Attitudes, and Dispositions" by Niederhauser and Lindstrom). For the purposes of the current chapter, teacher integration of technology into the classroom is assumed to have at least three major components that reside within the teachers' realm of control or influence: attitudes, skills, and pedagogical practices. Many scholars in the field consider these second-order barriers (Ertmer 1999) or intrinsic factors. This chapter will include an introduction of how measures might be selected to assess teachers' dispositions and preparation for using technology in the classroom. Measures for attitudes will be discussed first in this section. Measures for skill (competency), pedagogical practices, and technology integration will be incorporated in the following sections, and finally the interaction and application of these measures will be examined.

Selection of Quality Measures

Many forms of valid and reliable instruments exist for obtaining measures related to technology in teaching and learning. One ongoing dialog in the scholarly community is with respect to the value of self-report versus observation data. This is an area where tools exist to accurately address the issues. Cattell (1973) pointed out that almost every information-gathering procedure in education employs an observer. When the observer is the person about whom the information is being gathered, we call this procedure self-report. The primary issues in this area are three:

- Is an outside observer a more accurate (consistent, reliable) reporter of activities such as the level of technology integration a teacher is able to accomplish in his/her classroom, than the teacher him-/herself?
- Is an outside observer a more appropriate (unbiased, relevant, valid) judge of activities such as the level of technology integration a teacher is able to accomplish in his/her classroom?
- What are the practical limits, including instructional time ramifications and cost-benefit considerations, of the two techniques?

These questions do not typically have simple answers, and yet there are emerging areas of consensus where quantitative and qualitative research is triangulated for stronger outcome measures. It appears that well-done self-reporting (no high-stakes, valid, and reliable instruments) on a large scale, complemented by well-selected (nonintrusive, randomly assigned, systematically reported) observations of the same environment, may be the most cost-effective approach to gaining a true picture of information technology use in most educational environments. Initial findings are emerging that indicate that a well-trained outside observer may provide a slightly more valid (relevant) appraisal of a classroom environment than the teacher him-/herself but that the teacher may provide a more reliable (consistent) appraisal than an observer who is typically in the classroom 1 or 2 hours of a school year (Knezek et al. 2005; Mayes 2014). One finding that has emerged in recent decades is that both the teachers themselves and outside observers with rich knowledge of daily classroom activities are reasonably accurate judges of teachers' classroom integration abilities (Christensen and Knezek 2008). While there are many techniques used to measure, this chapter will predominantly focus on self-report assessment.

Attitudinal Measures

Researchers have known for decades that IT attitudes and beliefs have powerful influences on actions. Teachers' attitudes are known to play an important role in the effective use of technology (Buabeng-Andoh 2012; Sang et al. 2010). Attitudes affect the teachers' level of confidence in using technology as well as their personal use and adoption of technology for use in class. Teacher attitudes can often determine the success or failure of an initiative to introduce technology into the classroom. While there are many attitudes that impact instruction, the longer-term dispositions that tend to impact technology integration in education include anxiety, beliefs, confidence, and perception of usefulness. In this chapter, we will follow the general definition of dispositions published by Allen et al. (2014): "We call these human qualities dispositions – a person's core attitudes, values, and beliefs demonstrated through both verbal and non-verbal behaviors as one interacts with oneself, others, one's purpose, and frames of reference" (Allen et al. 2014, p. 2).

Measuring teachers' attitudes is one important step in obtaining an overall picture of an educator's level of readiness for or proficiency in technology integration. This area of measurement is focused in the affective psychological domain and is commonly identified with concepts such as receptivity, motivation, will, interest, propensities, or long-term dispositions. Instruments to measure attitudes of teachers toward technology have been available in the literature for more than 30 years and are still being developed and refined today. Concepts measured by these instruments are normally validated through factor analysis and will frequently be referred to as constructs (core concepts identified through factor analysis) or simply factors in this chapter. Exemplars of instruments measuring teachers' attitudes are presented in this section.

Loyd and Gressard (1984) developed the 30-item **Computer Attitude Scale** (CAS) to measure attitudes toward computers for students, but it has been adapted over the past three decades for use by preservice and in-service teachers. The subscales include *computer liking*, *computer confidence*, and *computer anxiety*. Loyd and Gressard (1984) found that positive attitudes toward computers are positively correlated with teachers' extent of experience with computer technology and that with familiarity, anxiety decreases while confidence increases. The scale has been widely used for decades and translated into other languages such as Turkish and Hebrew for use in other cultures, retaining respectable reliability and validity.

The **Teachers' Attitudes Toward Computers** (TAC) questionnaire was developed to measure teachers' attitudes and was based on 14 previously published instruments for assessing attitudes toward computers, including Loyd and Gressard's (1984) CAS (Christensen and Knezek 2000). The TAC (Christensen and Knezek 2009) includes nine factor-validated constructs: *interest/enthusiasm*, *comfort* (lack of anxiety), *accommodation*, *interaction* (electronic mail), *concern* (negative impact), *utility/productivity*, *perception*, *absorption*, and *significance*. Findings comparing teachers who received year-long, needs-based technology integration professional development versus those who did not revealed a significant increase on computer importance and decrease in computer anxiety for those who received professional development (Christensen 2002).

More recently, Leng (2011) developed an updated version of the Loyd and Gressard's (1984) CAS by updating the items from referencing exclusively computers to referencing the broader area of ICT and also modifying items in other ways to make them more suitable for current environments. The **Information and Communication Technology Attitude Scale for Teachers** (ICTAST) instrument was tested for validity and reliability and found to retain good reliability and construct validity (Leng 2011). Leng (2011) retained the three original subscales, *anxiety*, *confidence*, *liking*, and added the additional subscale, *usefulness*. Findings indicated a strong relationship between attitudes and access to technology (Leng 2011).

Albirini (2006) developed the **Attitudes Toward Computer Scale** (ATCS), consisting of a scale to measure overall positive or negative attitudes toward technology. In addition, the instrument includes four subscales: *access*, *competence*, *perceived usefulness*, and *perceived cultural relevance*. In a study involving more than 300 teachers, attitudes toward technology were found to be predicted by computer attributes, cultural perceptions, and computer competence. In another study using the ATCS to measure teachers' attitudes, Hart and Laher (2015) found perceptions of usefulness of technology to be the strongest predictor of teachers' attitudes. The increasing emergence of usefulness of technology indicates that it is an important construct for instruments measuring teacher attitudes. Davis defined perceived usefulness as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis 1989, p. 320).

Attitude measures are one major component of teacher development for technology integration. The following section will address two other major components – competency and self-efficacy.

Competency and Self-Efficacy Measures

In the competency-based environment that surrounds twenty-first-century education, proficiency in technology has assumed an important role, whether it is used to enhance instruction; for communication between teachers, students, and parents; or to assess student learning. The ability to integrate twenty-first-century technology for learning in schools is an expectation for teachers in most parts of the world today. Because technologies are constantly changing and the most productive use of technology is dependent on content, it is now considered more important to develop general competencies focused on how technology can be used for teaching and learning. For example, in Norway, there is a focus on a cross-curricular approach to technology competence in the curriculum. This approach includes the areas of processing information, creating and communicating information, and the ethics of technology use (Tondeur et al. 2017).

Measuring whether or not teachers are confident in their ability to integrate the evolving tools is important in order to target professional development. Using valid and reliable instruments to assess teachers' perceived proficiency with twenty-first-century technology tools is an important step in targeting appropriate levels in school-wide training activities, as well as planning meaningful developmental pathways for individual teachers.

Researchers have developed survey instruments to assess teacher self-efficacy and technology use to determine the role self-efficacy plays in the integration of technology in the classroom. Milman and Molebash (2008) developed a survey, **Confidence in Personal and Instructional Use of Technology**, that specifically addressed their state standards for educator technology proficiency for undergraduate and graduate students enrolled in an introduction to technology course. Their analysis showed their course was effective in increasing personal confidence in using technology, both pre to post and longitudinally 5–7 years later when they the former students were practicing teachers (Milman and Molebash 2008).

Wang et al. (2004) used the **Computer Technology Integration Survey** to measure the development of preservice student confidence, by including vicarious learning experiences and goal-setting activities in an introductory technology course. The survey measured confidence levels using two factors: *computer technology capabilities and strategies* and *external influences of computer technology uses.*

Research on a large sample ($n = 5938$) of teachers in Taiwan used an ICT **Integration Proficiency Measure** to assess changes over time in teachers (Hsu 2017). The instrument includes six factors: (1) *preparation*, (2) *production*, (3) *communication*, (4) *instruction*, (5) *development*, and (6) *issues*. Findings from this study suggested that teachers' pedagogical usage of technology changes more slowly than other technology measures included as scales. However, in the area of issues related to students' health and safety, teachers' concerns grew over time regarding Internet usage (Hsu 2017).

The **Technology Proficiency Self-Assessment** (TPSA) was initially developed in 1999 to measure teacher confidence (self-efficacy) when using technology for educational purposes (Ropp 1999). The original instrument included four scales (*email*, *WWW*, *integrated applications*, and *teaching with technology*) and has been refined over the past 15 years with the continual goal of measuring educators' self-efficacy in their ability to integrate technology into the classroom environment. The TPSA was based on the International Society for Technology in Education (ISTE) standards for educators in place at the time of development. Ropp (1999) reported significant improvements in technology proficiency and computer self-efficacy measures during a semester-long hands-on technology in education course. Christensen and Knezek (2017a) gathered teacher data, including the TPSA, over ten consecutive years from a large school district. Data gathered from the approximately 1320 teachers indicated that teachers generally gained over time in their confidence in their competence in using technology as well as teaching with technology (Christensen and Knezek 2017a). Researchers in Turkey translated the original TPSA into Turkish and conducted a reliability and validity study with in-service teachers, finding the instrument to be a reliable source for assessing technology self-efficacy in teachers (Gencturk et al. 2010).

Christensen and Knezek (2017a) revised and extended the TPSA to include two new scales for twenty-first-century competencies related to teaching with emerging technologies. The updated 34-item TPSA, called the **TPSA C21**, assesses educators on the following 6 constructs: *email*, *WWW*, *integrated applications*, *teaching with technology*, *emerging technologies*, and *teaching with emerging technologies.* The revised TPSA C21 constructs can be categorized according to two higher-order dimensions, with old versus new technology tools along one axis, while teacher-introduced technologies used with and by students to promote student learning, versus technologies for teachers' own professional development, serve as the distinguishing characteristics along the second axis (Christensen and Knezek 2017a).

The **Intrapersonal Technology Integration Scale** was developed to measure intrapersonal variables that impact educators' dispositions toward integrating technology for instruction (Niederhauser and Perkman 2008). The survey was validated on preservice teachers and includes four subscales: *self-efficacy*, *outcome expectations*, *interest*, and *behavioral intentions*. The self-efficacy subscale was intended to measure confidence in integrating technology in the classroom, while the interest subscale was intended to measure the level to which the educators were interested in integrating technology in instruction. Outcome expectations were used to measure the benefits these educators anticipated would occur with technology, and the behavioral intentions assessed the intention to integrate technology in the future. Use of the Intrapersonal Technology Integration Scale with preservice teachers revealed that self-efficacy and outcome expectations were related to each other and both contributed to the prediction of performance (Perkman and Pamuk 2011).

The **Technology Uses and Perceptions Survey** (TUPS) was initially developed by Hogarty et al. (2003). It has been updated to include new technologies and pedagogical strategies. The revised TUPS measures ten domains related to classroom technology integration (Rizhaupt et al. 2017), including *teacher confidence in their competence in using technology*, *teacher attitudes toward integrating technology*, and *teacher perceptions of the usefulness of technology for learning*. It is recommended as a descriptive tool to inform school improvement efforts related to technology implementation programs (Rizhaupt et al. 2017).

Researchers in Belgium (Tondeur et al. 2017) developed a **Preservice Teachers' ICT Competencies** instrument to measure teacher ICT competencies. They found a two-factor structure and confirmed that the instrument measures *competencies necessary to support student learning in the classroom* and *competencies needed to design instruction*. This competency structure aligns with measures on the TPSA C21 in which there are tools to prepare teachers to teach and also the use of technology to enhance learning.

In the area of assessment of competencies, many highly respected instruments exist that are not classified as self-report questionnaires. Two examples are described in the following section. The first might best be described as a technology literacy test, while the second is a structured observation instrument using technology to support the observation.

The **WayFind Teacher Assessment** created by Learning.com is an online performance-based assessment in which teachers or school districts pay to complete a 1–2 hours assessment of *technology literacy* following ISTE standards (Learning.com 2012). While the WTA appears to have a useful place in teacher education, it has a required fee, and someone must download, analyze, interpret, and manage the results (Banister and Reinhart 2012).

During the twenty-first century, it has become more practical for expert observers to use handheld technologies to complete structured assessments and record the strengths and weaknesses of technology-using teachers' performance during an actual class where students are learning. One tool that supports observational data collection is the **Technology Integration Matrix** (TIM) developed by the Florida Center for Instructional Technology at the University of South Florida (Mayes 2014). The Technology Integration Matrix (TIM) was produced by blending Jonassen's five characteristics of meaningful learning (Jonassen et al. 2003), with the stages and levels of adopting technology into the learning environment as defined by the Apple Classrooms of Tomorrow (ACOT) project (Dwyer et al. 1989). The combination of these two conceptual frameworks resulted in a rubric-like instrument for measuring levels of technology integration. This type of theory-based instrument and high-quality, interactive, user interface designs allow less obtrusive counting and recording of specific instances of teaching and/or learning behaviors in an authentic classroom. TIM is one example of a hybrid system that uses technology to help validate concrete instances of teaching and learning with technology.

Evidence is emerging that hybrid systems involving teacher-technology partnerships are destined to become more sophisticated and more prevalent in primary and secondary teaching and learning in the future. Tools are currently being created to give teachers nearly instantaneous feedback on the performance of their students. Many of these are based on artificial intelligence technologies (Luckin et al. 2016). Commercial examples such as Khan Academy, which as of 2017 aims to offer individualized instruction in primary and secondary math and select topics in science, history, business, art history, and test preparation, already make more than 100,000 practice exercises and instructional videos available for potential guidance by primary and secondary teachers (Edusurge 2017). Primary and secondary school-teachers need competency to accept and use new tools in classrooms to determine learning needs, prescribe learning tasks or enhancements, and monitor student progress using data feedback systems. As advances are made in learner analytics and "big data" analysis that could possibly provide daily feedback to the individual teacher level, we can anticipate the prospect for cooperative planning and modifications of learner activities among the classroom teacher and school leader levels.

Pedagogy Measures

The instructional strategies that teachers use in the classroom are evolving due to the influences and influx of technology. Watkins and Mortimore (1999, p.17) offered a definition of pedagogy as "any conscious activity by one person designed to enhance learning in another." For the purposes of this chapter, pedagogy includes teaching style (teacher-centered, student-centered, etc.) and encompasses what is normally understood as teaching approach or instructional strategy.

Measures of pedagogical style have been developed over past decades and refined by researchers. For example, Jacobson et al. (2010) refined the **Learner and Teacher-Centered Pedagogical Practices Survey** (Center for Research of Pedagogy and Practice 2005) based on data gathered from 1882 teachers in 51 schools in Singapore, in order to assess *deep thinking/creativity connectedness*, *transmission instruction* (vs. constructivist instruction), *assessment*, and other constructs not reported here because they were represented by no more than 2 items per construct. Jacobson et al. (2010) also used the same dataset to refine additional scales from instruments by Becker and Anderson (1998), including the (a) **Use and Impact of Computers in Schools** and (b) **Teachers' Perceptions of Their Work Environment**. Validated scales include *learner-centered use of computers*, *assessment of teachers' computer skills*, *perceived advantages of computer use*, *perceived disadvantages of computer use*, *work environment indicators*, *teachers' professional development*, *and practices encouraged by school*. Findings from this large study were that teachers who used computers more frequently in learner-centered ways had more positive perceptions toward technology and used computers more frequently per week (Jacobson et al. 2010).

Shulman's Pedagogical Content Knowledge (PCK) framework emphasized the intersection of pedagogy and content knowledge, encompassing knowledge about different types of learning and the many different ways to teach (Shulman 1986). TPACK added the technology component to the pedagogy and content knowledge (PCK) framework (Mishra and Koehler 2006). An assessment instrument based on the Technological Pedagogical Content Knowledge (TPACK) framework was developed to measure teachers' understanding of each component of the TPACK framework (Schmidt et al. 2009). Four of the components related to pedagogy: *pedagogical knowledge* (PK), *pedagogical content knowledge* (PCK), *technological pedagogical knowledge* (TPK), and *technological pedagogical content knowledge* (TPACK). Since the TPACK survey was developed (Schmidt et al. 2009), it has been adapted and used by many researchers and translated into several different languages. Archambault and Barnett (2010) administered the TPACK survey instrument to 596 K-12 teachers online. The researchers reported that three separate factors (p*edagogical content*, *technology-curricular content knowledge*, and *technological knowledge*) were extracted and there was a strong correlation between pedagogy and content.

Koh et al. (2010) revised the Schmidt et al. (2009) survey and found that the pedagogy items combined pedagogical knowledge and pedagogical content knowledge into one factor. Researchers gathered data using questionnaires for *pedagogical beliefs* (9 item pairs), *teaching activities with technology use* (5 item pairs), and factors associated with technology integration (30 items) (Liu 2011). The goal of the research was to determine the factors related to pedagogical beliefs of teachers and technology integration. The results indicated that while most of the teachers held learner-centered beliefs, less than one third of the teachers implemented learner-centered activities with technology.

Several models of technology integration include measures of attitudes, competency/self-efficacy, and pedagogy as determinants of technology integration.

Measures have also been developed to assess levels of technology integration directly. The following section will address several of these measures.

Technology Integration Measures

A collaboration of public schools, universities, research agencies, and Apple Computer Inc., began the study of technology-infused classrooms as opposed to the previous focus on technology skills (Dwyer 1994). This research began in 1985 and influenced the study of technology-infused classrooms and how we look at teaching and learning with technology. The Apple Classrooms of Tomorrow (ACOT) project, as this longitudinal study was called, influenced the direction of research on educational technology by focusing on technology-using teacher proficiencies in developmental stages. Many measures have since been developed using a stage-based developmental framework compatible with ACOT, often based on well-regarded theoretical perspectives. Several of these are discussed in this section. For the purpose of this chapter, technology integration is defined as the adoption and use of technology by teachers for classroom learning.

One long-lasting product of the ACOT longitudinal study was an instrument to measure teacher development in technology integration. The **Apple Classrooms of Tomorrow** (ACOT) survey (Dwyer et al. 1989) defines educator progress in terms of five stages: *entry*, *adoption*, *adaptation*, *appropriation*, and *invention*. The five stages were defined by researchers and practitioners as developmental stages that teachers go through as they advance toward higher levels of technology integration in the classroom.

Another measure of technology integration is **Stages of Adoption of Technology** (Stages) (Christensen 2002). Stages is a self-assessment of a teacher's level of adoption of technology. There are six possible stages in which educators rate themselves: Stage 1 (*awareness*), Stage 2 (*learning the process*), Stage 3 (*understanding and application of the process*), Stage 4 (*familiarity and confidence*), Stage 5 (*adaptation to other contexts*), and Stage 6 (*creative application to new contexts*). Because the Stages of Adoption of Technology instrument is a single-item survey, internal consistency reliability measures cannot be calculated. However, a high test-retest reliability estimate (0.91) was found on a pre-posttest including a large group of teachers (Christensen and Knezek 2001a).

The **Concerns-Based Adoption Model Level of Use** (CBAM LoU) instrument is targeted toward describing behaviors of innovators as they progress through various levels of use – from *nonuse* to *managing* and finally to *integrating use of the technology*. The instrument is based on the eight levels of use defined in the Levels of Use Chart (Hall et al. 1975). The levels of use are (0) *nonuse*, (I) *orientation*, (II) *preparation*, (III) *mechanical use*, (IVA) *routine use*, (IVB) *refinement*, (V) *integration*, and (VI) *renewal*. The concept of levels of use also applies to groups and entire institutions. The instrument is time-efficient to use as an indicator of an educator's progress along a technology utilization continuum.

While ACOT, Stages, and CBAM LoU are each one-item instruments, Hancock et al. (2007) found that these three single-item instruments, taken together, produce a **Technology Integration Scale** (TIS) with an internal consistency reliability of alpha = 0.84 for a typical set of teachers.

As previously described as related to pedagogical measures, the **Technological Pedagogical Content Knowledge** (TPCK) model, also known as Technology, Pedagogy, and Content Knowledge (TPACK), was formalized by Mishra and Koehler (2006). This instrument contains seven components in the TPACK framework, i.e., *technological knowledge* (TK), c*ontent knowledge* (CK), *pedagogical knowledge* (PK), *pedagogical content knowledge* (PCK), *technological content knowledge* (TCK), *technological pedagogical knowledge* (TPK), and *technological pedagogical content knowledge*, all of which are components necessary for describing complex interactions in technology-supported classroom environments. Several instruments have been developed to assess TPACK components. The **TPACK Assessment Instrument for Pre-Service Teachers** was developed and validated to measure all seven TPACK domains (Schmidt et al. 2009). The TPACK Assessment Instrument was produced as a 47-item instrument with scale internal consistency reliabilities ranging from alpha = 0.75 to alpha = 0.85. Later Heitink et al. (2016) extracted eight **TPACK Core** items, with alpha = 0.91, from the original instrument by Schmidt et al. (2009).

Measures of technology integration described in this section are often used as direct outcome measures (goals in themselves) or as dependent variables to study how professional development in areas such as technology skill or pedagogy contribute to higher levels of technology integration in the classroom. Technology integration measures can also be viewed as intermediary variables, where the goal is to study how higher levels of integration contribute to greater student learning. The following section will focus on uses of technology integration measures.

Use of Information Technology Measures in Education

The ubiquitous presence of technology in society would indicate that emerging technology tools should not only be introduced into education but used effectively to support learning. Teachers at all levels are encouraged to incorporate technology into the classroom with the expectation that it will enhance student learning. Technology integration, in which the students are the primary users, has been shown to increase student understanding, engagement, and critical thinking (Sheehan and Nillas 2010). Whether or not teachers are prepared or even receptive to integrating technology into the learning environment is a multifaceted issue. Many factors contribute to successful teacher-led integration of technology in the classroom. Some of the identified factors include professional development, school culture, administrative support, access to technological resources, adequate planning time, pedagogical teaching style, beliefs about technology and learning, attitudes toward technology, and self-efficacy in using technology for learning.

Most education professionals in the twenty-first century agree that good teaching practices should determine technology use rather than technology driving the practice of teaching (International Society for Technology in Education (ISTE) 2010). “If the use of technology to enrich learning is ever to become effective, we must stop regarding it as a separate entity and see it as part of everyday instruction” (Johnson 2013, p. 84). Having precise, multifaceted measures of teachers’ abilities regarding important attributes related to information technology in education can aid in ensuring that decision-makers of the future are properly introduced to important IT-focused societal goals.

Combining Measures to Create a Comprehensive Context

Psychometricians have known for decades that many of the constructs measured by the instruments presented in this chapter are related to each other. Figure 1 illustrates the relationship between lack of computer anxiety (*comfort*) as well as other attributes measured by the Teachers’ Attitudes Toward Computers (TAC) instrument, as teachers advance from lower to higher stages of adoption of technology. This strong linear relationship of an increase in comfort (decrease in anxiety) as teachers advance through higher stages of adoption of technology has been found in multiple studies (Christensen and Knezek 2001a, b). Similar trends have been found for Concerns-Based Adoption Model Level of Use (CBAM LoU) and Apple Classrooms of Tomorrow (ACOT) teacher stages (Christensen and Knezek 2001a). This linear relationship allows researchers and professional development practitioners to estimate (approximate) the probable median level of technology integration proficiency of a group of teachers (e.g., educator’s from one school) by assessing their

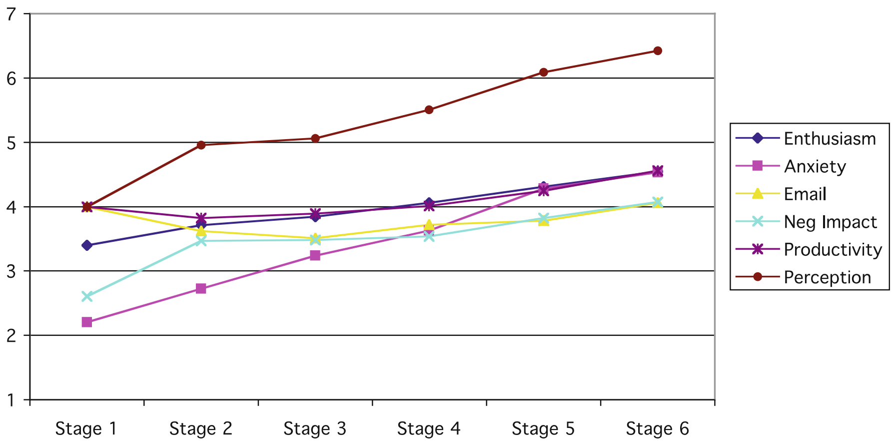

Fig. 1 Teacher attitudes toward computers by stages of adoption of technology

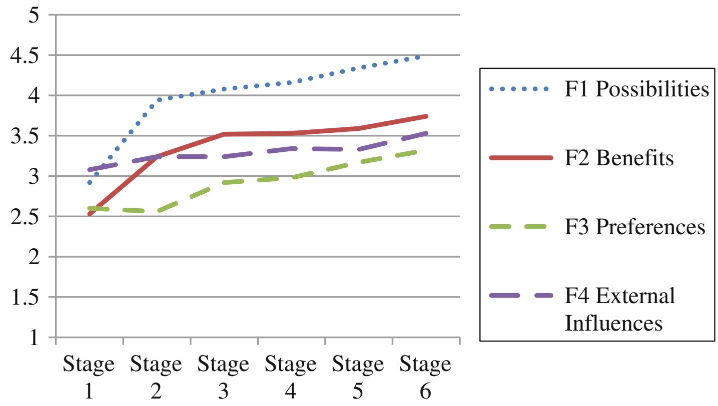

Fig. 2 Teachers' mobile learning readiness by stages of adoption of technology

attitudes toward technology – or vice versa. Targeting professional development is then possible without administering an extensive battery of instruments to obtain comprehensive measures in all areas.

Newer technologies such as mobile learning devices have shown similar linear relationships to stages of adoption of technology. Christensen and Knezek (2017b) demonstrated that the general progression toward higher technology integration proficiency as attitudes become more positive also applies to teacher willingness to accept newer information technologies such as mobile learning. The **Mobile Learning Readiness Survey** (MLRS) includes four dimensions of readiness to teach with mobile devices. These four factors are *possibilities*, *benefits*, *preference*, and *external influences.* As shown in Fig. 2, teacher willingness to adopt mobile learning in their classroom has a strong relationship with their level of technology integration, as was true for the longer-established attitudinal constructs that produced Fig. 1 (Christensen and Knezek 2001b). This relationship indicates that the mobile learning readiness constructs (*possibilities*, *benefits*, *preferences*, and *external influences*) are positively associated with teacher level of proficiency in technology integration, as measured by the Stages of Adoption of Technology instrument.

Sherer et al. (2017) examined the relationship between three measures of technology attitudes and TPACK self-efficacy beliefs. The three core attitudes toward ICT measures included the *General Attitudes Toward ICT* (GATT) *scale*, the *Attitudes Toward the Educational Use of ICT* (EDATT) *scale*, and a *Perceived Ease of Use ICT scale*. Using structural equation modeling, the researchers showed that there is a positive relationship between the attitudes and the TPACK self-efficacy dimension (Sherer et al. 2017). Specifically, the more general attitudes were related to the pedagogical and content-related dimensions of the TPACK. However, the more technological attitudes showed a stronger relationship to the technological knowledge dimension of TPACK (Sherer et al. 2017).

Discussion

Many factors enter into choosing the best instruments in the technology in education arena. Among the most important considerations for choosing and using particular instruments are (a) the appropriateness of the instrument for the task at hand, (b) the quality of the measurement tool, (c) the amount of disruption to the environment, and (d) the cost. Well-validated and reliable instruments are required in order to produce credible results. Each of the instruments presented in this chapter has associated publications that verify that the constructs they purport to measure have well-established validity (content, construct, and criterion-related) that demonstrates they are appropriate for the measurement task at hand. The scales of each instrument have also been reported to have acceptable reliability (consistency of measurement) based on standard criteria.

There are limitations to the list of instruments presented as examples in this chapter. The list was compiled based on the criteria of breadth, with the goal of introducing a wide range of respectable instruments that exist for attitudes, skills (competencies), and pedagogical practices, in the general realm of technology integration within the domain of information technology in primary and secondary education. The trade-off is that depth is shallow within any specific focused area. Numerous other instruments exist that are reliable and valid but not described in this chapter, and others will undoubtedly emerge.

Another limitation is that the instruments presented in this chapter are predominantly self-report surveys, which are described by the US Northeast and Islands Regional Technology in Education Consortium as psychological inventories that are reported by the subject, commonly asking direct questions related to perceptions, attitudes, or intended actions (NEIRTEC 2007). There are numerous rationales for using self-report surveys to assess information technology (IT) attitudes and competencies and some special considerations as well. One rationale is that the technique typically has an anonymous quality not possible through outside observation. Another is that it is difficult to observe certain indicators such as attitudes and beliefs from outside the person, and therefore data provided by the subject may be more accurate than data gathered by an outside observer. Also, in many situations, time constraints and funding restrictions make self-report the only practical solution for gathering data.

A primary reason for focusing on self-report surveys in this chapter is that they have a long-established tradition for reporting empirical evidence of their accuracy (reliability) and appropriateness (validity) for the task at hand, as justification for their worth. As we look to the future, we can envision a day when currently emerging technology recording aids ranging from physical activity monitors to learner analytic systems assign “quantifiable scores to individuals” as required for measurements as defined in the opening paragraph of this chapter. These are viewed by the authors as complimentary rather than competitive prospects for the future measures, compatible with the current generation of instruments described in this chapter.

Conclusion

Teachers are the key players in the success or lack of success of any technology initiative in the classroom. Teachers must perceive that technology is a useful tool for improving learning for their students before it is adopted into classroom practice. The perceived usefulness of technology can influence teacher attitudes toward technology which contribute to the overall receptivity of technology integration.

Most countries of the world agree that technology competencies are important for twenty-first-century teachers. Reviewers of the 2016 US National Educational Technology Standards (NETS) have stated the issue succinctly as “Technology is a reality but students and teachers need new ways to envision its purpose and possibilities” (Stoeckl 2016, np). Therefore technology integration proficiency for teachers involves more than just technology skills; it includes being able to envision technology’s purpose and possibilities and having confidence in the path chosen.

The preparation of teachers is recognized as a critical ingredient for the integration of technology into the classroom. The “effective professional development of teachers in the integration of technology is necessary to support student learning” (ISTE 2008, p. 3). Teachers who have had technology training are more likely to show positive attitudes toward use in the classroom (Miranda and Russell 2012). Thus education can help teachers to feel less anxiety and more confidence and generally value technology more highly (Lambert et al. 2008). Teachers with classroom experience who have not received technology professional development are less likely to use technology in the classroom and less likely to see the benefit of the use of technology in the classroom (Cope and Ward 2002).

Numerous instruments have been developed to help diagnose where teachers need assistance and to accurately prescribe how development can be fostered to aid teachers in integrating technology into teaching and learning practices. It is desirable to include more than one type of measure to more comprehensively assess teachers’ needs and prescribe appropriate professional development. A multifaceted profile can provide a robust description of a teacher’s current level of development, which can serve as a solid foundation for prescribing additional training leading to greater proficiency in technology integration. Greater technology integration proficiency should lead to better educated students with higher IT skills, which will in turn better serve the goal of productive future citizens in our society.

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Section V

Professional Learning and Development of Teachers

Section Introduction: Professional Learning and Development of Teachers 24

Peter R. Albion and Jo Tondeur

Abstract

Teachers play crucial roles in realizing the potential of technology for transforming education in a rapidly changing world. Their ongoing professional learning underpins their capacity to respond to the needs of learners. This section examines the knowledge required by teachers and how that can be developed.

Keywords

Professional development · Professional learning · Agency

A casual observer of education might wonder why both "learning" and "development" appear in the title of this section, assuming that professional learning naturally flows from professional development. However, as argued by Timperley (2011) and others, the link is not so clear in practice, with much professional development resulting in a little or no change in the professional behaviors of teachers. Moreover, much teacher professional learning that does produce effective change in teacher behaviors occurs outside of formal professional development. The authors in this section are conscious of the difference and address both professional development and professional learning where appropriate, with the fourth chapter contrasting

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frequently top-down formal professional development with the mostly informal and self-directed professional learning.

Similarly, because the focus of the handbook is on the application of information and communication technology (ICT) to enhance learning in school classrooms, teacher learning about the use of ICT is the appropriate focus of this section. However, the power of ICT for enhancing learning is as applicable for teachers as it is for their students. Hence the chapters in this section consider both what teachers need to learn about ICT and the application of ICT to promote their professional learning.

In the first chapter of the section, Albion and Tondeur observe that education and the work of teachers must evolve in response to rapid development of ICT and concurrent changes in society. They argue that the rate of change is such that centralized recommendations for new pedagogical applications of ICT and associated teacher professional development cannot match the pace. Moreover, the circumstances of teaching are highly varied so that teachers must orchestrate available ICT with their own skills to meet the diverse needs of learners in different contexts. The solution proposed is to promote teachers' agency to individually and collectively engage in appropriate teacher learning. This approach promotes the capacity of teachers to respond creatively to contextual needs rather than the prevailing trend to standardize classroom activity.

In the second chapter, Angeli and Valanides explore the knowledge required by teachers for effective integration of ICT. Despite a degree of consistency around Technological Pedagogical Content Knowledge (TPACK), they conclude that the continuing emergence of new elaborations makes development of a robust theory improbable. Instead, they propose an approach based on affordance theory. ICT offers teachers both technical and pedagogical affordances but they must first perceive and appropriate technical affordances before they can move to perceiving pedagogical affordances. Angeli and Valanides argue that there is a need to focus on deepening understanding of teachers' technological knowledge, the TK of TPACK, in relation to how teachers appropriate the affordances of ICT to solve pedagogical problems. The step from technical to pedagogical affordances can be challenging and probably relies upon acquiring sufficient technical skill with a tool that it becomes transparent in use, thereby enabling focus to shift to creative application to pedagogical problems.

Forkosh-Baruch, in the third chapter, considers the preservice preparation of future teachers to transform education with ICT. She begins by examining how identity affects the use of ICT by teacher candidates and, in common with Angeli and Valanides, notes the gap between personal and pedagogical use of ICT. Examination of approaches to teacher preparation around the world leads to proposal of a model in which technical skills with ICT provide a foundation for development of pedagogical skills through collaboration between academic courses in universities with practicum in schools. Concrete practical recommendations for preservice teacher training are provided at the end of the chapter.

Prestridge and Main, in the fourth chapter, examine how teacher professional learning occurs in the context of teams, communities, and networks. Their focus is on the pedagogical application of ICT that rests upon the necessary foundation of technical skills noted by Angeli and Valanides and Forkosh-Baruch. The methods they propose engage teachers in learning from each other, which enables the lessons learned by individual teachers experimenting with the application of ICT in their classrooms to be appropriated by colleagues. The interactions among teachers can be mediated and facilitated by ICT so that teachers personally experience the benefits of learning with ICT. Thus, collaboration becomes an effective method of multiplying the benefits of teacher agency in which teachers explore the application of ICT in their own contexts and share their learning with colleagues.

The often-strained relationship between research and practice in education, including the application of ICT, is tackled by McKenney and Pareja Roblin in the fifth chapter of this section. They consider the opportunities presented by directly engaging practicing teachers in research modes such as teacher inquiry and design-based research separately or together. Enabling teachers to research their own practice draws upon and extends their agency for discovering and confirming the value of practices attuned to their individual contexts. When coupled with the collaborative approaches described in the previous chapter, these modes of research can be powerful for quickly extending the reach of effective practices for applying emerging forms of ICT to meet the changing needs of education.

In the sixth and final chapter of the section, Baran explores how teachers engaging in pedagogical inquiry can become the agents of their own transformation to work effectively with online and mobile learning. Models such as mentoring, professional learning communities, and design-based learning resonate with the ideas presented in the previous chapters, but the practical recommendations for implementation are specifically related to the field of mobile learning.

Taken as a whole, the six chapters in this section attest to the need for teachers to be empowered to operate as professionals who can take substantial responsibility for their own professional learning. By exercising their personal agency to learn about the technical and pedagogical affordances of ICT, gathering evidence through practice-linked research to guide development of ICT supported pedagogy, and engaging in collaborative learning for and with ICT, teachers can be significant agents of educational transformation through ICT.

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Information and Communication Technology and Education: Meaningful Change Through Teacher Agency

25

Peter R. Albion and Jo Tondeur

Contents

Abstract

The quality of teachers is a very strong influence on the quality of education. In an era when societies and technologies are changing rapidly, both the nature of the education that is appropriate and the means available for its delivery are also changing rapidly. Hence, if teachers are to contribute to the ongoing transformation of societies by transforming education through the use of technologies, they will need to engage in personal transformation through ongoing learning. The wide variety of contexts in which teachers work with differing resources, the variability in their prior learning and in the needs of learners, the rapid changes in technologies, and the shifting expectations of society make it impossible for

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central authorities to prescribe educational experiences that will be suitable for all circumstances. Teachers must be empowered to practice their profession by orchestrating resources and activities to match educational provision to learners' needs. Recognizing the agency of teachers as professionals is essential to enlisting them as contributors to the ongoing transformation of education through application of ICT. This chapter addresses the essential role of teacher agency in the transformation of teachers and the education systems in which they work.

Keywords
Teacher agency · Professional development · Professional learning community · Educational transformation

Transformative Effects of ICT in Society

Evidence of the transformative effects of information and communication technology (ICT) is widely visible in the changing ways that people around the world live and work. Over the past half-century, computers, laptops, and tablets have changed common practices in most work environments and in many homes. Smartphones are practically ubiquitous in developed countries and increasingly prevalent everywhere, enabling almost continuous connection to people and sources of information around the world. Significant changes in the ways that people access information and interact with each other have laid foundations for broad changes in society (Lim et al. 2013). As a consequence, there will be changes in the education required to prepare young people for full participation as citizens (Hawkridge 1990; Spector 2010). The transformative effects of ICT in most aspects of modern life can be seen in changing patterns of communication and commercial activity as well as in the processes and products of manufacturing. These developments have contributed to the "flattening" associated with globalization (Friedman 2006) and initiated changes in the composition and requirements of the workforce, resulting in the hollowing out of the middle class in developed countries (Milanovic 2014).

Professional and service occupations have generally been sheltered from the disruptive effects of ICT because they required intellectual or manual capabilities that were not replaceable in the same way as the skills typically employed in manufacturing. Now there are signs that sheltered status may be disrupted by new developments in artificial intelligence (AI) and robotics that will constitute a fourth industrial revolution following the prior revolutions based on the widespread adoption of steam power, electricity, and electronics (Peters 2017). Developments in data science open the possibility for ICT to substitute for humans in a variety of nonroutine cognitive tasks while advances in sensing and manipulation are enabling robotics to perform an increasing range of manual tasks.

New forms of ICT including AI and robotics are expected by some to reduce the need for human labor in widening areas of activity (Peters 2017), potentially constraining choices about how we live. Nevertheless, there are voices that question the breadth of recent claims made about the coming revolution in AI and robotics.

Some question the extent of the capabilities that can be developed by machines and some argue for the importance of human society playing its proper role in creating the future rather than accepting the inevitability of outcomes flowing from technological determinism (Wajcman 2017). Regardless of the extent to which a fourth industrial revolution catalyzed by ICT through AI and robotics changes the nature of work and how much work remains available to humans, it seems certain that there will be changes in both the quality and quantity of work required for society to function.

Education System Responses to Developments in ICT and Society

Whether education is regarded from a utilitarian perspective as preparation for work or more holistically as developing the full potential of human beings, it must change in response to broader societal change. As Peters (2017) notes, ICT will not spontaneously transform education in the ways required to adapt to these changes. That will require educators, policy makers, and societal leaders to seek and implement appropriate solutions to transform education in parallel with developments in ICT (Aesaert et al. 2013). Almost 30 years ago, Hawkridge (1990) discerned four different rationales that drive educational policies related to the integration of ICT in education: (1) an economic rationale: the development of ICT skills is necessary to meet the need for a skilled work force, because learning is related to future jobs and careers; (2) a social rationale: this builds on the belief that all pupils should know about, and be familiar with, ICT in order to become responsible and well-informed citizens; (3) an educational rationale: ICT is seen as a supportive tool to improve teaching and learning; and (4) a catalytic rationale: ICT is expected to accelerate educational innovations.

These rationales continue to be relevant and are visible in the policies and actions of governments around the world. To illustrate, in Australia by the turn of the century, statements from the national and state governments had expressed expectations that young people would leave school as creative and productive users of ICT and that ICT would transform learning and teaching in Australian schools (DEEWR 2008). The expectations were accompanied by substantial investment but progress has been acknowledged as uneven. Similar aspirations have been voiced in other countries and by international organizations promoting transformation of education for the global good (UNESCO 2011).

The past decade or so has seen developments in school computing curricula around the globe. Fluck et al. (2016) described the incorporation of computer science in the curricula of Cyprus, the United Kingdom, and Australia as examples of what is happening in many countries. They made a case for inclusion of computer science in school curricula and suggested how it might be implemented. The Australian Curriculum includes, within the Technologies learning area, a Digital Technologies subject with a focus on creating digital solutions by applying computational, systems, and design thinking in addition to an ICT General Capability intended to develop ICT skills across all learning areas (ACARA 2015a). Similarly, in 2008 the

Flemish government responded to the expectations of the society by providing a set of ICT attainment targets, formulated as ICT competencies (Aesaert et al. 2013). Besides the importance of competencies to direct or support teaching and learning, the Flemish government also emphasizes the importance of ICT as catalyst to innovate teaching and learning approaches (catalytic rationale): ICT can boost the creation of a powerful learning environment. Other countries have engaged in similar educational reforms with the intention of embedding ICT in curriculum and pedagogy.

Nevertheless, several studies have observed incongruence between national ICT curricula and the actual level of adoption of integrated ICT use (e. g., Hatzigianni et al. 2016; Tondeur et al. 2008). For instance, a large-scale study found that Australian children aged 8–9 years were using ICT at school in conventional ways with little evidence of use to support creative and project-based activities (Hatzigianni et al. 2016). This suggests that children may be acquiring basic skills with ICT as envisaged in the ICT General Capability but are less likely to be developing as creators of digital solutions as envisaged by the Digital Technologies subject (ACARA 2015a). Moreover, there is evidence from a national assessment of ICT skills (ACARA 2015b) that, far from improving over time, skills measured by that assessment have decreased. One plausible explanation for such a decrease is that the skills measured in the assessment relate mostly to the use of applications on personal computers but the focus of schools and students has shifted to emerging forms of ICT such as tablets and handheld devices like smartphones. New technologies require different skillsets and the rate of change in ICT is sufficiently rapid that attempts to compare very specific skills over time may be futile if they have been made less relevant by changes in ICT.

Even where children are developing relevant ICT skills in school, they may not be experiencing learning and teaching transformed by ICT. Some lag in implementation of new curriculum imperatives is to be expected but the changes promoted by new curricula including elements of computer science will require substantial changes in the practice of teachers (Sentance and Csizmadia, 2017). In the USA, a recent survey of 700 teachers found that, although a majority regard themselves as risk takers or early adopters of ICT, their most frequent classroom uses of ICT were for conventional applications such as drill and practice (Rebora 2016). Creative and transformative applications were less frequently reported. Although the survey was not statistically representative, it did include teachers from varied schools across the USA and is indicative of the broad patterns of ICT use in education. The major challenges to more extensive ICT use were reported as limited access to digital devices, lack of training, curriculum demands, and unreliable Internet access.

From the research findings, it seems that the aspirations of national educational authorities do not automatically result in changes in classroom practices. These results raise questions as to how the priorities of ICT policies can be implemented. In this section, we challenge policy makers and schools to develop a vision about teachers' professional learning within the field of ICT for teaching and learning. In this respect, Lim et al. (2013) noted that the expectation of educational transformation through application of ICT had driven extensive investment by governments and others to provide ICT for use in schools. They cited international research that demonstrated some successes but concluded that transformation had not happened on the anticipated scale and that, like many previous innovations, ICT had scarcely affected the practice of most teachers. They identified two gaps in educational use of ICT. The first relates to usage; the breadth and depth of students' use of ICT in school are much less than outside school. The second relates to outcomes; compared to sectors beyond education, the effects of ICT on schooling are much less. Although they suggested paths to improvement, including development of effective policies and plans and provision of effective leadership by principals, there is no universally applicable solution to effecting transformation of education through ICT.

Nevertheless, the imperatives for change stemming from the broader transformational effects of ICT described in the first paragraphs (Friedman 2006; Milanovic 2014; Peters 2017; Wajcman 2017) remain. Neither the content nor the process of education as conceived to meet the needs of the earlier industrial revolutions can suffice to meet the challenges of the present time. Hence it is appropriate to consider how teachers and educational institutions respond to ICT and what may be done to support their roles in effecting the transformation of education to more effectively meet the needs of our time.

Understanding Teachers' Responses to ICT

Consistent with the findings described above, Ertmer and Ottenbreit-Leftwich (2013) observed that most teachers are using ICT primarily as aids to content delivery rather than to effect meaningful change in classroom activity and student outcomes. They described the most common experiences of students as learning *from* ICT through online searches for information and preparation of written assignments. They ascribed the problem to schools and systems placing emphasis on technology when the solution rests with pedagogy. In their view the goal should be to shift the conversation to *technology-enabled learning* so that the focus is on learning *with* technology rather than ICT integration as an isolated goal.

Even in developed countries, some teachers still report limited access to ICT or its unreliability as barriers to use (Rebora 2016). However, the significant investments by governments over recent decades have enabled access in most classrooms in the developed world (Ertmer and Ottenbreit-Leftwich 2013; Hatzigianni et al. 2016; Rebora 2016). That is also true in many parts of the developing world, although in some instances, provision of ICT has apparently taken priority over employment of teachers to use it (Livingston 2016). As noted by Ertmer and Ottenbreit-Leftwich (2013), access to ICT is no longer a significant barrier to transformation of education in most contexts. In this respect, the quality of teaching and teachers seems to be the most important determinant of student achievement (Hattie 2008). Clearly, if education is to be transformed by the application of ICT, then the manner of that application will depend upon the presence of teachers who are appropriately prepared to apply ICT to enhance learning and teaching.

Consequently, the benefits of teacher preparation for working with ICT will depend upon teachers implementing that learning in their classrooms. However, as noted above (Ertmer and Ottenbreit-Leftwich 2013; Ertmer et al. 2014; Hatzigianni et al. 2016; Lim et al. 2013; Rebora 2016), when teachers use ICT in their classrooms the applications tend to be mostly routine rather than transformational. Thus, it becomes important to consider what factors enable or retard transformational use of ICT in education. Numerous studies of factors influencing teachers' use of ICT have been conducted over recent decades. There have been extensive developments in the availability and capability of ICT over that period but there are some consistent themes in the responses of teachers.

Like the more recent studies cited above (Hatzigianni et al. 2016; Rebora 2016), an earlier study of a representative sample of more than 4000 teachers across the USA found that most computer use in classrooms was relatively mundane. Computer use mostly occurred in specific courses in computer education or business education or for word processing work for presentation but, under the right conditions, computers were an effective instructional tool (Becker 2000). Those conditions were convenient access to equipment, a degree of teacher skill and comfort with technology, support by teachers for constructivist pedagogies, and freedom within the scheduled curriculum for students to use computers.

Ertmer (1999) distinguished between first-order barriers, external to teachers such as resources, training, and support, and second-order barriers, internal to teachers such as confidence and beliefs. Of the four conditions identified by Becker (2000) as favoring computer use, constructivist beliefs fit the category of second-order barrier, internal to teachers, but the others are external, first-order barriers. In more recent work, Ertmer et al. (2012) suggested that, in the USA at least, the first-order barriers such as access to resources had been reduced in significance, making it opportune to examine the effects of second-order barriers in the form of teacher beliefs. Their study of 12 teachers selected for their award-winning technology practices found alignment of pedagogical beliefs with practices and that, consistent with earlier findings about constructivist beliefs (Becker 2000), student-centered beliefs were associated with enhanced use of ICT in classrooms. Change in teachers' behaviors is more likely to occur when professional development experiences are situated within the context of teachers' own curricular needs (Koehler and Mishra 2009).

Teacher Agency and ICT Use

A useful concept in this context is teachers' agency, that is "their active contribution to shaping their work and its conditions" (Biesta et al. 2015). Similarly, Martin (2004) defined agency as the capability to make choices and act on these choices in a way that makes a difference in their lives. In the field of ICT, agency can be described as the ability for individuals to control and manage their use of ICT and online presence, including managing identity, initiating interactions, using technologies for self-identified purposes, and modifying or developing digital tools (Starkey 2017). As a consequence, requirements for developing digital agency are very closely aligned with earlier conceptions of uses of digital technologies that are differentiated into "consumer" or "producer" activities and outcomes (Shonfeld et al. 2017).

The concept of teachers' agency stresses the importance of professional development as an iterative process, aimed at extending and updating the professional knowledge and beliefs of teachers in the context of their work (Tondeur et al. 2016b). Several studies suggest that the involvement of teachers in collaborative design constitutes an effective strategy to develop digital resources in line with their pedagogical beliefs (cf., Kafyulilo et al. 2015; Sang et al. 2010; Voogt and Tondeur 2015). These types of initiatives also have the potential to bolster teachers' self-efficacy, which in turn has been found to influence teachers' beliefs about ICT use (Holden and Rada 2011).

Although Becker (2000) did not use the term, his fourth condition might be interpreted as corresponding to *agency*, which is a way of describing how teachers engage with policy and enact their professional practice (Priestley et al. 2015). Becker reported that teachers who were bound by fewer specific constraints about how they should teach could exercise professional judgment about their use of ICT and were more likely to find ways in which they could use it. Around the same time, Cuban (2001) studied primary and secondary school teachers in Silicon Valley, where it might be presumed that positive dispositions to ICT would be unlikely to restrict use. He found that teachers at all levels used computers for research and preparation but that classroom integration was more common in primary school classrooms than in secondary. The simple explanation related to timetable constraints in secondary schools limiting teachers' capacity to adjust to technical issues within a single teaching period compared to primary schools where the teacher was with a class all week and could rearrange activities to accommodate issues when or if they occurred. Again, more teacher agency to make and implement decisions was associated with more integrated use of ICT.

Almost two decades later, in a period of rapidly changing technologies and diverse classrooms, it is more important than ever that teachers can exercise professional judgment about the application of ICT to meet the needs of learners. ICT presents challenges because of the rapid pace at which it continues to develop. As new hardware and software appear in classrooms they bring new possibilities for learning and teaching and sometimes result in the disappearance of familiar capabilities and changes in the skillsets required by teachers and learners (ACARA 2015b). Preparation of teachers for working with ICT must be ongoing and will ideally prepare them to adapt to changes in ICT as they appear in their classrooms. Teachers, learners, and the classroom contexts in which they work differ widely so that there is no universally applicable approach to achieving educational goals. Professional development can address the knowledge and skills of teachers but what they learn must be applied to support learners who differ widely on dimensions including facility with ICT, and the ICT available in schools is far from uniform. It is the work of skilled teachers to plan and implement instruction that matches their own skills with the needs of the learners in their context to achieve the educational outcomes specified by the curriculum. Teacher professional agency is important to both the application of ICT in their classrooms and the provision of appropriate opportunities for professional learning about ICT.

Teacher Agency and Accountability

There are good reasons for education at all levels to be directed toward equipping graduates with the knowledge and skills required for full participation in society. That necessarily entails a degree of standardization around outcomes to be achieved and methods for assuring that achievement. That is, education systems and educators should be accountable to the societies that establish and fund them. In reviewing the apparent lack of progress in teacher professionalism over the past decade, Sachs (2016) noted that teachers tend to identify their accountability as being to students they teach and the communities in which they work, what can be described as *responsive accountability*. On the other hand, governments and employers focus on *contractual accountability* for learning outcomes that may be measured by performance on standardized tests.

The latter entails management of performance against standards and can lead to tightly regulated regimes in which teachers have little apparent agency and may be constrained into monitoring behavior of colleagues as well as themselves. The consequent erosion of trust develops habits of risk aversion and reluctance to stray from established practices regarded as safe. Bahia et al. (2017) studied the reactions of a group of university teachers in Portugal to the changes resulting from the Bologna process which is intended to ensure that higher education produces comparable outcomes across Europe. They found that the teachers struggled with reconciling the assessment requirements of the process with their focus on promoting learning by students. Achieving an appropriate balance between the standardized outcomes and attention to the needs of individual learners is challenging.

When, as appears to be the case in many countries, educational policy is directed toward improving achievement as measured by standardized tests, teachers may be constrained in how they approach their work. Buchanan (2015) argued that the emphasis on standards and accountability does not value teacher autonomy. She cited Hargreaves' (2000) conceptualization of teacher professionalism progressing through four historical phases (pre-professional, autonomous professional, collegial professional, and post-professional or postmodern) and expressed concern that the current circumstances match Hargreaves' dystopian vision of a post-professional phase in which the work of teachers is devalued and their autonomy eroded. In many contexts teachers and the schools in which they work are constrained by requirements of accountability against standardized tests and other measures to maintain legitimacy. In her study of nine elementary teachers across three schools in the USA, Buchanan (2015) found that agency was linked to whether their context supported teaching in ways consistent with the professional identity they had developed through their career histories. Where there was a good fit of identity with school culture, agency was expressed by going beyond expectations. Conversely, where there was not a good fit, teachers resisted requirements that did not match their professional identities. In her view, teacher agency could be understood as an expression of teacher identity in action but those identities were constantly being reconstructed in response to teachers' experience of practice. Teachers whose entire professional experience is in contexts with very limited professional autonomy will interpret that as normal and develop professional identities with limited expectations of agency.

Hargreaves and Fullan (2012) argued for education to move beyond the industrialized model to models that promote innovation and creativity for the information age. Pressing for teaching to be recognized as a profession if that transformation is to be achieved, they described the qualities of a profession in terms of professional capital, which they presented as an amalgam of three forms of capital: human, social, and decisional. Human capital embodies individual talent and encompasses the knowledge, skills, and dispositions developed through teacher preparation and experience. Social capital emerges from interactions with others, especially professional colleagues, which increases human capital by enabling access to the human capital of others. Decisional capital is the essential quality of a profession in which individual professionals have discretion to make decisions without constant reference to superiors. Nolan and Molla (2017) identified decisional capital with teachers' professional agency and linked it to the degree of autonomy and empowerment teachers have in day-to-day practice. It is this agency that empowers teachers with the relevant knowledge and skill to make decisions about how best to meet the needs of learners in their context rather than merely implementing some generalized practice received from higher authority.

Biesta et al. (2015) have argued that agency is not a property or characteristic possessed by individuals but is manifest in the actions that they perform. That is, agency exists only insofar as it is exercised and does not exist in the abstract. In this view agency is a phenomenon that emerges as an actor engages with a situation. They suggest that it is best understood as a fusion of past influences, future intentions, and present engagement. In their view, teachers too often lack a sense of longer term purpose for education, focusing instead on short-term goals and thus limiting their agency to implementing policy directives rather than contributing to developing vision for educational transformation. The focus on short-term goals may result from a combination of the need to deal with day-to-day activity and limited opportunities to affect broader aspects of their work.

Teacher agency is visible in the actions of teachers and potentially in tension with accountability requirements. Governments and other stakeholders are entitled to expect that education systems and educators will be accountable for providing the education appropriate to the needs of future citizens, but a too tightly constrained view of what is appropriate and how it should be delivered may be counterproductive. In a rapidly changing world, even among those who argue for a traditional curriculum and pedagogy, there is likely to be a degree of acceptance that future citizens will need to be prepared to be innovative and creative in the face of ongoing change. Consequently, there is potentially a paradox of expectations in seeking to maintain a highly accountable system that will prepare students to be innovators. Educational contexts involve complex human systems, and teachers need flexibility of action if they are to respond appropriately to the needs of individuals in their class within a changing technological and social environment.

The twin imperatives for technology identified in Australian Government documents (DEEWR 2008), namely developing children as fluent users of ICT and enhancing learning and teaching through application of ICT, are important in any modern education system. Both are affected by rapid changes in ICT. Teachers require current knowledge in both domains, the operation of ICT and application for learning and teaching. They also require appropriate degrees of agency to enable them to deploy available ICT effectively. The pace of change does not permit sufficient time for centralized systems to assess the potential of emerging ICT and prescribe its use in ways that will be equally applicable in widely varying contexts.

Teacher Agency in Educational Systems

A focus on teachers' agency could lead to "individual blame" rather than "system blame." Therefore, one should also stress the role of the school or institutional level (see e.g., Aesaert et al. 2015; Mouza et al. 2014). In this respect, Priestley et al. (2015) preferred to regard agency as emerging from the ecology of teachers' practice as they engage with their environments. Clearly, educational institutions differ with respect to performance levels, innovation capacity, and contextual characteristics (Tondeur et al. 2016a, b). This implies that agency should consider to a large extent the "power of site or place" (cf. Fullan 2007).

But although there is a strong belief among educational leaders, this does not always translate into "digital agency" (Starkey 2017). Therefore teachers should be engaged in ICT policy planning in their schools (Tondeur et al. 2008; Vanderlinde et al. 2010). It seems that successful ICT implementation depends upon goals shared by different actors and at different organizational levels. System and school administrators have power and responsibility for provision of ICT and other resources, often including the resources necessary for teachers' professional development, but may engage teachers in the decision-making processes. Ketelaar et al. (2012) argued that effective school leadership for innovation requires careful balancing of collaborative activity and respect for the individual identities of teachers. By enabling teacher agency and encouraging collaboration, leaders can draw upon the creative energies expressed through teachers' agency to implement an innovation more effectively. Thus, teachers' agency is related to actions taken at the institutional level as well as those taken individually. Examining institutional characteristics associated with teachers' professional development has the potential to lead to a greater understanding of the systemic nature of ICT integration in education.

The characterization of agency as an emergent phenomenon rather than an individual capacity (Priestley et al. 2015) invites investigation of the conditions under which teachers can achieve agency. Priestley et al. noted that agency is often linked to the idea of "change agent" in the context of school improvement agendas, but in many such cases teachers are merely implementing policy determined by others and have very limited scope for genuine professional agency. Past educational reforms have often failed due to a mismatch between the innovation and the meanings attached to the innovation by those involved in the instructional process (Hermans et al. 2008). But technological innovation in the classroom is not independent and isolated; it is situated in the ecological system of the school and connected to its broader systems. It also affects the relationships within and outside the school, and the ongoing interaction catalyzes changes in social relationships (Lim et al. 2013).

According to Zhao and Frank (2003), the dynamic coadaptation and coevolution of teachers' agency, school leaders, and students with technology and the system determines whether the affordances of technology for teaching and learning can be realized in schools. In this respect, the literature about school improvement (e.g., Reynolds et al. 2000) stresses the importance of "leadership" in developing a commitment to change (see also Dexter et al. 2016). The capacity of (teacher) leaders to develop and articulate, in close collaboration with other actors from the school community, a shared vision about educational technology use is considered a critical building block in this process. Therefore, professional development and/or learning of these leaders is crucial. This perspective adds to the holistic approach to teachers' agency.

Teacher Agency and Professional Learning

The ICT available to teachers and learners is evolving rapidly but is unevenly distributed. The technical features and operating procedures for new hardware and software change frequently; some changes are subtle but others are more substantial, such as the change from mouse-driven interfaces to touch screens. At the same time, the affordances of the devices and software for learning and teaching are changing. Teachers need to continually update their knowledge and skills for both technical operation and pedagogical application of emerging ICT available in their contexts.

Traditional professional development prepared and delivered from central authorities inevitably struggles to match the rate at which ICT is changing because of the lead-time required to design and implement programs updated for new hardware and software. Moreover, availability of ICT varies across contexts, even within the same system, possibly requiring multiple versions of professional development to ensure relevance (see, e.g., Lim et al. 2014). Pedagogical applications are prone to be even more challenging because the educators responsible for producing professional development must first master the technical aspects of emerging ICT before they can explore the educational affordances and only then can they prepare related professional development.

The mechanisms by which new forms of ICT enter classrooms range from system-wide initiatives to the actions of teachers who introduce their own ICT for a specific educational purpose. In recent years, there has been a growing trend toward "bring your own" approaches in which students in the one classroom may be using devices with very different capabilities (Prestridge and Tondeur 2015). That presents teachers with both challenges in managing the variety of ICT and opportunities to explore their affordances for learning and teaching. Hence, professional learning in situ is an important enabler for their application of ICT to enhance and transform learning and teaching.

Research has established connections between teachers' agency and their professional learning. Heikonen et al. (2016) noted that teacher agency enables teachers to manage their own learning with the intention to enhance student learning in response to contextual variables and that a sense of agency has a positive effect on intentions to remain in the profession. In a study of more than 1200 Chinese teachers, Liu et al. (2016) found that teacher agency and the sense of being trusted in their school positively mediated the effect of principals' leadership on professional learning. Moreover, higher levels of trust had a positive effect on teacher agency. Thus, feeling trusted as a professional encourages teachers to exercise agency by taking initiatives, and both trust and agency encourage engagement in professional learning. A small case study in a New Zealand high school reported evidence of the value of teacher agency for driving professional learning through teacher inquiry specific to the context as more effective than instrumental professional development sourced from outside providers (Charteris and Smith 2017).

The importance of balancing teacher agency with collaboration among teachers (Ketelaar et al. 2012) was noted above but it is also important when considering teacher agency in relation to professional learning which increasingly occurs in the context of professional learning communities and networks in which teachers share experiences and ideas. In a study involving 2300 Finnish primary and secondary teachers, Pietarinen et al. (2016) used structural equation modeling to investigate the relationship between teacher agency in professional community and classroom. They reported that agency does not automatically transfer between contexts but that learning in a professional community does affect learning in the classroom, and agency in the classroom is significantly dependent on agency in the community. Thus, it seems that teachers who feel supported by a professional community may be empowered to act with greater agency in their own classrooms. This appears to be supported by a study of professional learning communities in Scotland (Philpott and Oates 2016) where it was found that robust evidence obtained from classrooms supported teacher agency by enabling teachers to authoritatively evaluate practices.

Teachers' agency is important for empowering them to explore the possibilities inherent in new ICT and make decisions about whether and how they can enhance learning and teaching in their context. When that individual exploration is coupled with sharing through professional learning communities or similar venues, its potential for enhancing learning and teaching and for transforming the broader educational landscape through the application of ICT is multiplied. Access to the experiences of other teachers in professional learning communities can provide teachers with the authentic evidence they need to validate or modify their practice (Philpott and Oates 2016), and learning through professional communities has a positive effect on teacher agency and learning in the classroom (Pietarinen et al. 2016). In a time of rapidly changing ICT, trusting teachers as professionals and harnessing their contextualized learning about emerging ICT is likely to be more effective for realizing its potential for educational transformation than centrally mandated practices supported by packaged professional development.

Conclusion

Technology, especially information and communication technology (ICT), is changing rapidly. The transformational effects of those changes are visible in many areas of social and commercial activity but there is widespread concern that education is not being transformed at the same rate as other sectors. If children are to leave school equipped to thrive in the modern world then the content of their education must evolve to ensure they acquire knowledge and skills necessary to make effective use of ICT in a wide variety of activities. Moreover, there are widespread expectations that the introduction of ICT should transform education in ways parallel to those experienced in other sectors, but there is little evidence of that happening on a broad scale. If the content and experience of education are to be transformed through ICT then it seems evident that the challenges must be approached differently than they have been until now.

Across many parts of the world a consistent response to a perceived need to improve educational provision has been to increase accountability of schools and teachers. The expectation is that the desired outcomes can be achieved by clarifying standards to be reached, testing achievement against those standards, and in some cases mandating practices to be adopted by teachers. It is ironic that what is an essentially industrialized approach is being adopted to solve a problem in the postindustrial world without notable success in many contexts.

In this chapter we have argued that, in a time of rapid and variably dispersed technological change, top-down solutions emanating from a centralized authority are unlikely to be able to respond as quickly as necessary to the highly contextualized needs of learners and teachers. Rather than further constrain the actions of teachers by mandating practice it will be more effective to recognize their professionalism and support teacher agency for professional learning and classroom application of ICT. By encouraging teachers to explore the possibilities of emerging ICT and share their findings in professional learning communities, the crowdsourcing facilitated by networked ICT can contribute to solution of the challenges it presents.

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Knowledge Base for Information and Communication Technology in Education

26

Charoula Angeli and Nicos Valanides

Contents

Abstract

This chapter systematically explores the knowledge base required by teachers for the effective application of ICT in education. The Technological Pedagogical Content Knowledge (TPCK) framework and developments in associated research are reviewed. The authors suggest an alternate approach for better understanding the knowledge base required for application of ICT in education by providing a theorization about technological knowledge in relation to how a teacher realizes and actualizes the pedagogical affordances of technological tools in teaching and learning. The authors conclude that this body of knowledge cannot exist outside the frame of reference of the teacher, can be developed through systematic learning activities targeting or facilitating its development, and grows with ongoing participation or involvement in valuable professional experiences. Implications for the nature of TPCK and its development are discussed.

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Technological knowledge · Teacher knowledge · Technology affordances · Technological pedagogical content knowledge

Introduction

Technological Pedagogical Content Knowledge (TPCK or TPACK) was introduced in 2005 to describe the knowledge that teachers need to have to be able to teach competently with digital technologies (Angeli and Valanides 2005; Koehler and Mishra 2005; Mishra and Koehler 2006; Niess 2005). TPCK has been conceptualized as an advancement of Shulman's (1986, 1987) Pedagogical Content Knowledge (PCK) by adding to the existing PCK framework a new body of knowledge, namely, Technological Knowledge (TK). Consequently, the addition of TK expanded PCK to TPCK.

The purpose of this chapter is twofold. In the first part, the authors report on what we currently know about TPCK as a body of knowledge that teachers need to develop to be able to integrate ICT in their teaching. In the second part of the chapter, the authors argue that the existing body of research on TPCK has failed to explain TK theoretically, and propose a framework for directly addressing this gap in the literature. The chapter concludes with implications regarding the development of this new body of knowledge as well as the construct of TPCK in pre-service and in-service education.

The Theoretical Development of TPCK

PCK is the theoretical basis of TPCK (Angeli and Valanides 2015). Succinctly, PCK emphasizes the significance of transforming subject matter into forms that are pedagogically powerful and at the same time comprehensible to students (Grossman 1989, 1990; Shulman 1986, 1987; Cochran et al. 1993). Essentially, the transformation of subject matter requires a dramatic change in how teachers perceive their role "*from being able to comprehend subject matter for themselves, to become able to elucidate subject matter in new ways, recognize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students*" (Shulman 1987, p. 13). While researchers have proposed different PCK frameworks in terms of the constituent subdomains of teacher knowledge comprising the frameworks, four subdomains have consistently appeared in all proposed frameworks, namely, knowledge of subject matter (content), knowledge of pedagogy, knowledge of learners and their characteristics, and knowledge of context. A predominant model of PCK in the literature is the one proposed by Cochran et al. (1993), as depicted in Fig. 1. Cochran et al. (1993) preferred to use the term *Pedagogical Content Knowing* instead of *Pedagogical Content Knowledge* to emphasize that PCK is a knowledge base that is not static but dynamic and develops progressively as teachers are involved in useful teaching

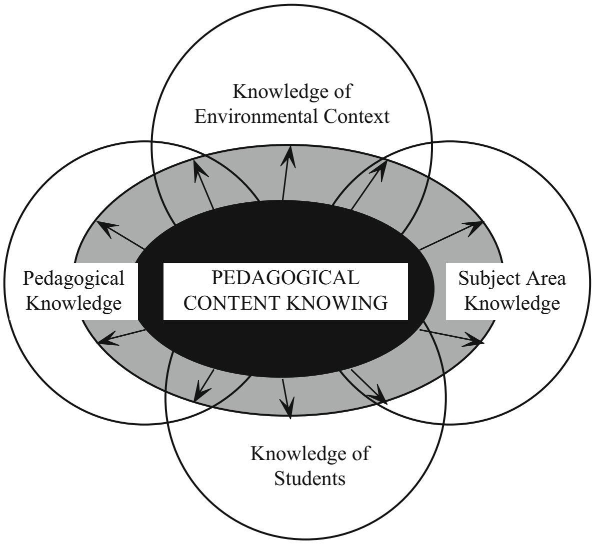

Fig. 1 Cochran et al.'s (1993) conceptualization of PCK

experiences. This is also the meaning expressed by the arrows in Fig. 1 signifying that PCK is a body of knowledge that changes due to teachers' new experiences and ongoing development.

In the early 2000s, different researchers proposed an enhancement to PCK in order to address the issue of teaching with technology (e.g., Angeli and Valanides 2005; Koehler and Mishra 2005; Mishra and Koehler 2006; Niess 2005). Niess (2005) and Angeli and Valanides (2005) used the four-component model of PCK shown in Fig. 1 as their theoretical basis and added a fifth component (i.e., a fifth domain of teacher knowledge), namely, knowledge of ICT, in order to specify TPCK as the knowledge that teachers need to have to be able to effectively teach subject matter with technology. Angeli and Valanides' (2005) conceptualization is depicted in Fig. 2 and shows TPCK as a unique body of knowledge defined in terms of five contributing knowledge bases, namely, content knowledge, pedagogical knowledge, knowledge of learners, ICT knowledge, and knowledge of context. In order to better define TPCK, Angeli and Valanides (2005) described the construct in terms of five competencies. Essentially, a teacher who has TPCK is able to:

1. Identify topics to be taught with ICT in ways that signify the added value of ICT tools, such as, topics that students cannot easily comprehend, or that teachers face difficulties teaching or presenting effectively in class. These topics may include abstract concepts (i.e., cells, molecules) that need to be visualized; phenomena from the physical and social sciences that need to be animated (i.e., water cycle, the law of supply and demand); complex systems (i.e., ecosystems, organizations) in which certain factors function systemically and need to be simulated or modeled; and topics that require multimodal transformations (i.e., textual, iconic, and auditory), such as, phonics and language learning.

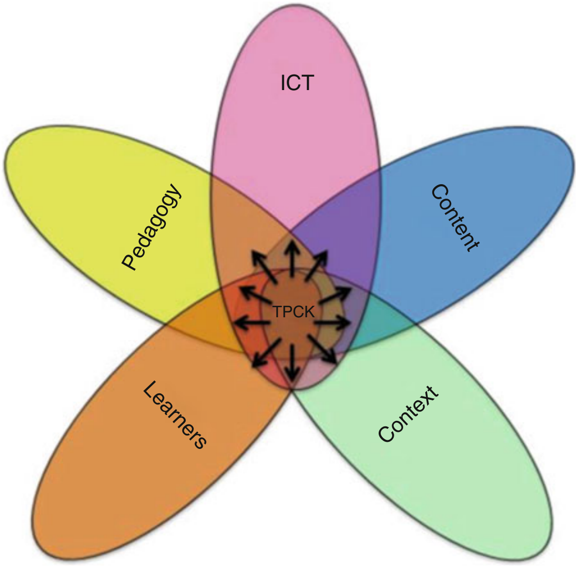

Fig. 2 TPCK (adapted from Angeli and Valanides 2005)

2. Identify appropriate representations for transforming the content to be taught into forms that are pedagogically powerful and difficult to support by traditional means. These include interactive representations, dynamic transformation of data, dynamic processing of data, multiple simultaneous representations of data, and multimodal representations of data.
3. Identify teaching tactics, which are difficult or impossible to implement by other means, such as, the application of ideas in contexts that are not experienced in real life. For example, exploration and discovery in virtual worlds, virtual visits (i.e., virtual museums), testing of hypotheses, simulations, complex decision-making, modeling, long distance communication and collaboration with experts, long distance communication and collaboration with peers, personalized learning, adaptive learning, and context-sensitive feedback.
4. Select tools with appropriate affordances to support 2 and 3 above.
5. Infuse computer activities with appropriate learner-centered strategies in the classroom. This includes any strategy that puts the learner at the center of the learning process to express a point of view, observe, explore, inquire, think, reflect, discover, and problem solve.

Koehler and Mishra (2008) proposed a different TPCK framework in the literature depicted in Fig. 3. In Fig. 3, TPCK (a term that they changed to TPACK) is described in terms of seven knowledge domains, namely, (a) content knowledge (C), (b) pedagogical knowledge (P), (c) technological knowledge (T), (d) pedagogical content knowledge (PCK) – the interaction of P and C, (e) technological content knowledge (TCK) – the interaction of T and C, (f) technological pedagogical knowledge (TPK) – the interaction of T and P, and (g) technological pedagogical

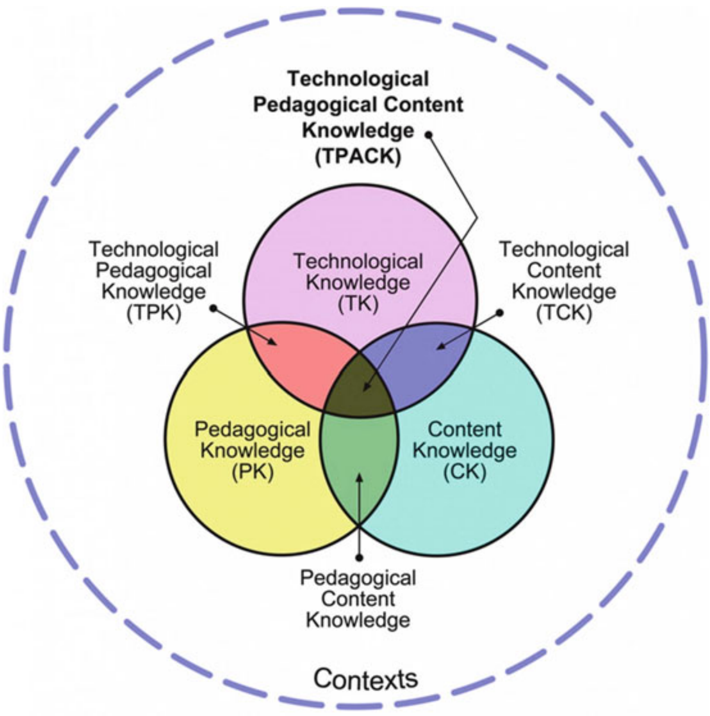

Fig. 3 TPCK framework (adopted from Koehler and Mishra 2008)

content knowledge (TPACK) – the interaction of PCK, TCK, and TPK. Angeli and Valanides (2009, 2013, 2015) discussed the differences between these two predominant conceptualizations of TPCK, as illustrated in Figs. 2 and 3, and stated that, while both models have the same theoretical basis (i.e., Shulman's work on PCK), they are epistemologically different. Succinctly, the main difference between the two frameworks is that TPACK is conceptualized and researched as an integrative body of knowledge with an emphasis on identifying and assessing TPACK's subcomponents, such as, TPK and TCK (e.g., Harris and Hofer 2011; Schmidt et al. 2009), while research based on Angeli and Valanides' (2005, 2009) framework examines TPCK as a distinctive body of knowledge (e.g., Kramarski and Michalsky 2010; Krauskopf et al. 2012). This new body of knowledge does not develop spontaneously, goes beyond mere integration or amalgamation of the constituent subdomains of teacher knowledge, and constitutes a transformative and unique body of knowledge that bolsters teachers' competency to elucidate subject matter in new ways by employing and investing on the affordances of technological tools. Furthermore, this body of knowledge can be developed only after deliberate instruction or training and grows progressively as teachers are involved in useful learning experiences.

In a recent review of the literature, Angeli et al. (2016) reported that, after 2008, a number of other TPCK models appeared in the literature that attempted to provide more elaborated perspectives on TPCK in order to exemplify the complexities of technology integration in various educational contexts (e.g., Benton-Borghi 2013; Porras-Hernández and Salinas-Amescua 2013; Yeh et al. 2014). For example, Yeh et al. (2014) proposed TPACK-Practical and conceptualized TPACK as a body of knowledge that teachers possess and apply when dealing with lesson design in their actual practice. TPACK-Practical is conceptualized as a framework with eight knowledge dimensions – namely, using ICT to understand content, using ICT to understand learners, planning ICT-infused curriculum, using ICT representations, using ICT-integrated teaching strategies, applying ICT to instructional management, infusing ICT into teaching contexts, and using ICT to assess students – in five pedagogical areas, that is subject matter, learners, curriculum design, assessments, and practical teaching.

Porras-Hernández and Salinas-Amescua (2013) enriched Angeli and Valanides' (2005) framework, by considering knowledge of context along two important dimensions, namely (a) scope (macro, meso, and micro) and (b) actor (students' and teachers' inner and external context). According to this perspective, contextual considerations, such as teachers' and students' characteristics, needs, preferences, prior knowledge, self-efficacy, pedagogical beliefs, subject or school culture, ethnicity, culture, community, and socioeconomic background, are important variables to consider in TPCK research.

Our purpose here is not to describe every single TPCK framework that has been published in the literature, but to provide a constructive appraisal of this line of work to the research community. While no one unified perspective on TPCK exists in the literature, all existing TPCK frameworks use as their basis, implicitly or explicitly, the five fundamental teacher knowledge bases – that is, knowledge of subject matter, pedagogy, learners, technology, and context. Contemporary research efforts that elaborated on this basic model considered several other variables that were regarded important for practice, such as Yeh et al.'s (2014) TPACK-Practical, or research, as suggested by Porras-Hernández and Salinas-Amescua (2013). If the aim of the TPCK research community is to suggest a new TPCK framework for encompassing the uniqueness or the newness of a context, practical or research, then this line of research will never realize its desired goal; that of developing a robust theoretical conceptualization of TPCK. Accordingly, the authors here argue that part of the effort toward developing a robust theoretical conceptualization of TPCK should be to understand or theorize more about technological knowledge (the TK component in the TPCK framework) in relation to how a teacher realizes and actualizes the affordances of technological tools for the purpose of transforming subject matter (content) into more comprehensible forms for students.

In view of that, the authors, in the second part of this chapter, suggest an alternative approach for conceptualizing the knowledge base required for application of ICT in education by providing a theorization of the relationship between teacher and technology within the framework of Gibson's (1977, 1979) tool affordances – an area of work that has remained for the most part scarce in the field of technology and teacher education. The authors suggest that the specific theorization can be pivotal for better clarifying the concept of TPCK and conclude with implications for the development of TPCK in pre-service and in-service education.

The Concept of Tool Affordances

While technology is a principal component of TPCK and the main reason for extending PCK to TPCK, so far the fields of instructional technology and TPCK research have provided inadequate accounts about how teachers learn to recognize, understand, and actualize the pedagogical affordances of ICT tools; an issue that is of critical importance for developing teachers' cognition about technology integration (Angeli and Valanides 2009, 2013; Krauskopf et al. 2012; Krauskopf et al. 2015). Consequently, as Oliver (2013) stated, "*current accounts of technology provide poor explanations of how technology use leads to – or fails to lead to – learning*" (p. 331), simply because we do not fully understand how teachers perceive and actualize tool affordances. A better understanding of affordances in teacher knowledge development can lead to better strategies in terms of training pre-service teachers in technology integration as well as supporting in-service teachers during professional development (Haines 2015).

According to Gibson (1979), "*. . .the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill*" (p. 127). An affordance has invariant properties, and exists independently of an actor's ability to perceive it; but, when it is perceived, it is always relative to the action capabilities of a particular actor (Gibson 1979). Gibson explained the notion of affordance by providing the example of a flat and rigid surface that affords support for one actor but not for another, due to his or her higher body weight. This means that the actor in the latter case is constrained by the affordances of the object, and that an affordance may exist for one actor but not for another. Thus, the "*offerings or action possibilities in the environment are directly related to the action capabilities of an actor*" (McGrenere and Ho 2000, p. 1). McGrenere and Ho (2000) stated that in Gibsonian terms, affordances are both objective and subjective.

They are objective in that their existence does not depend on value, meaning, or interpretation. Yet they are subjective in that an actor is needed as a frame of reference. By cutting across the objective/subjective barrier, Gibson's affordances introduce the idea of the actor-environment mutuality; the actor and the environment make an inseparable pair. (McGrenere and Ho 2000, p. 1).

Hammond (2010) stated that the notion of affordance has become popular in different fields in that it offers an alternative to the view that the world exists independently of the perceiver, while challenging at the same time the notion that properties are perceptual and exist only to the extent that they can be recognized. This view of affordance can be strongly criticized by radical social constructivists who would question the existence of inherent properties of objects outside of the actors' interpretations of them. Hutchby (2001) directly addresses this concern and argues that, while the uses of tools are socially determined, at the same time, tools have material properties that may not be realized by the actor. For example, if we take Microsoft Excel as a point of reference, teachers may not realize that Excel supports dynamic transformations of data from one form/representation to another and may use it for mathematical calculations only. Nonetheless, the material properties or technical features of Excel affording dynamic transformations of data exist and are readily available for use at all times. It is this interpretation of the concept of affordance that we adopt in this chapter in order to propose a theoretical model for explaining the relationship between teachers and technology in terms of how teachers perceive and develop mental models about tool affordances for appropriation in educational settings. Appropriation refers to how technology is adopted in everyday practice (Dourish 2003; Leonardi 2011), and people appropriate artifacts in ways that may differ from the designers' intentions (Folcher 2003).

For teachers, the process of learning about tool affordances is more than just learning about the technical features or the technical affordances of tools. Instead, it is a process of thinking creatively about how the technical affordances of tools can be thought of as pedagogical affordances to bring about educational goals and objectives in classroom teaching and learning. Webb (2005) explored the notion of affordances within the context of using Microworlds to support learning activities. Conole and Dyke (2004) also examined the concept of affordance in the context of pedagogical design and proposed a general taxonomy of ICT affordances for the modern age, including accessibility, speed of change, diversity, communication, reflection, and multimodality.

Herein, the authors assume a different perspective and seek to propose a theoretical construction of teachers' ICT knowledge by focusing on the teacher-tool relationship within the context of pedagogical and learning design. Central to this theorization are the terms *technical affordances* of tools/software and *pedagogical affordances* of tools/software. A piece of software has technical features or technical affordances. For example, the technical affordances of Kidspiration include among others, Picture View, Writing View, Audio, and Hyperlink. These technical affordances are invariant and available to all, at all times. Pedagogical affordance is a term that Angeli and Valanides (2013) used to explain how teachers perceive subjectively the functional value of software in pedagogical/learning design. Table 1 shows an example of how some technical features of a software (in this case Excel) are mapped onto pedagogical affordances. It is noted that, in this conceptualization, technical affordances are invariant and defined by the designers and developers of the software, while pedagogical affordances are perceived by teachers in various ways. The latter is emergent and directly related to pedagogical and learning design for the purpose of attaining educational objectives. In a recent study, Haines (2015) studied two teachers' conceptions of blogs and wikis as tools for language learning, and found that, while teachers learned the tools easily, they faced difficulties in utilizing them in powerful pedagogical ways. She concluded that teachers' understanding of the pedagogical affordances of tools is an emergent and demanding cognitive process directly related to instructional design tasks. These conclusions are in agreement with earlier research reported by Stoffregen (2003) who viewed affordances as being emergent properties of both the teacher and educational context.

Table 1 Technical and pedagogical affordances of Excel (adapted from Angeli and Valanides 2013)

Excel technical affordances/features	Pedagogical affordances	Explanation
Insert – Cells/rows/columns/worksheet/chart/pictures Format – Cells/row/column/sheet/style Data – Sort/text to columns/group and outline	Excel as a tool for organizing data	Meaningful and clear organization of data Attractive and intuitive organization of data Appropriate selection of visualizations for young learners Integrated presentations of pictures, text, numbers, and spoken words Appropriate symbols to promote emergent literacy
Function/IF	Excel as a tool for providing context-sensitive feedback	Feedback is provided in different modalities taking into consideration students' current level of literacy skills
Hyperlink	Excel as a tool for creating a hypertext story	The story is presented from the perspectives of multiple characters The story has multiple possible entry points The story has many internal threads The story constitutes an integrated whole Easy navigation and learner control
Formula bar Insert – Function/sum/average/count/max	Excel as a tool for performing calculations	Arithmetic calculations and mathematical formulae Mining mathematical formulae
All of the above as needed	Excel as a modeling tool	Children see clearly how their decisions/actions affect the outcomes Children add or remove objects and observe the consequences The results of an action or decision are communicated with the use of appropriate visualizations when possible

Our theoretical discussion so far has exemplified the importance of two propositions: (a) the technical affordances of tools are invariant properties, while their pedagogical affordances are emergent and subjective; (b) the pedagogical affordances of tools derive meaning only within the context of the activities that teachers consider in their pedagogical designs. As Tchounikine (2016) stated, educational software packages "*…are mobilized by users in the context of the activities they consider. They become instruments for users in the context of these activities, when and through the way they allow users to achieve the tasks that users consider in the way they consider them*." (p. 8). Thus, the teacher-tool relation is not to be thought of as a 1:1 relation, because one software package may be turned into multiple instruments.

All in all, the goal of the teacher is not to use the tool per se, but to solve different pedagogical problems with the tool. Thus, teachers' perceptions of software, in terms of pedagogical utilization, are related to the instructional design tasks they cogitate, and how they use the software to help them realize the tasks, given teachers' current understandings, knowledge, work practices, and context.

A Theoretical Model of Teachers' ICT Knowledge

Based on the discussion to this point, we present in Fig. 4 a theoretical perspective of teachers' ICT knowledge developed through a process by which teachers turn software into instruments (Rabardel 2001), that is, into means for realizing their instructional designs. According to this perspective, educational software and tools have a mediating role, and the model in Fig. 4 addresses this by considering both the technical and pedagogical affordances of tools. This is illustrated as a process through which teachers transform the technical affordances of tools into pedagogical affordances within an instructional design context. The latter is a constructive, productive, iterative, emergent, and creative process that can benefit from explicit pedagogical training in pre-service teacher education programs and in-service teacher professional development. During this process, technical affordances are perceived and actualized as pedagogical affordances in instructional design lessons.

In more detail, the proposed theoretical framework, shown in Fig. 4, is represented as a five-stage process model. The first stage in the process shows that educational software packages are characterized by a number of built-in technical functions or technical affordances, as these have been determined by software designers and developers. These technical affordances exist independently of teachers' awareness of their existence. Subsequently, teachers, with certain knowledge, expertise, and educational goals, interact with the technical features of tools and come to recognize and familiarize themselves with the technical affordances of tools (Pozzi et al. 2014; Bernhard et al. 2013). Thus, the second stage related to

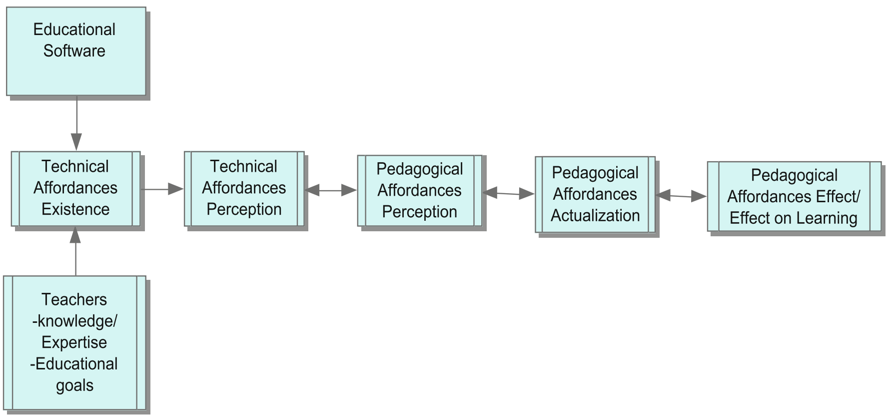

Fig. 4 Teacher ICT knowledge theoretical framework

technical affordances perception is about recognizing the existence of technical affordances and their potential for performing an action (Leonardi 2011). For example, teachers learn or find out about the SORT feature in Excel, and they ponder about how they can use it to sort a big data file in ascending order.

Subsequently, in stage 3, teachers come to realize/perceive the technical affordances as enablers of pedagogical action. This is an iterative and emergent process that involves transformation of the technical affordances into pedagogical affordances. For example, a teacher learns how to insert hyperlinks in an Inspiration diagram, but he or she gradually realizes that the use of hyperlinks in concept maps facilitates discovery and inquiry learning.

In a recent research study, Ioannou (2016) found that during a 15-h teacher professional development seminar about TPCK, teachers were not able to perceive the pedagogical affordances of tools. Interestingly, the teachers in his study were experienced computer science middle school teachers with excellent technical skills and knowledge about technology. Ioannou (2016) concluded that teachers cannot easily conceive how the technical affordances of tools can be transformed into pedagogical affordances and that the advancement of their understanding from technical to pedagogical affordances should be facilitated.

The fourth step in the model is actualization of pedagogical affordances. Actualization is a goal-oriented and iterative action during which pedagogical affordances are put into actual classroom practices (Leonardi 2011). McGrenere and Ho (2000) found that actualization is a gradual process with different degrees of difficulty. It can be an individual effort or a collaborative effort situated in real classroom practices. Haines (2015) also found that affordance actualization aids teachers to reconsider their perceptions of the pedagogical affordances of tools, in terms of action possibilities and constraints for their practice, and redefine them. Actualizing pedagogical affordances depends on several teacher-related factors, such as skills and instructional design knowledge, as well as school-related factors, such as availability of resources and a conducive curriculum. It is also, according to Bernhard et al. (2013), "*a function moderated by perceptions of the efforts that it takes to actualize the affordance*" (p. 6).

Affordance actualization results in (a) reconceptualization of pedagogical affordances and (b) learning effects. In essence, when teachers integrate tools in their lessons, they gradually develop more informed understandings of the added value of the tools and consequently more complete and sophisticated mental models of the pedagogical affordances of tools. At the same time, the integration of tools in instructional lessons mediates the transformation of the content to be learned into forms that students can understand better, while at the same time it enables the implementation of new pedagogical practices promoting the active role of students in learning. Consequently, the actuation of an affordance produces measureable results such as changes in student learning. In sum, as Volkoff and Strong (2013) stated, actualized affordances provide explanations of causality at a level that is specific with respect to the technology (i.e., what is the added value of the technology in teaching?) and the organization (i.e., how does technology affect student learning?).

Implications for Theory and Practice: The Development of Teachers' ICT Knowledge

The model in Fig. 4 is aligned with current research evidence and theoretical conceptions about tool affordances and instructional/learning design. It explicates that the development of teachers' ICT knowledge requires a systematic and goal-oriented process targeting the development of teachers' understandings of the notion of pedagogical affordances within the context of rich instructional design practices. The model can be implemented in both pre-service teacher education courses and in-service teacher professional development programs. In pre-service teacher education, the five-stage model can be implemented in the context of instructional technology courses and methods courses. Teacher educators and trainers must explicitly inform teachers about, as well as exemplify, the five-stage model, the expected outcomes per stage, and what it entails in terms of their preparation. The process depicted in Fig. 4 should be enacted for each tool taught in a course or training session. Depending on the difficulty of the tool, the duration of each cycle of enactment can be about 10 h on the average, so that over the course of an academic semester, teachers can receive training on about four different ICT tools. Succinctly, teacher educators first engage teachers in activities where the focus is to learn how to use a tool. The goal during the first two stages is for teachers to become familiar with the technical features and technical affordances of tools. The third stage in the model aims at linking the technical affordances of tools with teaching. For this to happen, teacher educators need to make explicit connections between the technical affordances of tools and their pedagogical affordances. This can be done in the context of instructional design activities during which pre- or in-service teachers learn to think about technology as a pedagogical tool to solve teaching/learning problems. This third stage in the model is the most challenging to enact, because it is emergent, demanding in terms of time and effort, and does not constitute a 1:1 correspondence between the technical affordances of tools and their pedagogical affordances. The link between technical affordances and pedagogical affordances can be strengthened during the stage of actualization, which must: (a) have a focus on content (subject matter) (Desimone 2009); (b) be grounded in teachers' own classroom practices (Putnam and Borko 2000) to promote ongoing and sustainable teacher development (Darling-Hammond and McLaughlin 1995); (c) address obstacles to student learning (i.e., student misconceptions or alternative conceptions) and enablers of student learning (i.e., content transformations, approaches to destabilizing student misconceptions) (Angeli and Valanides 2009; Dopplet et al. 2009); (d) use preferred instructional practices utilized in teacher development, such as modeling and coaching (Ioannou and Angeli 2013, 2014; Angeli and Ioannou 2015; Darling-Hammond and McLaughlin 1995); (e) be grounded in inquiry, reflection, collaborative problem solving centered around pedagogical problems or problems of practice that are teacher-driven (Angeli and Valanides 2009; Darling-Hammond and McLaughlin 1995); and (f) be collaborative with a focus on communities of practice rather than on individual teacher practices alone (Darling-Hammond and McLaughlin 1995). Within this situated teacher development framework, aspects of the learning-by-design framework are incorporated for facilitating the development of complex and interrelated ideas among content, pedagogy, learners, context, and technology (McKenney et al. 2015; Angeli and Valanides 2009). Conway and Zhao (2003) stated that within the context of learning by design "*it becomes crucial to ally teachers' knowledge about not only various general pedagogical approaches, but also pedagogical content knowledge, as well as the learning affordances and constraints of various computer-based technologies allied with the current more ambitious reform-based educational goals for students*" (p. 27).

Finally, the fifth and last stage allows for reflection based on the educational outcomes observed or obtained, enabling teachers to reconsider their perceptions of the pedagogical affordances of tools and their actualization in learning design tasks.

Obviously, effective technology integration presupposes robust knowledge and understanding of the technical affordances of tools and how these can be transformed into pedagogical affordances, in order to be used in teaching and learning for the purpose of elucidating content into more understandable forms for the learner. The development of this body of knowledge is, therefore, directly related to the development of teachers' TPCK, and has implications for the existing theoretical conceptualizations of TPCK or TPACK.

To remind the reader, in the first part of this chapter the authors referred to two prevailing views of TPCK in the literature: (a) the transformative view explicating TPCK as a distinct or unique body of knowledge that needs to be taught (Angeli and Valanides 2005, 2009), and (b) the integrative view defining TPACK as a body of knowledge that is created from other forms of teacher knowledge *on the spot* during teaching (Koehler and Mishra 2008). These two views have raised important research questions during the last decade regarding the construct of TPCK and its development. For example, research questions framed from the transformative view investigated the construct of TPCK itself, while research questions framed from the integrative view inquired about the constituent components of TPACK, such as TPK and TCK.

In fact, many researchers pursued studies from the perspective of TPACK as an integrative body of knowledge and sought to identify and measure the constituent knowledge bases of TPACK, such as, CK, TK, TCK, TPK, and PCK. Recent research findings from this line of research have been reported by Shinas et al. (2013) who examined the construct validity of the Survey of Preservice Teachers' Knowledge of Teaching and Technology, a survey that according to its developers is grounded in the integrative framework of TPACK and is designed to measure seven subdomains of TPACK (Schmidt et al. 2009). Shinas et al. (2013) administered the survey to 365 pre-service teachers enrolled in an educational technology course and conducted an exploratory factor analysis on the data. Their results revealed that participants did not always make conceptual distinctions between the TPACK domains and raised issues about the validity of the TPACK framework and the research instruments that have been developed based on its theoretical foundations. Shinas et al.'s (2013) results are in agreement with the research findings of other researchers who also problematized the validity of the TPACK framework and the inherent difficulty in distinguishing the boundaries between the constituent sub-domains of TPACK, such as TPK and TCK (Angeli and Valanides 2009; Archambault and Barnett 2010; Cox and Graham 2009; Graham 2011).

From the perspective presented and discussed in the present chapter and the line of argument that was developed based on the theoretical discussion about the technical and pedagogical affordances of tools, TCK, for example, cannot possibly exist without the mediating role (action capabilities) of an actor (teacher) and his (her) knowledge, expertise, and educational aims and goals. Thus, TCK should not/cannot be included as a common and identifiable body of teacher knowledge in any framework describing teacher knowledge. This inference is also supported by Shinas et al. (2013) who concluded that "*factors were congruent across only technological knowledge (TK) and content knowledge (CK) and not congruent across pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), and TPACK"* (p. 339).

Concluding Remarks

In this chapter, we presented an alternate perspective on teachers' knowledge of ICT. A theoretical model has been proposed illustrating a five-stage process through which teachers perceive and actualize the pedagogical affordances of tools in the context of learning design activities. In order to better situate the new theoretical framework depicted in Fig. 4 with the existing body of research on TPCK, it is specified that the model in Fig. 4 provides a theorization about technological knowledge (TK) in relation to how a teacher realizes and actualizes the affordances of technological tools in teaching and learning. This theorization in conjunction with contemporary research evidence seems to refute the existence of at least some of the knowledge bases integrated in the TPACK framework (Mishra and Koehler 2006, such as, for example, TCK, and provides further support to the transformative perspective of TPCK (Angeli and Valanides 2005, 2009). The proposed model contributes to the bigger effort related to the theoretical conceptualization of TPCK as an extension of Shulman's PCK and the knowledge that teachers need to have to be able to teach competently and adequately with technology. It should be emphasized also that this conceptualization maintains the point of view that TPCK is a way of *knowing* that can be developed only after deliberate instruction or training and can grow progressively through involvement in useful professional experiences.

At this point, the model should be considered as an emergent theoretical model, since it has not been tested empirically yet, although ample research evidence converges with the model's theoretical conceptualization. Mixed-method research designs may be adopted for providing details about the validity of the model in terms of how the concept of pedagogical affordances emerges, and what influences positively and/or negatively teachers' conception and actualization of pedagogical affordances in their professional practice. In conclusion, the model provides further support to the transformative view of TPCK as a unique body of knowledge that requires purposeful training, and cannot possibly exist and/or be studied in terms of artificial and fabricated bodies of knowledge, such as TCK, outside the frame of reference of the teacher.

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27 Preparing Preservice Teachers to Transform Education with Information and Communication Technologies

Alona Forkosh-Baruch

Contents

Abstract

Preparation of preservice teachers for their changing role in the information era requires equipping them with the knowledge, skills, and dispositions required to transform education, assisted by the vast capabilities made available by information and communication technologies (ICT). This chapter tackles the complex undertaking of preparing preservice teachers to integrate ICT, in light of its promise to transform education. Initially, we attend to the issue of professional identities of preservice teachers and teacher candidates in the twenty-first century. We review preservice teacher training in the twenty-first century, examining their proficiency in utilizing ICT in general and for educational purposes in particular,

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noting the gap between needs and ICT skills and utilization for pedagogical practices. Then, an array of examples of cases portraying ICT-integrated training worldwide is presented, illustrating attempts to encounter current state and training needs in order to attain the best ICT-integrated pedagogical practices. As a result, three possibly coinciding modes of preservice teacher training toward ICT integration are offered, as well as an exploration of their possible overlap. The chapter ends with recommendation for policymakers, practitioners, and researchers when attempting to improve preservice teacher training.

Keywords
Preservice teachers · Information and communication technologies (ICT) · Teacher education · Teacher training · Teacher identity

Identity of Preservice Teachers in the Twenty-First Century

Teacher identity is the professional personality structure constructed during the period covering an individual's educational process and career development, from their preservice stages. It is related to how teachers make themselves known to others (Lasky 2005). Today, students attending preservice training are actively engaged with twenty-first-century technologies. Still, these uses do not make them experts on technology-enhanced teaching and learning. In accordance with other professions, preservice teacher candidates engage in digital literacies in modes that reflect their identities as preservice learners as well as their practice in technology integration (Burnett 2011; Niess 2015). The question is what learning trajectories can assist in preparation of preservice teachers to critically engage with information and communication technologies (ICT) as a lever for teaching, to technology-based best practices?

The current generation of candidates entering preservice teacher education institutes differs from previous generations of preservice teachers in two major aspects. The first, teaching in a twenty-first-century technology-saturated environment is challenging in itself, as change is in the setting at large. The second, candidates differ in their identities, as a result of the changing world in which we live (e.g., globalization and multiple impact sources, diversity as a result of inclusion policies) as well as a need for critical digital literacies, for example, additional skills and capabilities which were formerly uncommon among this population (Kimmons et al. 2015; Pangrazio 2016). However, they may not be technologically knowledgeable or exhibit ICT skills as anticipated; they may prove to be poorly prepared to utilize ICT as students and as future teachers (Kumar and Vigil 2011; Lei 2009). However, preservice teachers will be expected to play an active role in implementing ICT in education; therefore, expectations from them include utilizing ICT in their practice in a broader manner than former generations of preservice teachers.

Usage of digital technologies for transforming teaching and learning by preservice teachers requires understanding of their professional identity within a new digital world and understanding the impact on their pedagogical perceptions and actions. Since the new generation of preservice teachers uses technology in a personal context, this can be a basis for utilizing ICT in a professional context as well, as ICT skills are universal in nature, penetrating our personal as well as professional lives (Chang and Chou 2015; Lim et al. 2011). Awareness of their digital identity, however, is only a prerequisite for developing a positive digital professional identity and understanding its impact on future educational practices.

Preservice Teacher Training in the Twenty-First Century

Preservice teacher education programs lay the foundations of the future of society by preparing preservice teachers to adapt education to the information era. Hence, they aim to supply the new generation of teachers with the knowledge and skills required for entry-level teaching, as defined by education systems worldwide (Niess 2015). These may include not only essential ICT knowledge and skills and preparation for integration of ICT in several subject areas and pedagogical experiences, but also developing up-to-date technology-enabled curriculum design skills to assist their future students to become twenty-first-century citizens, as well as digital curation and customization of existing resources (Deschaine and Sharma 2015). Despite this, new literacies in the knowledge society have meager impact on preservice teacher education institutes. Most teacher preservice education programs do not emphasize de facto technology use and fail to prepare preservice teachers to feel confident in their use of ICT in their future teaching (Istenic et al. 2016).

This may be the result of inadequate access to ICT as well as competition with print literacy, with which some preservice teachers, despite their belonging to the "digital natives" generation, feel more confident and competent (Burnett 2011). Indeed, being the first generation of "digital natives," preservice teachers undergo preparation programs that sometimes address themes similar to those of prior generations. While expected to be literate as well as passionate about ICT integration and technology-saturated environments, preservice teachers, while possibly fluent in utilizing technology on a need to know basis, are not necessarily equipped with the ICT knowledge and skills expected from the net generation (Lei 2009).

When examining their beliefs regarding ICT as a lever for better pedagogy, attitudes, experiences, and ICT proficiency, a curriculum for preparing preservice teachers to implement technology in their future teaching can be developed. Positive attitudes to technology integration and beliefs in the usefulness of ICT for empowering teaching, as well as computer self-efficacy, affect technology acceptance and integration positively (Prestridge 2012; Sadaf et al. 2016). Hence, this, along with information about their preferences in technology utilization, for example, social media, may serve teacher educators in the selection of preservice candidates and, furthermore, in defining goals for preservice education in the information era (Hammond et al. 2011).

Research also identifies an apparent gap between statements about the need for ICT integration in teaching (e.g., digital learning environments), and specific and practical knowledge on how to use ICT for empowering teaching. The popular understanding of ICT in education consists mostly of deploying devices and tools, for example, Word, learning management systems, or interactive whiteboards; hence, ICT utilization for teaching and learning is mostly confined to basic usage of digital tools; hence, the goals of teacher education programs are consistent with this line of practice that is common in schools. Moreover, the computerization of education systems is often perceived in terms of deployment of administrative systems (e.g., feeding student information, communication with parents), rather than pedagogical practices, again, confining training to immediate needs of the education system (Haley-Mize and Bishop 2015). Hence, there is vagueness regarding the desired goals for teacher training: should it be focused on present practices, or should it include future trends, thereby assigning a role of arrowheads to preservice teachers.

Teacher Education: Selection, Training, and Framework Construction

Preservice teachers are usually inexperienced in designing technology-based teaching and learning. Moreover, especially those trained to be elementary school teachers possess relatively basic ICT skills (Neiss 2015). In fact, also the use of ICT among teacher educators in preservice teacher education programs is low altogether, resulting in a low probability of modeling (Drent and Meelissen 2008). Positive attitudes toward utilizing ICT for education purposes and toward technology, as well as enhanced ICT literacy, may have positive effects on attitudes toward teaching as a profession (Celik and Yesilyurt 2013). Hence, if these are facilitated in teacher preservice training, the result may be empowerment of novice teachers altogether.

Selection of preservice teachers is becoming increasingly important, since teachers coming into the teaching profession need to be proficient in using ICT in general, and for improving teaching and learning in particular (Haydn 2014). Technological proficiency is currently not necessarily a prerequisite to entering teacher education programs, although preservice teachers are mostly proficient in basic technologies. However, their relative literacy in the more advanced and collaborative technologies may be insufficient, though possibly required in their future practice. This implies that preservice teachers may be in fact literate with basic technologies but might have some difficulties with the more advanced technologies. Hence, while advanced skills may contribute to constructing a more gradual and possibly differential ICT curriculum (Lei 2009), they are usually not considered as prerequisites in preservice teacher selection of candidates. Some programs aim to teach preliminary ICT skills in initial teacher education courses, thereby setting a threshold for these skills.

In summary, the literature addresses the need to establish a framework for teacher preservice education in an ICT-enriched school setting. Recommendations include research and development components, thereby setting a goal of capacity building. Programs should include a well-developed vision of ICT in education and teacher education (Stürmer et al. 2015), and according to this vision, a comprehensive curriculum (consisting also of practicum as well as courses), professional development of teacher educators (for modelling purposes), technical ICT plan (e.g., devices, software and application utilization, infrastructure), partnership between institutes within the educational milieu and beyond (e.g., industries), and accompanying research (Lim et al. 2011).

Review of Preservice Teacher Education toward ICT Integration

Although there is general agreement that ICT integration in teaching and learning is necessary for educating students in the information era, according to a review of preservice teacher education programs which integrate ICT, these do not seem to develop sufficient skills to reach this goal (Lim et al. 2011). Given the challenges of teacher preservice education in the digital age, capacity building may allow preservice teachers to examine their pedagogical beliefs in the framework of an ICT-enhanced teaching environment and explore ICT integration thoroughly as a means of empowering these beliefs.

Efforts have been made worldwide in attempts to achieve best preparation for preservice teachers in technology-enhanced teaching (UNESCO 2011). These efforts are evident not only in practice per se, but also in meticulous long-term planning, executing, and assessing outcomes of programs that focus on teacher preservice education in the twenty-first-century knowledge society, as described here. Modes of ICT integration are congruent with types of teacher training programs that are common worldwide, ranging from traditional modes of training (e.g., Saudi Arabia's traditional pedagogy, Belgium focusing on an ICT tool kit, or Finland offering basic ICT courses) to innovative pedagogical practices using ICT (e.g., attempts in Singapore to identify gaps in integrating TPACK for better teacher training), to integration in field practice.

ICT-Integrated Training Worldwide: Examples of Cases

The cases illustrated here are diverse in nature, in nationality, and in the depth and scope of ICT integration. This shows that there is no one mode of training used worldwide, but rather an array of training models.

Finland. This country had revised its teacher education program in the past decade. In a study at the University of Helsinki teacher education program, participants were interviewed and filled questionnaires at the faculty level. Data showed that ICT courses in different training programs varied widely (Meisalo et al. 2010). Courses focused on acquiring basic ICT skills had been recommended but not mandatory for preservice teachers. Student teachers acknowledged a gap between training and practice in their preservice education, which was perceived as rather conservative. Diffusion and adoption of innovative ICT usage was identified as a complex process, lacking the transfer from strategies to practice. Also, the study highlighted the need for more cooperation and teamwork, especially in multidisciplinary projects (Vihma and Aksela 2014). However, mentor teachers and teacher educators in some cases served as role models, which were of great value to preservice teachers attempting to produce innovative practices using the strategic guidelines presented by the national plan (Vahtivuori-Hänninen and Kynäslahti 2016).

Canada. A different angle on using technology for teacher preservice education also refers to a major challenge caused by a constant gap between the theory and actual classroom practice (Winslett 2014). Teacher education programs in Canada utilize videos in teacher preservice education for analyzing real-life teaching and learning situations as well as educational events. This develops useful teaching skills, fostering reflection through self-observation or observation of others in the act of teaching and using various learning models (Blaik Hourani 2013). In the study facilitated by Canadian teacher education programs, three impacts were significant: anticipating and preparing for teaching practice, analyzing the teaching–learning situation, and stimulating reflection. Given the importance of self-efficacy for teachers' professional development, online videos may be extremely useful, their use being flexible in terms of time and space (Karsenti and Collin 2011).

Saudi Arabia. In its preservice teacher education, traditional approaches in pedagogy are still broadly acknowledged, allowing less opportunity for effective ICT integration. Reasons include lack of infrastructure, accessibility issues, ineffective curriculum design, inadequate teacher educators' computer literacy, and meager professional support, despite government initiatives in this field (Al-Zahrani 2015). Results show that preservice teachers are interested, enjoy using ICT, are confident, satisfied, and expect to integrate ICT with novel pedagogical approaches. However, interviews highlight frustration regarding expectations to adopt conservative teaching modes. Overall, results indicate that preservice teachers have the skill and capability to work effectively with a variety of ICT tools (Robertson and Al-Zahrani 2012).

Belgium (Flanders). Here, a self-report instrument that measures preservice teachers' ICT skills in education was developed, based on an existing comprehensive framework. The underlying supposition for this instrument was that the dynamic nature of technological developments requires emphasis on generic ICT skills for teaching and learning. The result indicated two factors labeled "Competencies to support pupils for ICT-use in class" and "Competencies to use ICT for Instructional Design," which represent two foci of training (Tondeur et al. 2016a).

Singapore. In a large-scale study, 1185 preservice teachers filled a TPACK survey. An exploratory factor analysis found five distinctive constructs: technological knowledge, content knowledge, knowledge of pedagogy, knowledge of teaching with technology, and knowledge from critical reflection. A major finding arose from relative inexperience of preservice teachers, explaining the merging of pedagogical knowledge and pedagogical content knowledge items: preservice teachers exhibited lesser ability to link content and pedagogy when ICT integration, in lesson planning and in their practice, compared to more experienced in-service teachers (Koh et al. 2013).

Chile. Another national study about the availability and use of ICT in teacher education institutes was launched as part of the OECD international "ICT in Initial Teacher Training project." The main findings show promising conditions for pedagogical utilization of ICT in preservice teacher education, in infrastructure, support, policies, and self-reported ICT-related skills. Faculty and preservice teachers reported comfort in using ICT for teaching. Policies encourage ICT integration in teacher education, but few institutions formally implementing ICT in practice and it is low in their training priorities. Also, in common with other countries, most institutes integrate ICT in the curriculum as specific subjects or courses, rather than in a cross-disciplinary manner, which is less effective for promoting best practices. In fact, most students are not trained to fully use a wide range of possibilities of ICT in teaching or to fully comprehend its impact on teaching and learning (Brun and Hinostroza 2014).

Asia Pacific Region. Another training program consists of creating a tool kit for teacher education institutions in the Asia Pacific Region (i.e., Indonesia, Thailand, the Philippines, and Vietnam) (Lim et al. 2011). The aim was capacity building in developing ICT in education skills (Lim and Pannen 2012). The 3-phase 1-year project included an initial integration of the tool kit involving over a dozen teacher education institutes; scaling of the integration; and ensuring sustainability of the program. The program enabled to combine top-down and bottom-up approaches toward a systematic perspective on planning ICT in education training. According to an additional study (Xiong and Lim 2015), feedback and reflections from preservice teachers' learning experiences in ICT integration are essential for rethinking about training programs in the information era. Hence, a reciprocal approach, consisting of supplying ICT tools for teaching, as well as constant evaluation of preservice programs and adaptation to current needs is essential for better-quality preservice education.

Turkey. ICT may be a means of connecting preservice teachers for better support in their training by peer-learning. Attitudes and practices were examined by a study intended to identify motivators and barriers in the development of online communities of practice for preservice teachers' professional development in Turkey. The study comprised of two phases: an initial mandatory period including preservice teachers, and a voluntary participation period, including also in-service teachers, as well as additional preservice teachers (Baran and Cagiltay 2010). Three types of barriers caused decreased activity and possibly decreased the quality of knowledge sharing: personal barriers (e.g., feeling of reluctance to initiate a dispute, lack of time, preference to access a less interactive knowledge source, hesitancy to misdirect other community members); interpersonal barriers (e.g., availability of other community members caused preservice teachers to think twice before sending messages or materials in fear of criticism, diversity of student background and disciplines); and environmental barriers (e.g., poor computer literacy courses, poor ICT access, difficulty in management of the asynchronous communication) (Özcan et al. 2016). In another Turkish study, consisting of almost 2000 preservice teachers, two major factor categories influencing ICT utilization were examined: external factors, for example, types of support from the college; and internal factors, for example, attitudes, self-efficacy, and ICT skills. Conclusions stated that effective ICT integration was dependent on both types of factors, which were interrelated; hence, the integration process is complex and multifaceted (Tezci 2011).

The conclusion from the body of knowledge is manifold: a) there is a gap between policy and practice; b) ICT skills are insufficient – the discussion should focus on new educational paradigms; c) training itself should adopt new paradigms, for example, online communities of practice, simulation of best practices; d) hindering factors as well as facilitating factors should be addressed and monitored; e) focusing on teacher educators as role models. This may be exhibited in three modes of training, as detailed below.

ICT Modes of Training

Three modes of training may coincide: the "constituent competencies" mode of training, the "integrating ICT through curricular design" mode, and the field practice component. The first two modes should not be seen as dichotomous, but rather as a continuum, since the actual utilization of ICT consists of several types of activities; the latter should be realized based on the two other modes. The Belgium self-report instrument measuring ICT skills indeed indicated the two factors, that is, the competency-related factor and the ICT for instructional design factor, representing the two emphases of training. Still, the overall focus of preservice teachers' preparation regarding ICT integration in their teaching practice should be pedagogical; hence, the scope of training is determined according to the institute's emphasis on technological proficiency versus pedagogical expertise using technology. The field practice is a result of the college vision regarding ICT integration in schooling.

Constituent Competencies

This type of preparation consists of separate courses for distinct proficiencies: content courses, which aim to develop knowledge in specified disciplines (subject areas) that are taught within the K12 national or regional curriculum; methodological courses, aimed to develop teaching methods as outlined by the curriculum for preservice education; technology courses, aimed to develop skills and proficiencies in using ICT in the classroom (e.g., utilization of computers and mobile devices, exposure to software – content-based as well as general software, fixing minor malfunctions), and practice in K12 institutes (Niess 2015). Indeed, studies emphasize the need to develop basic technological skills among preservice teachers as a prerequisite for developing their ability to implement ICT in their future professional lives (Instefjord and Munthe 2016), for example, the need to become familiar and possibly fluent with ICT and to master basic tools and interfaces so as to become a "native speaker" of the digital language, as evident in the case of Saudi Arabia. This focus is somewhat evasive, since technological proficiency is constantly changing given the frequency of technological developments and change.

While this mode of training highlights the importance of technological aspects, it assumes expertise in teaching with ICT. The latter, according to this mode, is attained separately and supplementary to technological expertise, in terms of content knowledge (according to the preservice teachers' specialization) and pedagogical proficiency. Research has reported the ineffectiveness of technology courses that are detached from pedagogical themes in preservice teachers' curriculum (Anderson et al. 2011), as portrayed in the Chilean case, in which most ICT integration is achieved in specific courses, rather than in a curricular design mode, which is seen as insufficient for promoting best practices.

Many of the preservice teacher education programs include, as practice of this mode, one single course focusing on ICT in education. This course is usually a preliminary course, which fails to prepare preservice students for the complexities of teaching in twenty-first-century schools (Instefjord and Munthe 2016; Lim et al. 2011). Moreover, preservice students learn many of their ICT skills prior to their higher education studies (e.g., in school, online, from family members or friends, or by self-learning), for example, word processing, spreadsheets, presentation tools, social media, or search for information; this excludes, surprisingly, collaborative tools for sharing information and constructing joint products (Blackley and Sheffield 2015; Burnett 2011).

To sum up, many factors may be reasons for the lack of success in linking preservice education to the digital era. They may include time constraints within the traditional time frame, teaching paradigms that are not up-to-date, faculty technological skill, negative attitudes toward technology, and misunderstanding of ICT integration in teaching. The latter raises a fundamental issue, according to which preservice teacher education that offers courses focusing on ICT skills has limited impact on the quality of teaching. Skills for ICT use taught in separate courses that are disconnected from content and pedagogy, moreover, from educational practice, may be futile (Jordan and Elsden-Clifton 2013).

Integrating ICT through Curricular Design

The principle behind this mode of teacher preparation asserts that separate educational technology courses aimed to enhance technological proficiency are not sufficient for preservice teachers' professional development (Haley-Mize and Bishop 2015), but rather an integration of pedagogy and technology and seeing them as intertwined, as attempted in the Singapore program. However, as shown also in the Finland case, this is a complex endeavor: the focus of this mode is to highlight pedagogical and curriculum design competencies rather than technological skills, thereby emphasizing instructional design processes. In terms of content, this requires various subject matter, content domains, and multidisciplinary topics, all aimed to demonstrate the pedagogical advantages and affordances of given technological tools (e.g., platforms, software) and devices (e.g., smartphones, geographic information systems) to transform teaching (Niess 2015). Furthermore, preservice teachers are instructed to work with technology-based systems that allow adaptation of learning materials to their students (Instefjord and Munthe 2016). The Asia Pacific Region case makes an attempt to scale and sustain the combined integration of technology and pedagogy in preservice training programs, thereby enabling two-way top-down and bottom-up integration processes; these are constantly reevaluated, aimed to improve training altogether, and ICT integration in particular.

Another focus of this mode is authentic real-world tasks in classroom settings, sometimes referred to as situated learning (Tondeur et al. 2016a). Focusing on instructional design engages preservice teachers to actually teach within their training process, utilizing technology not only for their practice as students, but also engaging K12 students in learning in a technology-saturated setting, as a major component of their role as future teachers. Naturally, this utilization of technology is not sufficient, but rather has to be accompanied by reflections and insights regarding the role of ICT integration in teaching and learning (Niess 2015). Of course, the challenge would be to ascertain ICT competencies alongside and intertwined in pedagogical and curriculum design courses.

Finally, utilizing technology as a means of narrowing the digital divide, defined by socioeconomic status as well as by special and possibly diverse needs of students, means highlighting the social role that technology plays in twenty-first-century education. The focus of an instructional design mode, hence, is not on the technical proficiency with ICT, but rather on its utilization for the benefit of distinct needs, for example, equity and accessibility (Benton-Borghi 2013). The Turkish attempt to develop online communities of practice for training and professional development of preservice teachers is an example of utilizing the characteristics of ICT for peer learning, in which availability of several participants allows examination of several types of ICT integration.

Practical Field Experience

The preservice field practice is considered a major component of the teacher preparation process worldwide, as it exposed the preservice teachers to authentic teaching practice in schools. This, in turn, may strengthen the connection to courses within the college (Latham and Carr 2015). However, while this is a result of the two first modes of training toward ICT integration, the practicum framework does not necessarily include a carefully planned and systemic paradigm for ICT integration. Furthermore, schools play a major role in defining the nature of diffusion of technology into their curriculum, thereby posing possible conflict for preservice teachers. On the one hand, mentor teachers, those who receive the preservice teachers into their classrooms, follow an existing educational paradigm; this often results in assimilation of ICT practices into current pedagogy. On the other hand, preservice teachers are assumed to be prepared to implement novel pedagogies, which inherently utilize ICT as a necessity in curriculum and lesson planning as well as teaching and learning (Kimmons et al. 2015). In a recent book, several studies highlight understanding of ICT-integrated best practices in schools, for example, using tablets to empower pedagogy, game making using ICT, collaboration using online environments (Zhang et al. 2016); hence, these may serve as models for preservice teachers to follow and relate to in their field practice. This requires preplanning and careful assigning of mentor teachers, who are ICT literate and may be innovators in their practice, for example, an innovative teacher training model in High Tech High (Griswold and Riordan 2016).

Modelling would be of the utmost importance and a crucial element in the process of attaining knowledge and training preservice teachers to utilize ICT in their practice (Hill and Flores 2014). This is well portrayed in the Canadian case, in which technology is used for simulating teaching experiences. Teachers tend to teach in ways that they have been taught; hence, showing them or having them present integration of best pedagogical practices using ICT may change their knowledge construction regarding their role as teachers as well as the role of ICT in their future teaching (Gill et al. 2015; Haley-Mize and Bishop 2015).

Notwithstanding, the risk of teaching ICT skills in the pre-preparation stage and focusing on pedagogy in preservice stages and in-service professional development may be an impediment for teachers who do not feel adequately prepared to integrate ICT effectively in pedagogical practices (Tondeur et al. 2016c; Hsu et al. 2013). Hence, while the major issue is whether twenty-first-century educational goals are being met in contemporary teacher preservice practice, de facto preservice teachers need scaffolding in the form of ICT support.

In summary, since the role of preservice practice is to better prepare teachers for their teaching role, and it is considered as a vital component for their professional development of practical teaching skills, integration of pedagogical practices using ICT is considered of vital importance (Jordan and Elsden-Clifton 2013). Figure 1 summarizes an overview of the preservice education process and components.

The main idea behind the illustration presented in Fig. 1 is that the technical aspect of the training as a stand-alone training component is suited for the pre-program phase, that is, a threshold of ICT proficiency is required for teacher preservice education, though constantly addressed also within the teacher preparation period. However, it is handled on a need-to-know basis, according to educational needs. In preservice training, academic courses and school practice should be connected to each other, as well as to pedagogical methods and disciplinary content, all interrelated, with the general setting being an ICT saturated environment. These in turn assist and contribute to developing innovative pedagogical practices using technology, within top-down but also bottom-up paradigms, which continue in in-service training and practices.

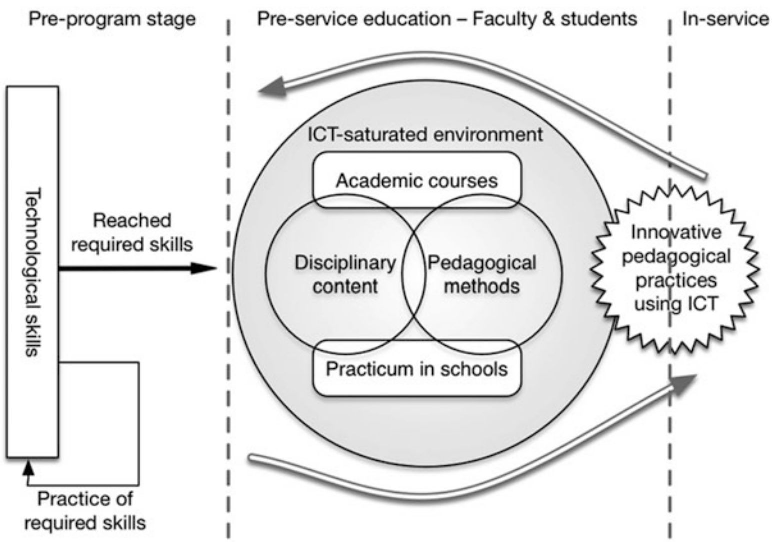

Fig. 1 An overview of the training process

Conclusion. Teacher preservice education focused on utilizing ICT is threefold in its major components. The first aspect is to apply ICT as student teachers in academic courses, consisting of technical knowledge aimed to promote ICT skills. The second component is to promote disciplinary and pedagogical knowledge that may assist future teachers to utilize ICT in novel ways, as a lever for educational change, whether as a process or in a relatively radical and disruptive manner. The third is the de facto application of innovative pedagogical practices in teaching within practice schools, which is the final target of the teacher preservice training process. Hence, we can identify three stages of training. The first stage includes knowledge of potential ICT uses in educational contexts in general; this consists of noncritical, nonselective use of ICT in academic courses. The second stage is of a more specific nature, including consideration of more specific possibilities for developing pedagogical methods and practice that implement ICT in context-specific scenarios, thereby acknowledging the complex nature of ICT application in educational contexts. The third stage consists of a more reflective nature, including creation of a systematic and systemic plan that gathers ideas, insights, and practical experience, in the course of constructing principles for critical engagement with ICT. In this final stage, the preservice student is able to identify and explore contingent conditions for best educational practices using various technologies, as well as to attain deep understanding of the complex nature of ICT integration in teaching and learning (Gill et al. 2015).

ICT Integration: Learning by Doing

Preservice teachers involved in ICT integration, either in courses or in their practicum within schools, are likely to acquire positive attitudes toward ICT integration, enhanced technological knowledge, and, most importantly, to implement ICT-based innovative practices within their practicum in schools (Polly et al. 2010). This depends on the quality of their training, in terms of preparing teachers for teaching and mentoring students, who are born into a world that is completely different from the one they were raised in, that is, the digital era that is in constant change.

For best impact, training requires that the ICT integration process be a spiral process, performed in a nonlinear mode. The top-down nature of the process in the initial stages of preservice teacher preparation allows more standardized assessment of its impact; however, the potentially disruptive nature of ICT integration requires facilitation of bottom-up initiatives. For best impact, the training process needs to be dynamic in nature: possibly technological to begin with, but subsequently focusing on the pedagogical and disciplinary opportunities for change and innovation. In some cases, it is unavoidable to be revolutionary and disruptive, while in other cases, it is more evolutionary and progressive in its nature. In many teacher education institutes, local initiatives for ICT-based teaching and learning are developed. These, in turn, sometimes have vast influence on didactic processes within schools in which preservice teachers are trained within their practicum (Jordan and Elsden-Clifton 2013).

The impact of preservice training for ICT utilization is manifold, including stages of using ICT as students, as well as implementing ICT in classrooms as future teachers. Since ICT is implemented in different modes worldwide, its impact is controversial; this is evident in ICT integration in education in general (e.g., see OECD 2015). Therefore, collaboration between teacher training programs for universal construction of ICT integration approaches as well as for their assessment may serve local as well as global interests (Tondeur et al. 2016b). This may help to evaluate long-term impact and sustainability of ICT integration in teacher preparation programs. The following section details the actions recommended for best ICT integration in preservice teacher training, leading to sharing of best practices using ICT.

Recommendations

Teacher education colleges are compelled to provide adequate training in accordance with world trends. ICT has created opportunities for disruptive innovations in pedagogical practices that challenge the traditional educational milieu, change teaching and learning paradigms and practices, and make place for emerging new paradigms. The following recommendations are derived from the review of studies worldwide, as well as from the models of ICT integration in teacher training – de-facto and desired (but possibly difficult to achieve). Recommendations may assist practitioners, policymakers, and researchers in their pursuit of improving preservice teachers' education.

1. *Affective states matter.* Preservice teachers' attitudes and beliefs regarding ICT may indicate the extent and quality of ICT utilization. Hence, shaping positive beliefs about the role of ICT for educational purposes, as a means of transforming educational practices and education in general (i.e., vision of education in a global, ICT-enriched society), may facilitate its usage.
2. *Added value.* ICT should not be seen by preservice teachers as replacing or magnifying current educational practices, but rather preservice education programs should focus on the benefits of utilizing ICT to empower pedagogy innovatively, in a transformative manner (e.g., disruptive innovation). Hence, each teacher training institute must examine its vision of twenty-first-century education, in a global as well as a local perspective, and then define its goals accordingly with regard to ICT integration.
3. *Healthy variety.* While ICT integration is an international endeavor, pluralism and the freedom of choice in the ICT integration process is fundamental, at a national as well as an institutional level. For best utilization of ICT as a lever for educational change, flexibility is crucial. This requires dynamic ICT-based training, according to the characteristics of the institute, the population of preservice teachers, and the general student population of the country.
4. *Desired diversity.* Teacher training institutes should compose a clear vision regarding the role of future teachers in the education era. This does not imply

a top-down training process, but rather general guidelines that also encourage faculty as well as preservice teachers to initiate innovative pedagogical practices using technology. Preparing teachers to use ICT in different institutes, or even within an institute, may be of diverse nature but can still meet its goals.

5. *Final goal.* Training of preservice teachers should be practice-related, and related simultaneously to teaching as well as learning, thereby creating a holistic pedagogical master plan for ICT integration. Hence, preservice teachers can benefit from focusing on ICT integration in academic courses as well as in their practicum experiences. The combination of both modes enables them to experience ICT as a student as well as a teacher.
6. *Technological prerequisites.* With regard to technological skills – this should not be considered as part of the academic teacher training curriculum, but rather may be attained separately, as a prerequisite. Teacher training institutes may benefit if they collaborate on this issue, by creating mass courses for nonacademic credit, simply to assist students to reach a required threshold for their ICT proficiency.
7. *Pedagogy.* The focus of teacher preservice education should not be on mastering ICT skills (this was recommended to take place before the actual training, or in its initial stage, e.g., compulsory courses as a prerequisite for acceptance to a full program). After this compulsory (noncredit) stage, training should promote integration of ICT for better teaching and instructional design, and mostly – for better learning. This requires simultaneous attendance to technology, pedagogy, and content knowledge from the initial stages of programs for training teachers and should include ICT integration through curricular design. The process at large should benefit from the connection of teacher preservice programs to the K12 education system, that is, kindergartens and schools, which may be considered as laboratories for examining innovative instructional design and pedagogical practices using technology.
8. *Best practices.* These should be identified as a means of scaling ICT integration initiatives in preservice teacher training. This may include faculty initiatives for academic courses taught innovatively as a result of ICT-based practices, or preservice teacher initiatives for practicum practices within training schools. Encouraging sharing of experiences among preservice teachers and instructors may promote sustainable and scalable practices worldwide.
9. *Modelling.* Faculty within teacher training programs should set an example for their trainees, that is, preservice teachers. Training programs should undergo change in this respect, including faculty as co-trainees, in addition to their role as instructors, engaging them in a joint endeavor of co-learning with their students. Students may bring to this process their relative ICT proficiency, unconnected to its pedagogic utilization, while instructors bring their disciplinary and pedagogical expertise. Hence, the changing role of teachers in the information era also has bearing on the teacher educator's role.
10. *Quality assurance.* Teacher education programs should undergo continuous evaluation processes, in an attempt to adapt them to an era of constant change. These changes are evident in terms of developing technologies (e.g., holograms and augmented reality), pedagogies (e.g., online mass courses adapted to

personal learning by using big data), and even content (e.g., multidisciplinary trends). Consequently, academic research within and about teacher preservice programs should be mandatory. Learning from best practices as well as from failures or mistakes must be perceived as a means of improving the preparation of future teachers.

Concluding Remarks

The purpose of this chapter was to present an overview of the state of preservice teachers' preparation toward ICT integration. The chapter contributes to the reader an array of different initiatives (mostly followed by research) in countries worldwide. It further suggests modes of ICT integration, leading to a proposed comprehensive model aimed to tackle ICT competencies as well as ICT integration through curricular design, leading to better field practice. The ultimate goal is, naturally, to transform the K12 education system, by utilizing ICT in a way that facilitates novel practices – and these should be shared globally. The ultimate message to policymakers involved in preservice teacher education, as well as to researchers, is that pedagogy and curriculum design are imperative for better pedagogy in classrooms, but, in fact, ICT competencies should not be overlooked, as they are a prerequisite for the former. Hence, basic skills should be tackled prior to the educational training; then when entering the training program focus should be on twenty-first-century ICT-based pedagogy.

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Teachers as Drivers of Their Professional Learning Through Design Teams, Communities, and Networks

28

Sarah Prestridge and Katherine Main

Contents

Abstract

Engaging teachers in cooperative and collaborative processes through which they learn from each other is fundamental in rethinking professional development as being '*done*' to teachers compared with teachers '*doing*' or driving their professional learning. This rethinking is underpinned by opportunities that have arisen not only through social networks and the pervasiveness of online media but also from the shift in valuing the exploration of individual interests and needs as well as in the pedagogical reform process. The tenets of effective professional learning, namely, active engagement, teacher voice, creation and collaboration, inquiry and reflection, will be explored in this chapter through two modes of discourse. First, a reckoning of what counts as professional learning activities is proposed to establish the driving force or purpose for teacher learning. This is then developed further in the second part of this chapter where we discuss the various approaches to professional learning with a theoretical analysis of teacher collaboration, teacher teams, communities of practice, and broader social networks.

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Understanding the genesis, development, and purpose of professional engagement and interaction is key to supporting teachers as the 'deliverers' of educational reform who are those tasked with transforming education through ICT.

Keywords

Professional learning · Professional Development · Social Networking · Teacher Teams · Communities of Practice

Teachers are in a critical position as those responsible for *delivering* educational reforms, innovations in pedagogies, and curriculum change. With Information and Communications Technologies (ICT) as a driver, a deliverable, and a determinant, teachers are expressing the need for effective professional development that will enable them to create new visions, teaching practices, and dynamically flexible learning spaces that are technologically enhanced (Goldman and Lucas 2012; Tsiotakis and Jimoyiannis 2016). In response, some schools offer teachers professional training in specific technologies. They may also have in place opportunities for teachers to individually or collaboratively design curriculum units with an expert ICT teacher or have this teacher take the lessons. Additionally, there may be a school-wide approach to the adoption of a specific device such as tablets or iPads paired with specific training focusing on one flagship class/year level, the more competent teachers, or to meet the needs of a specific target group (e.g., extension group). Such school-based approaches have been found to be limiting as they do not cater to the highly diverse needs of *all* teachers and often replicate historical and cultural practices in schools (Phelps et al. 2011). In addition, teachers are seeking their own learning opportunities by completing targeted workshops on robotics or participating in a Massive Open Online Course, using Facebook to follow and extend their own teacher networks and/or listen to expert podcasts to further their knowledge and skill in ICT integration. With the permeation of the Internet in personal and professional life as well as the opportunities it brings for social networking, teachers have the opportunity now to add to their professional learning repertoire by taking part in such activities. This chapter will explore a few different aspects of professional development and professional learning associated with enabling teachers to harness the transformative potential of ICT in their classrooms.

Fundamentally, professional development is more about change in classroom appropriation of an ICT than access to, or competency with, a new tool or resource. Change is considered a reformation of both mindset, the philosophical disposition a teacher holds, and the pedagogical content knowledge that informs and therefore actions new teaching processes. Professional learning is not about replication of existing practice or the assimilation of ICT into existing teaching approaches. For too long, we have been satisfied with what Lankshear and Bigum (1999, p. 456) described as "technologizing" traditional teaching, which Bigum (2002) more resolutely confirmed as meaning that teachers are still 'domesticating' the computer in classrooms. This domestication of ICT is still evident today, with studies into classroom practice finding that teachers are still appropriating ICT as supplementary or as an augmentation to existing practices (Ertmer et al. 2012; Prestridge 2012, 2016, 2017). An outcome of effective professional engagement is for teachers to ‘re’shape, ‘re’think, and ‘re’conceive ICT-infused pedagogies that effectively impact student learning.

Professional development and professional learning will be explored in the first section of this chapter to provide foundational understandings of the driving force or purpose to a professional activity. The difference between professional development and professional learning will be examined as these terms are often used interchangeably and that can affect the assumptions that drive and shape teachers' engagement in these professional endeavors. Building on this in the second section of this chapter, we discuss the various approaches to professional learning with a theoretical analysis of teacher collaboration, teacher teams, communities of practice (CoPs), and broader social networks. These modes of professional engagement and interaction may be manifested at local sites or via online media and contribute significantly to supporting teachers as the ‘*deliverer*’ of educational reform.

Foundational Understandings About Professional Development and Professional Learning

When teachers are involved in trialing iPads in their classroom, would it be called professional development or professional learning? When teachers are involved in training on new software or following a hashtag on Twitter®, is it professional development or professional learning? In educational theory, policy, and curriculum documentation, these terms are interchangeable. To help us understand the difference, if any, clarification of these terms is required as both have roles in the context of enabling teachers to improve their professional practice that positively influences student learning.

Teacher professional development has been defined as “activities that develop an individual's skills, knowledge, expertise and other characteristics as a teacher” (OECD 2009, p. 49), which encapsulates most school-based staff development, in-service, and training events educators have come to associate historically with traditional structured professional development. This definition has been perpetuated over time and is still closely linked with a top-down training model of in-service based on the assumption that “teachers need direct instruction about how to improve their skills and master new strategies” (Lieberman and Miller 2014, p. 7). These and various other authors critique such assumptions that professional development is ‘*done*’ to teachers (Little 1993, 1999; McLaughlin 1994). Little, in her early work in the 1990s on the role of professional development in educational reform, proposed that the validity of professional development should be evident in its capacity to equip teachers to act as shapers, promoters, and well-informed critics of reform. Rather than being ‘done’ to teachers, professional development positions teachers as pedagogical experts who engage in the pursuit of genuine problems over time with a broader professional community that affects change in beliefs, attitudes, and practice. The longstanding dissonance of professional development being ‘done’ to teachers compared to teachers ‘doing’ or driving their learning remains.

Professional learning, on the other hand, is more self-directed based on professional needs or interests. It has been explained as learning that is not formally planned or provided as part of the school strategic direction but considered as part of the serendipitous or natural study work that teachers undertake daily in their classrooms (Day and Sachs 2004). More so, it is considered to involve changes in a teacher’s capacity for practice associated with shifts in professional knowledge, attitudes, beliefs, and/or mindsets. These types of attributes are more complex barriers to the integration of ICT (Ertmer 2005) than barriers such as hardware or access, and have been found to be much more difficult to shift but have greater potential for enabling effective appropriation of ICT (Prestridge 2017).

Accordingly, then, professional learning orientates an internalized goal-centric model of learning that Raphael et al. (2014) explain as “ownership over compliance, conversation over transmission, deep understanding over enacting rules and routines, and goal-directed activity over content coverage” (p. 147). Essentially, professional learning is a ‘*growth in practice*’ model that values active engagement, teacher voice, creation and collaboration, inquiry and reflection. This type of learning can occur through professional learning communities within and beyond schools, through teachers’ personal networks, or organized special interest groups that exist in local school communities or online. This will be explored further in section “Approaches to Professional Learning” of this chapter.

One nuance associated with professional learning that differentiates it from professional development is in what Raphael et al. (2014) alluded to in their explanation, that is, “goal-directed activity over content coverage.” In traditional professional development, a program of activity is consumed by teachers with expectations that new knowledge is gained and therefore transmitted by the teacher to ‘better’ or ‘more informed’ classroom practice. This would be considered by Raphael et al. as content coverage. Whereas, with respect to professional learning, the focus for what is considered ‘learning’ moves from product to process. This shift has been conceptualized by Evans (2014) as encompassing behavioral development – processual, procedural, productive, and competential change; attitudinal development – perceptual, evaluative, and motivational change; and intellectual development – epistemological, rationalistic; comprehensive and analytical change. These processes as goal-directed activity direct the outcome of professional learning as teachers becoming conscious of their pedagogical changes with the development of professional learning capabilities. Self-realization and learner autonomy have been identified as educational outcomes of online professional engagement (Prestridge and Tondeur 2015). Finally, some of the key findings of professional learning indicate that it is a messy unpredictable process that can be an unconscious incidental event (Smylie 1995), unanticipated through social activity (Adger et al. 2004), implicit (Eraut 2007), contributing to making conscious ‘knowledge-of-practice’ (Cochran-Smith and Lytle 2001), but usually situated (Hoekstra et al. 2007) and more selective and self-determined for teachers in a later career stage (Cameron et al. 2013).

What does this mean for ICT integration? Which is the better approach to enable teachers to transform their pedagogical practice with ICT? If we understand professional development as a series of activities for new knowledge about a tool or teaching practice that is more likely to be externally organized and professional learning to be about the process of engagement internally driven for self-actualization and learner autonomy to inform practice, then which concept should be foregrounded? Drawing from the literature mentioned here, it is clear that there are nuances, synergies, and convergences of features of each approach that makes it difficult to suggest a more preferred or more valuable option other than drawing on both professional development and professional learning elements that are relevant to the given purpose and context. However, in saying this, we believe that the teacher needs to be the driver, the center of any professional experience rather than the content or the ICT; that the learning process, the metacognitive gain and shift in mindset, is more important than gains in ICT skill competency or knowledge; and that learning takes place as part of a community where the contributions of the teachers are the currency for content rather than the teachers being the passive recipients of knowledge. In describing this, philosophically, professional learning precedes professional development in design.

The following section will explore approaches to professional learning that identify features that could be used to design effective engagement opportunities for teachers as drivers and critical participants in development activities for ICT integration. Informing understandings about teachers working collaboratively, teaching teams, communities of practice, and social networks will be examined.

Approaches to Professional Learning

Communities of practice, teaching communities, teacher teams, and learning communities are terms that have been used interchangeably within the literature. Each term has been used to describe a type of social structure used by educators to collaborate to improve their practice. Communities of practice have been defined as a self-selected purposeful social structure whereby educators regularly come together to work for the collective benefit of students (Lave and Wenger 1991). The term was conceptualized through a reexamination of learning theories that argued that much of an individual's learning is a result of our participation in social interactions. Communities of practice are designed to capitalize on that premise. DuFour (2014) argued that professional learning communities have two broad purposes: (a) to improve the skills and knowledge of educators through social interaction and professional dialogue, and (b) improve the learning outcomes of students. Much of the work of these two types of collaborative groups is accomplished through action research cycles of investigation of shared practice and ongoing learning. As such Communities of practices and professional learning communities are similarly structured and are closely aligned in their overarching goals.

Teacher teams can be defined as two or more teachers working collaboratively and taking responsibility for teaching the major part of the instruction for the same group of students. Team practices can include all or some of a range of activities including planning, teaching, resource sharing, and assessing (Main 2012). Thus, these professional interactions also initiate and provide professional learning opportunities as teachers learn from collaborating with others and that learning is ongoing through active engagement in improved practice (Voogt et al. 2016).

For professional learning to be effective, it must be relevant, collaborative, and future focused, and encourage teachers and leaders to reflect on, question, and continuously improve their practice (Australian Institute for Teaching and School Leadership [AITSL] 2012). Working collaboratively can be argued to be a very effective form of professional learning for teachers as it is embedded within the context of a teacher's own classroom, is conducted over time, and is positioned where they can receive feedback and reflect through an iterative cycle of planning, practice, and reflection. These elements have been designed in professional development activities that support teachers to become conscious of their ICT beliefs and practices (Prestridge 2013). With education systems now recognizing the wide range of benefits that can be realized by purposely having teachers work together, greater opportunities are being afforded for teachers to work together rather than in isolation. The benefits of teachers collaborating that align with professional learning include early career teachers learning from more experienced teachers (Westheimer 2008), increased professional dialogue that supports innovation and new ideas (Meirink et al. 2010), and the broadening of teaching strategies (Shipley 2009). Thus, when working collaboratively, either face-to-face or online, teachers have reported a wide range of professional and personal benefits (see, for example, meta-analysis by Blitz 2013, p. 6). Collaborative activities form a basis of professional development models and structures. The benefits of working collaboratively as well as how different formal structures of teacher collaboration, both face-to-face and online, are operationalized will now be discussed.

Teacher Teams

Teacher teams have been introduced in schools across the world as part of school improvement initiatives and school reform efforts. Recognizing the potential of teachers working together has resulted in a significant amount of research which has attempted to understand how effective teams function (see, for example, meta-analysis by Vangrieken et al. 2015). The size, configuration, and practices of teaching teams vary widely. Each team is unique and must accommodate differences among team members (i.e., levels and types of expertise, personalities, understandings of team practices), students (i.e., age, year level, class configurations), physical layout of classrooms, and the school program under which the team will be operating (i.e., interdisciplinary team or interdisciplinary curriculum, primary school, middle school, or senior school). These differences result in teaching teams and team practices looking very different across year levels, within year levels, and from setting to setting across schools. However, there are also several commonalities that can be identified in any team's development. Key to effective collaborative practices is understanding the characteristics and tasks associated with each stage of the team's development.

Aligning with the seminal work of Bruce Tuckman (1965) around the life cycle of business teams, teaching teams have also been shown to go through a life cycle with a beginning, middle, and an end. Tuckman's theory of small group development outlined four key stages, namely, forming, storming, norming, and performing. There are a number of key tasks that need to be undertaken at each stage of the teams' life cycle for the team to move forward positively. First, in the forming stage, the main tasks are to establish the procedures that will govern the team such as its goals, individual member's roles, agreed upon rules and to set common expectations that will guide the team. Some of the most common reasons teams fail are disorganisation, unclear or conflicting goals and expectations, competing commitments (time management), lack of motivation, and conflict (Main 2012). The storming stage is an essential part of the team's life cycle where team members begin to challenge ideas and reassess the team's goals and expectations. During this stage, the team needs to develop a plan as to how the team will be able to achieve its goals which often requires reestablishing team rules and expectations. It is also critical at this stage for team members to put into place effective conflict management strategies that will ensure that they are able to manage conflict in a positive way and build trust within the team. The norming stage is where the focus has moved from the individual to uniting as a team and getting the job done. Team members begin to feel a sense of belonging and a stronger commitment to the team as trust builds and progress is made. The final stage, performing, is achieved when the team is working cohesively and there is a balance between achieving the team's goals and maintaining and building relationships between team members. Tuckman's theory has proven to have transferability across disciplines and, although teams do not necessarily progress through these stages in a sequential pattern, there are characteristics and tasks associated with each stage. As a team progresses through its life cycle, team members must manage three different processes simultaneously, namely, task processes (the job to be done), team processes (how the team functions), and relationship processes (how team members get along with each other).

Understanding the reciprocal dependency between team processes has increasingly been recognized as being critical to developing theoretical models of team effectiveness (Nicolaides et al. 2014). For team members to be able to work together, there needs to be a simultaneous balance between using team processes (e.g., appointing a leader, setting regular meetings, assigning specific roles, agreed team rule) to complete the task (e.g., knowing how to plan, teach, and assess a unit; complete a special project) and maintaining the relationships (Main 2012, 2017).

The effectiveness of teams is measured by more than its productivity (task completion) or performance (team working together). It also involves the development of each individual's self-efficacy and personal satisfaction with their work (Main 2012). The professional learning that occurs through working in teams supports the development of one's sense of efficacy as well as enhancing their commitment to the team. This positive cycle of influence creates a sustainable pattern of self- and team improvement through nurturing shifts in practice (Butler and Schnellert 2012). In their analysis of studies involving curriculum design teams, Voogt et al. (2016) found that where teachers' worked collaboratively and where their professional learning outcomes were focused on pedagogical content knowledge and design knowledge and skills as well as being linked to the curriculum, it led to "an improved quality of teachers' knowledge and skills (. . .) and the quality of the curriculum design process" (p. 136). They further noted that teacher self-efficacy was related to the teachers developing ownership in the curriculum change process and that this sense of ownership was a critical element for successful implementation of any change.

Teacher teams or curriculum design teams that are school, district, or wider reaching through online pathways can involve teachers in codesigning units of work which effectively use ICT. These can be a part of structured professional development or opportunistic, informal interest-based professional learning activities, for example, Teach Meets on Coding. A Teach Meet can be organized by teachers themselves within their school districts or by a professional organization such as a Department of Education or Computer Association. At these meetings, teachers share good practice on nominated topics and teachers who are interested attend. These face-to-face meetings can be organized through an online community where conversations can occur before and after, in ways that expand teachers' professional networks and their pedagogical understanding of ICT. The Teach Meet, if local, can give teachers the opportunity to meet face-to-face. In the fully online space, teams of teachers from different schools can work collaboratively to analyze lesson plans and video recordings of classroom teaching through an online platform, as found in Zhang, Liu, Chen, Wang, and Huang's study (2017). Using an online platform enabled the teachers in the study to collaborate across time and place, and the process of providing feedback and suggestions for improvement on lesson plans and delivery was considered by the teachers beneficial for linking theory to practice and exchanging information. Lin et al. (2008) researched virtual teacher teams who were collaborating on developing ICT lesson plans identifying the factors that affect the process of knowledge sharing and creation online, such as teachers taking on roles of task performers or idea providers. Teachers as active participants in the curriculum design process are driving their professional learning and are positioned as the expert within educational reform.

Communities of Practice

In the late 1980s and early 1990s, social anthropologists began to recognize the significant learning that comes from our participation in social life and personal interactions (Lave and Wenger 1991). Through a process of reconceptualizing the then current learning theories, the term "Community of Practice" was developed, as noted previously. A Community of Practice (CoP) was defined as a group of people who intentionally interact regularly with each other around a common concern or a passion and work together to learn how to do it better, that is, how to improve their practice (Lave and Wenger 1991). The intent behind the term CoP is that the learning is embedded within a shared practice rather than just a shared learning experience. Thus, in the case of a CoP in an educational setting, it can be viewed as a form of ongoing professional learning with the process of learning setting its members on a positive trajectory for improving practice. Thus, in a CoP, a group of teachers work together to improve both their own performance and that of their colleagues in their day-to-day practice (Farnsworth et al. 2016).

Within a CoP, teachers work together and can collaborate on a range of curriculum and planning tasks and can also engage in co-teaching and peer observation to facilitate performance monitoring. Making these practices known breaks down professional barriers and establishes a sense of collaboration and community between educators within the setting (Ranmuthugala et al. 2011). Working in this way acknowledges the value of teachers as professionals and helps to further develop the established pedagogy and a vision to improve practice. As such, a CoP seeks to locate the learning in the process of co-participation (building social capital) and not just within individuals. Hence, collaborative practice can become the main method of professional development for educators improving practice and "learning" and for making educators who are working together accountable to each other (Main 2012).

Communities of practice or professional learning communities have been promoted for over a decade as an effective form of professional learning (DuFour 2014). In more recent times, the Internet and mobile communication technologies have extended and changed the construct of CoPs as well as the way that they operate within a school context, district, or beyond. With increased opportunities and greater flexibility of time and space, CoPs are extending to include not just teachers within a school but also drawing on outside expertise and developing hybrid CoPs that use a combination of face-to-face and online interactions. Blitz (2013) conducted a comparative review of face-to-face and online CoPs (professional learning teams) and noted that online communities could achieve many of the same beneficial outcomes as face-to-face CoPs (see, for example, Zhang et al. 2017). Those working in the online environment were also found to be more self-reflective; however, the professional learning was shown to be the same regardless of the model of CoP (Blitz 2013).

The success of online CoPs is reliant on the members of the community voluntarily sharing their knowledge and experience. Knowledge giving and receiving as social and cognitive practices in online CoPs are dependent upon teacher's interpersonal connections and proactive self-regulation in these spaces (Tseng and Kuo 2014). In practice, the lack of engagement by members has been seen as a significant issue (Macdonald and Poniatowska 2011) and, as experienced in face-to-face CoPs, the presence of the "social loafer" syndrome can disrupt the flow and effectiveness and commitment of all members to the group. However, to overcome this, Matzat (2013) noted that a high level of embeddedness (i.e., the degree of off-line interaction between members of an online community) can promote commitment to the group and reduce the tendency for social loafing. Further, in this large-scale, comparative study, Matzat (2013) found that "blended communities," where there was a mix of off-line interactions that complemented the online community, "deliver more benefits than purely virtual communities" (p. 49). However, in one study, where only 7% of the members met and networked in an informal off-line meeting, the benefits including increased communication, more open sharing of materials, and an increase in trust between members were realized. Thus, it is possible to increase the effectiveness of an online CoP by increasing the embeddedness of the membership through strategies such as recruiting members within an area where some may already know each other or by providing opportunities for face-to-face meetings through conferences or other forms of professional development.

Social Networking

Educators' professional learning landscape has shifted greatly with web-based technologies offering the opportunities for on-demand, 24/7 learning delivered to the palm of the *teacher's* hand (Simonson et al. 2011). With the ease of use of Web 2.0 tools, the explosion of apps, and the growth of social networking, there has been a move by teachers to self-action their professional learning opportunities online (Prestridge and Tondeur 2015; Vu et al. 2014). Issues associated with isolation and cost, which have previously precluded teacher engagement (Cameron et al. 2013), are easily overcome within these virtual spaces. Social networking sites such as Facebook®, Instagram®, Pinterest®, TeacherspayTeachers®, Twitter®, and Google Plus® provide the more common online places to communicate and contribute to a current worldwide topic. Additionally, professional societies use online environments that have the capability to group teachers, provide a space to build a personal profile, discuss and make a repository of resources which are also places teachers are networking.

The move from school-based training to online course work to self-generating on-demand learning shifts the approach from professional development with content delivery to professional learning through the primary practice of actioning teacher's content generation, such that teachers themselves are generating the content through collaboration and independent inquiry. Simply, teachers use their classrooms as sites for investigation from which they explore issues, ideas, problems, questions that arise and share these out through social networks online. In these networks, teachers discuss, extend ideas, make suggestions, and work together. As such, inquiry-based professional learning is grounded in teachers' intentional investigation and reflection on their own practice in light of other teachers' practices, associated theories, knowledge, and the larger educational, social, and political contexts. Online social networks can provide both the space/place and tools to actively communicate, reflect upon, and collaborate with other like-minded teachers as part of facilitated professional development programs, as mentioned above in the online CoP created within a specific online software platform (Zang et al. 2017); or using more common media such as Facebook (Goodyear et al. 2014). These spaces can also support the more organic professional learning activities where teachers are moving in and out of online social media based on their own timely needs and interests (Sumuer et al. 2014).

Research in this area is currently limited but it is an area that provides an abundance of opportunity as teachers themselves are currently exploring how to leverage social networks for their own professional learning. In this field, studies focus on varying elements such as Webinars as opportunities for authentic dialogue which network teachers worldwide (Albers et al. 2013); models of professional development online such as programs designed based on teacher-generated content and requirements for facilitated engagement (Prestridge 2016); the difference between the uptake of formal and informal professional learning activities (Petras et al. 2012); the alignment between networking and the conceptualization of learning-as-social participation (Niesz 2007); and ethical issues in social networks (Foulger et al. 2009). What is interesting and needs more research to understand will be the ways and whys that direct how teachers engage in these social networks, such as moving in/out and serendipitously between social media; the reasons for inactive, lurker activity compared to active participation; consumer culture verses contributing culture where teachers prefer to take ideas and resources rather than contribute their own; how an online presence or teacher profiling is created and contributes to a sense of connectedness and presence; the list goes on. What is evident in this field is that professional development in these kinds of social media–supported spaces requires the philosophical approach described earlier as professional learning. Thus, professional development through social media needs to be designed so that activities are self-directed by teachers based on internalized goals to fulfil their needs and interests as part of, and in alignment with, the greater grouping or community.

Final Words

It has been long established that technology integration in K-12 classrooms is usually overly teacher-centered and tends to replicate traditional pedagogies that supplement student learning (Al-Zaidiyeen et al. 2010; Ertmer and Ottenbreit-Leftwich 2013; Prestridge 2012, 2017; Tsai and Chai 2012). These classroom practices have been historically replicated in teacher professional development models that provide training on ICTs rather than pedagogical reform. It is the ‘chicken before the egg’ syndrome: ICT practices are being modelled in professional development approaches. Moving toward the use of ICT to support students’ engagement in higher-order thinking means moving toward models of teacher professional development that advocate for and embrace critical thinking paradigms. Whether it be considered professional development or professional learning that involves teachers working in teams, through CoPs, blended or solely face-to-face or by using social media, better professional outcomes are enabled when teachers collaborate. Teachers collaborating and teachers as drivers of their professional experiences has been the resounding message of this chapter.

In closing, we live in an ever-changing world. This world is getting smaller with the advent of technologies. Teachers are using ICT both as instructional devices and to support students to use them as learning devices. Teachers worldwide can (while some already are) share, collaborate, challenge, and create new knowledge and understandings that influence what they do with their students in classrooms. However, for this to be the status quo, some things need to change. Fundamental shifts need to be made with regard to teachers as pedagogical experts influencing their professional learning as active members of a larger professional culture that ensures the continual renewal of self-understanding and a requirement for contribution to the pool of knowledge moving forward. Teachers are the deliverers of educational reform, as it is "education" that they co-construct that is most powerful.

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Connecting Research and Practice: Teacher Inquiry and Design-Based Research 29

Susan McKenney and Natalie Pareja Roblin

Contents

Abstract

The relationship between research and practice presents challenges across the field of education including in the use of Information and Communication Technology (ICT). Educators in the field often see research as being divorced from the reality of their daily practice. Teacher inquiry and design-based research offer opportunities to engage practitioners in research by making more direct links to their own practice. This chapter briefly introduces the broad range of opportunities and hurdles posed by technology integration in K-12 education, and then describes three crucial dimensions that influence the way educators perceive

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and handle technology use over time; these relate to teacher will, skill, and surrounding infrastructure. Thereafter, ways in which research-practice interactions might contribute to developing these dimensions are discussed, with specific attention to two kinds of interactions: teacher inquiry and design-based research. In addition to offering examples throughout the chapter, attention is also given to the fact that these two approaches used together can have productive synergies. The chapter concludes by pointing to new developments that hold potential implications for future work related to technology integration supported by teacher inquiry, or design-based research, or both.

Keywords
Teacher inquiry · Design-based research · Technology integration · Research-practice interactions

Introduction

Technology Integration: Opportunities and Hurdles

Advances in technology provide new opportunities for improving educational practice, but making effective use of them presents many challenges to K-12 teachers. For example, Information and Communication Technology (ICT) has the potential to help educators better meet the needs of diverse learners through customization, differentiation, and (more equitable) access to information. Additionally, ICT can enhance teaching and learning experiences by making the learning of abstract concepts more concrete through visualizations or simulations or by combining technological media with other modalities such as hands-on work (McElhaney et al. 2015). Finally, ICT can render some aspects of teaching and learning more efficient by allowing re-creation of aspects of the real world that may be too difficult or time consuming to implement in conventional classrooms (e.g., rerunning a video takes less time than recreating a demonstration) or by facilitating learner tasks (e.g., by providing automated feedback or smart scaffolds).

As with most educational media over the last 100 years, realizing the added value of ICT, as opposed to mere substitution of analog resources by digital ones, is not easy (Christensen and Knezek 2002). This is due, in part, to the rapid pace of technological advances. Continuous developments in learning technologies make it difficult for educators to stay abreast of options and make informed choices, since options are constantly changing (McKenney 2013). It also means that investments into ICT and ICT use are regularly under threat of becoming obsolete, since operating systems and hardware requirements are changing so quickly. Further, harnessing the potential of ICT within the constraints of daily classroom practice requires understanding of cultural values that affect ICT use (Srite and Karahanna 2006). In fact, establishing norms regarding socially acceptable use of technology constitutes a struggle which plagues our offices, restaurants, and living rooms, just as much as it does our classrooms. Finally, there is a huge gap between what is technically possible and what school ICT infrastructures can handle. Technical woes faced by teachers range widely from firewall barriers, to bandwidth limitations, to outdated hardware which lacks the processing power to handle large files or new media (Zhao et al. 2002).

The Importance of Will, Skill, and Infrastructure

Despite newspaper headlines and profits made through booming industries, the challenges of technology integration hurdles are not likely to be swept away by radical innovation, since it has long been recognized that radical change is not feasible in education (Berliner 2002). Rather, as educators learn and develop while on-the-job, they make incremental progress toward productive use of ICT. Incremental innovation targeted at what teachers and schools can realistically implement with sustainable amounts of guidance or collaboration has been referred to as innovation within the zone of proximal implementation (McKenney 2013). Building on previous work (Knezek et al. 2003; Knezek and Christensen 2016; McKenney 2017), we examine three crucial dimensions that influence the way educators perceive and handle innovation over time: will, skill, and infrastructure. Here we devote specific attention to implications for technology integration in K-12 schools.

Each of the will, skill, and infrastructure dimensions is necessary for productive technology integration in schools. For the purposes of this chapter, the term *will* broadly encompasses affective aspects that have been shown to influence how teachers perceive and handle technology use over time. These aspects include teacher self-efficacy (Lee and Tsai 2010) and confidence (Ertmer and Ottenbreit-Leftwich 2010), willingness (Baylor and Ritchie 2002) and commitment (Hennessy et al. 2005), as well as attitudes and beliefs (Ertmer et al. 2014; Ottenbreit-Leftwich et al. 2010; Tondeur et al. 2017). This dimension is crucial for technology integration because it is the gateway through which teachers consider the relationship between their own practices and the affordances of technology, and it typically mediates their professional experimentation. The term *skill* refers to teacher professional competencies including the knowledge that underpins them. These professional competencies include pedagogical practices and routines as well as the technological pedagogical content knowledge (Mishra and Koehler 2006) and classroom management and orchestration (Dillenbourg 2013), which enable the enactment of those techniques. Finally, the term *infrastructure* refers to the human and material resources that are known to foster or inhibit teacher technology integration efforts (Zhao et al. 2002). These resources include the ICT hardware and software present in the learning environment, the curricula, books, and other (digital or analog) educational resources (Lim et al. 2013), as well as the human resources readily available in terms of leadership, capacity, and support (Staples et al. 2005). This dimension provides regularization and sustainability; without it, only the zealous few are likely to initiate or sustain technology integration. Successful technology integration in schools attends to the will, skill, and infrastructure dimensions collectively.

It should be noted that these three dimensions influence and are influenced by the others. For example, frustrations with hardware (infrastructure) can have negative influence on attitude (will), or observation of learning gain based on classroom use (skill) can have positive influence on beliefs (will). While each plays a crucial role in how educators perceive and handle technology use over time, it may not be feasible to invest in comprehensively developing all dimensions simultaneously. Rather, incremental investment that also attends to connections between these dimensions may be more realistic.

How Can Research-Practice Interactions Help?

While there are many ways for practitioners to develop the will, skill, and infrastructure needed for technology integration, interactions around classroom research can be particularly fruitful in this regard. It should be noted that research-practice interactions influence the processes of research and practice as well as the roles and expertise of researchers and practitioners. In line with the definition of Broekkamp and van Hout-Wolters (2007), the *process of research* in this instance is regarded as the systematic development of knowledge of education and *the process of practice* as the activity of those that are directly involved in teaching in educational institutions, determination of local and central educational policies, and development of educational tools. Accordingly, the term *practitioners* refers to teachers, school leaders, educational consultants, instructional coaches, or those who design curriculum, assessments, or professional development. Finally, the term *researchers* indicates those who, informed by state-of-the-art scholarship in the field, conduct scientific investigation with the goal of generating new knowledge to inform the work of others. We note that practitioners may engage in research processes, as is the case with teachers conducting inquiry into their own practice. Further, when practitioners and researchers interact, expertise can be exchanged to the mutual benefit of each.

There are many forms of researcher-practitioner interactions. These interactions can range from indirect relationships, which are typically focused on the extraction of data for researcher-defined purposes, to clinical ones in which the researchers provide services to meet practitioner needs, to more mutualistic ones, in which practitioners and researchers collaboratively set the agenda (Wagner 1997). This last type of interaction can be particularly beneficial for developing the will, skill, and infrastructure to support technology integration in schools, as it facilitates the exchange of expertise. Mutualistic interactions can benefit practitioners by increasing awareness of important advances in educational technology as well as of relevant scholarship, or by creating opportunities to develop and apply new knowledge (Coburn and Penuel 2016). Benefits to researchers are also present, since serving practice is a fundamental goal and collaboration enables that, especially because (i) studies situated in practice bring with them the ecological validity that renders the derived knowledge more useful (McKenney and Reeves 2012) and (ii) regular interactions with practitioners help keep researchers aware of, and sensitized to, the realities and concerns of those regularly working in classrooms (McKenney 2016). The following section discusses two forms of mutualistic research-practice interactions and describes how they can be productive in developing the will, skill, or infrastructure for technology integration in schools.

Mutualistic Research-Practice Interactions

Teacher Inquiry

Teacher Inquiry Characteristics

Teacher inquiry can be generally defined as the systematic and intentional study of educational practice carried out by teachers in their own classrooms (Cochran-Smith and Lytle 1993). It is used as an umbrella term to refer to diverse forms of educational research where teachers play a central role, such as action research (e.g., Kemmis and Wilkinson 1998), teacher research (e.g., Cochran-Smith and Lytle 2009), self-study research (e.g., Loughran 2004), communities of inquiry (e.g., Cassidy et al. 2008), and lesson study (e.g., Lewis et al. 2006) among others.

Despite the diversity of forms and underlying epistemological principles, most approaches to teacher inquiry share several key features (cf. Cochran-Smith and Lytle 2009). First, teachers are viewed as knowers and agents of educational change, rather than as mere consumers of research produced by others (Cochran-Smith and Lytle 1999). Second, and in line with the expanded view of teachers' roles, teachers take on a researcher role, thereby becoming both subjects and agents of inquiry. Third, because teachers conduct research in the context of their own classrooms, problems experienced in their daily work become the focus of study. Fourth, the knowledge generated by teacher inquiry is primarily intended for application and use within the local context in which it is developed; however, the unique insights generated by teacher inquiry may also inform practice and policy beyond local contexts (Cochran-Smith and Lytle 1993). Finally, teacher inquiry is a collaborative enterprise, typically involving partnerships between practitioners and university researchers (Somekh 2006).

Research-Practice Interactions in Teacher Inquiry: Affordances and Challenges

Teacher inquiry can potentially make a strong contribution to create closer ties between educational research and practice. Next, we discuss how mutualistic research-practice interactions can be facilitated by teacher inquiry, examining both the affordances and challenges of this approach.

Whereas the duration, complexity, and rigor of the research process may differ, teacher inquiry generally encompasses iterative cycles consisting of the following phases: (i) identifying a problem specific to the local context of participating teachers; (ii) planning and implementing instructional solutions; and (iii) using evidence to drive reflection, analysis, and next steps (Ermeling 2010; Kemmis and Wilkinson 1998). It is through active teacher engagement in these phases of inquiry, in close collaboration with university researchers, that research-practice interactions materialize, and that teacher inquiry can provide a context for sustained collaboration where the perspectives and expertise of both teachers and academics are brought to bear (Pareja Roblin et al. 2014).

Besides facilitating research-practice interactions, teacher inquiry has been shown to foster teacher learning and the development of a critical stance (Cochran-Smith and Lytle 2009; Hagevik et al. 2012), thereby leading to meaningful changes in teachers' practice (Ermeling 2010). For this reason, teacher inquiry is often viewed as a powerful strategy for professional development (Zeichner and Nofke 2001), which is reflected in its growing adoption across various pre-service and in-service teacher education programs all over the world (e.g., Carter et al. 2016; Dickson 2011; Dobber et al. 2012).

Notwithstanding the opportunities that teacher inquiry offers to facilitate mutualistic research-practice interactions and to foster teacher learning, this form of educational research is not without challenges. One key challenge relates to the development of teachers' research competencies. Teachers are unlikely to have the time needed to develop full and robust understanding of multiple research methods (Berger et al. 2005). Another related challenge pertains to the dissemination of the knowledge generated by teacher inquiry. Although teacher inquiry can (potentially) further our understanding of teaching and learning, it is not always motivated by a need to develop knowledge that could be generalized beyond the local context (Cochran-Smith and Lytle 1993). In fact, research suggests that knowledge generated via teacher inquiry rarely moves beyond local contexts (Enthoven and de Bruijn 2010). Both challenges have motivated criticism about the legitimacy of teacher inquiry as a form of educational research (Zeichner and Nofke 2001). The current move toward Masters level degrees in teacher education across many European countries, together with the growing integration of teacher inquiry in the curriculum of teacher education programs, represents important steps forward in supporting the development of teachers' research competencies and recognizing their role in the generation and dissemination of public knowledge.

Teacher Inquiry Can Help Develop Will, Skill, or Infrastructure for Technology Integration

Mutualistic research-practice interactions featured in teacher inquiry can contribute to the *will*, *skill*, and *infrastructure* needed for productive technology integration in schools. More specifically, teacher inquiry can support the *will* for technology integration by facilitating changes in teachers' beliefs about technology and its relationship to the curriculum. For example, Dawson and Dana (2007) investigated the benefits of integrating teacher inquiry into technology-enhanced field-experiences to help prepare teachers for technology integration. As part of the requirements to fulfil a three-credit, graduate-level course on Educational Technology, prospective teachers engaged in inquiry to systematically study their experiences integrating technology in elementary classrooms. Each prospective teacher had to identify an inquiry question, develop a plan for data collection and analysis, and report findings and conclusions in a paper. A case study of one of the teachers engaged in this program revealed that teacher inquiry led to major conceptual shifts in this teacher's beliefs about teaching in general and teaching with technology in particular.

Teacher inquiry can also help to develop the necessary *skill* for technology integration by expanding teachers' knowledge about the educational uses of technology (Laurillard 2008), and by promoting experimentation with innovative pedagogies supported by technology (Dawson 2006; Saunders and Somekh 2009). The Pedagogies with E-Learning Resources (PELRS) project (Pearson and Somekh 2006; Saunders and Somekh 2009; Somekh and Saunders 2007) is one example of how teacher inquiry might contribute to advance teachers' knowledge for technology use. Led by Manchester Metropolitan University between 2003 and 2009, PELRS sought to develop the necessary knowledge base in schools for using technology to transform students' learning. This was accomplished through a partnership between university researchers, teachers, and school leaders. Teachers engaged in action research with the support of university researchers, playing a leading role in planning learning events, participating in the analysis and interpretation of data, and presenting their work in public fora (Somekh and Saunders 2007). Through teacher engagement in action research, PELRS supported the development of new pedagogical practices that unlocked the affordances that technology can offer for transforming students' learning experiences (Saunders and Somekh 2009). Moreover, PELRS contributed to create the *infrastructure* needed to support technology use through the development of pedagogic frameworks for ICT integration. Collaboratively developed by teacher-researchers and university researchers, these frameworks prompt new ways of thinking about the use of ICT to support teaching and learning.

Design-Based Research

Design-Based Research Characteristics

Design-based research (DBR) is a genre of inquiry in which the design of innovative solutions to problems in educational practice provides the context for scientific investigation, yielding results that can also inform the work of others (DBRC 2003; McKenney and Reeves 2012). The solutions developed through DBR can take various forms, including programs, processes, products, policies – or a combination of these. As with other studies, the scientific understanding derived from DBR may be used to describe, explain, predict, or manipulate educational phenomena.

Educational design research is theoretically oriented, interventionist, collaborative, responsively grounded, and iterative (McKenney and Reeves 2012; van den Akker et al. 2006). DBR is theoretically oriented because it uses existing theoretical insights to frame both research and development, and because it strives to contribute scientific understanding (i.e., produce knowledge that can be of value also outside the specific research setting). Because DBR explicitly aims to make a positive contribution to practice, it is interventionist. DBR requires multiple participants (especially researchers and practitioners) with varied expertise, and therefore is collaborative. The DBR process uses findings from one phase to inform subsequent ones, which makes it responsively grounded. Finally, because DBR anticipates and involves multiple cycles of inquiry and action, it is iterative. Design-based research thus features research-practice interactions through their *processes* as well as the *roles and expertise* of those involved. Studies that additionally focus on *multiple stakeholders' perspectives*, develop theory related to *implementation*, and work to develop *capacity for sustaining change* are better characterized as design-based implementation research (Penuel et al. 2011).

Research-Practice Interactions in Design-Based Research

Design-based research can be conducted by professionals in research institutes (e.g., universities), educational settings (e.g., schools, training groups), and related institutes (e.g., ministries, industry). Practitioners are inherently involved in educational design research, most often in reactive roles, though sometimes as codesigners and occasionally as researchers (Long and Hall 2015). While rare, practitioners may also function as lead investigators in design studies (Swanwick et al. 2013). Given its aforementioned collaborative nature, interorganizational partnerships in DBR are quite common. The DBR process varies widely depending on the context, goals, stakeholders, and resources available but, in general, three phases are central to the enterprise: analysis and exploration; design and construction; and evaluation and reflection (Bannan-Ritland 2003; McKenney and Reeves 2012). Each DBR project shapes these phases differently but through them the dual outputs of an intervention (which gradually matures throughout the project) and scientific understanding are pursued.

During each phase (analysis and design, design and construction, evaluation and reflection), attention is given to implementation and spread. During earlier stages, implementation and spread are considered by studying the problems to be solved and their root causes, as well as exploring inspiring examples, organizational strengths, and budding opportunities that might contribute to a solution. As a solution begins to mature, practitioners and researchers often take on additional roles, for example, those of organizers, consultants, designers, and developers, in working toward solutions. Later stages of DBR feature (especially formative) evaluation, often conducted in the target setting, with the goal of improving the designed solution and optimizing it for implementation.

Due to its scope and complexity, educational design research presents a tremendous challenge (Anderson and Shattuck 2012; McKenney and Reeves 2013). This is because it requires substantial expertise and time. Researchers require access to, and fluency in, multiple areas of literature (e.g., educational innovation, research methods, and the topic of inquiry) as well as a diverse skill set (e.g., educational researcher, intervention designer, implementation facilitator) (McKenney 2016). Given the nature of the work involved, DBR tends to be long term, spanning months and years, rather than days and weeks (O'Neill 2016). For those not able to devote major portions of their time to the effort (e.g., due to teaching load), the task may be insurmountable. Yet, despite the challenges, studies are beginning to show that the potential benefits to both immediate practice and scientific understanding can be gained (Plomp and Nieveen 2014).

Design-Based Research Can Help Develop Will, Skill, or Infrastructure for Technology Integration

Powerful collaborations in multidisciplinary teams have been central to successful DBR studies that focused on technology integration, as the following three examples illustrate. Related to *will*, Kim et al. (2013) describe their multiyear project which aimed to improve the use of technology in poorly performing rural K-8 schools. Over the course of 4 years, teachers received (at their choice) technologies, professional development workshops, and technical and pedagogical assistance. In addition to developing understanding about support to teachers, the team also examined how and to what extent the following were related to each other: teachers' beliefs about the nature of knowledge and learning, their beliefs about effective ways of teaching, and their technology integration practices. The study revealed that teacher beliefs, among other factors, influenced their technology integration practices. While some researchers have found that behavioral change can precede changes in beliefs (Guskey 2002), Kim et al. (2013) conclude that changes in beliefs are prerequisites to changes in teacher behavior, that the provision of adequate supports in line with teacher beliefs could improve teacher levels of technology integration, and that this is consistent with other research.

Design-based research can also help develop skills for technology integration. For example, Kafyulilo et al. (2016) describe the design-based research embedded in the creation of a professional development arrangement (including workshops, collaborative design in teams, and cycles of lesson implementation-reflection-redesign) to develop technology integration *knowledge and skills* among science teachers in Tanzania. Different versions of the program were designed and tested to accommodate the differing needs of pre-service and in-service teachers. Based on insights gathered through iterations of design and testing the arrangement, the study produced design guidelines for developing pre- and in-service teachers' technology integration knowledge and skills, as well as empirically based recommendations for practice and policy (Kafyulilo 2013). In addition, teachers participating in this study were able to make science animations using PowerPoint and record videos to use in their teaching. Further, in an impact study conducted with both the pre-service and in-service teachers well after the program concluded, results showed that most pre-service teachers and some in-service teachers retained their technology-using practices (Kafyulilo 2013). Further, this study also connects the knowledge and skills to the surrounding human *infrastructure*. Specifically, it notes that the pre-service teachers felt recognized and supported by the ministry of education and school principals, while many in-service teachers received little recognition or support from management. Therefore, the Kafyulilo study also concludes that these factors are important catalysts for continued use of technology integration practices.

An example of design-based research related to the material *infrastructure* is the multiyear development of Quest Atlantis, a 3D multiplayer virtual environment that helps students construct scientific understanding. Across multiple publications, the design research involved in developing this tool has been described, focusing on characteristics of the tool (Barab et al. 2005), the sociotechnical structures in which they are used (Barab et al. 2007), and an emerging theory of learning during use, referred to as transformational play (Barab et al. 2010).

On the Horizon

As shown in this chapter, teacher inquiry and design-based research offer vehicles for research-practice interactions that can support educators in technology integration, especially through contributions related to teacher will, skill, and surrounding infrastructure. To date, teacher inquiry may have emphasized more will and skill aspects, whereas design-based (implementation) research has seemed to demonstrate a stronger focus on developing the aspects described under infrastructure (McKenney and Reeves 2012; Penuel et al. 2011). Each genre of inquiry offers interaction through research-practice processes, as well as the potential for interactions between individuals, facilitating the exchange of expertise between researchers and practitioners.

Teacher inquiry and design-based research are each valuable in their own right, but recent trends show that, together, they can have productive synergies (Bannan-Ritland and Baek 2008). For example, McKenney and Mor (2015) offer guidelines for tools to support teachers in data-informed educational design, while Dawson et al. (2013) developed an online tool to support teacher action research for technology integration. The trend toward design-based research in which researchers and practitioners collaborate to develop will, skill, and infrastructure for teacher inquiry related to technology integration seems extremely promising. Other new developments that hold potential implications in this area include increased attention for research-practice partnerships (Coburn and Penuel 2016), teacher inquiry to support technology-rich formative assessment (Luckin et al. 2017; Mor et al. 2015), and the use of design-based (implementation) research at scale to offer equitable opportunities for teacher professional development in relation to technology integration (Clark-Wilson et al. 2015).

While no panacea exists, the approaches of teacher inquiry and design-based research offer much to educators wishing to realize the potential added value of ICT. They are especially powerful because they embrace, rather than control for, the dynamic and challenging realities of daily classroom practice. Because of this, familiarity with these approaches seems essential for all researchers and practitioners committed to improving technology integration in today's schools.

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Professional Development for Online and Mobile Learning: Promoting Teachers' Pedagogical Inquiry

30

Evrim Baran

Contents

Abstract

Teachers' successful transformation to online and mobile teaching requires a reexamination of their traditional pedagogies, the content they teach, the student profiles, and the context of learning. Professional development that promotes teachers' pedagogical inquiry is a key to such transformation. Creating online and mobile spaces to enhance professional learning, recent models implement situated, on-demand, anytime, and customized learning opportunities for teachers. This chapter examines how professional development can be delivered

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effectively by looking at strategies to support teachers' effective online and mobile teaching. The following models are illustrated in this chapter with their focus on teacher transformation and teacher change in professional development programs for online and mobile learning: Mentoring, professional learning communities, and design-based learning. Several recommendations are presented to enhance teacher professional development programs for mobile and online learning.

Keywords
Professional development · Mobile learning · Online learning · Pedagogical inquiry

Introduction

The rapid diffusion of technologies in society has created a need to transform the educational landscape (Johnson et al. 2016). Formal and informal education environments are increasingly adopting emerging technologies that encourage re-conceptualization of teaching and learning at all levels. Within the widespread adoption of web-based and mobile tools in society, educators are now looking for ways to provide more flexible learning opportunities to the learners in various contexts. Meanwhile, the advances in learning sciences research provide educators new tools and approaches to foster, sustain, transfer, and measure learning with mobile and online technologies (Bransford et al. 2004). It is now widely accepted that for a change to occur in online and mobile learning environments, teachers' ability to implement reformed practices should be improved (Dede et al. 2009; Kearney and Maher 2013). This effort requires the study of the ways to support teachers' transformation for online and mobile teaching, and the development of necessary evidence-based professional development programs.

Teachers experience changes in their pedagogies as they transition from traditional teaching to mobile and online teaching. Their successful transformation from face-to-face teaching to online and mobile teaching requires a reexamination of their traditional pedagogies, the content they teach, the student profiles, and the context of learning. For example, they need to know the affordances of online and mobile technologies to be able to design learning experiences using these platforms (Kearney and Maher 2013). Adopting student-centered approaches, teachers need to give learners more control in their actions (e.g., promoting learner reflections, self-directed learning) in online and mobile learning environments (Means et al. 2009). Most importantly, they need to hold positive attitudes and beliefs towards teaching in online and mobile learning environments. Professional development is key to successful transformation. While earlier forms of professional development focused heavily on stand-alone courses and workshops, recent research suggests creating online and mobile spaces to enhance teachers' professional learning (Prestridge and Tondeur 2015). Professional development programs that utilize the affordances of mobile and online platforms can enhance teachers' situated, on-demand, anytime, and customized learning (Prestridge and Tondeur 2015). This chapter examines how such professional development can be delivered effectively by looking at strategies to support teachers' effective online and mobile teaching.

Supporting Teachers' Transformation for Online Teaching

The growing interest in online learning challenges educational institutions to rethink their cultural, academic, organizational, and pedagogical structures in adapting to a new culture of teaching and learning (Howell et al. 2004). While educators and organizations around the world are more involved in online learning, growth in teacher involvement and acceptance has been slow, accompanied by limited change in pedagogies (Natriello 2005). Research has identified several reasons why there is still limited understanding about fostering higher-order thinking in online classrooms. The most important reason is the tendency to carry traditional educational practices to the online environment (Kreber and Kanuka 2006). Teachers often rely on their traditional pedagogical approaches formed over the years of developing expertise in the face-to-face classrooms (Kreber and Kanuka 2006). Having little (if any) prior experience of teaching in online environments, teachers tend to transfer traditional approaches to these classrooms and continue ineffective approaches that are already present in traditional classrooms (Roy and Boboc 2016). Most importantly, when technology integration is present, it is still implemented at a low-level with teacher-centered practices rather than high-level use with student-centered activities, such as problem solving and inquiry-based learning (Ertmer 2005). Research calls for a need to shift from teacher-centered to learner-centered pedagogy in online learning environments as teachers coordinate and regulate students' active learning (Baran and Correia 2009). Professional development programs for online teaching should integrate models for student-centered pedagogies in online learning environments so that online teachers design and implement such pedagogies in their teaching.

Moving from face-to-face to an online teaching environment, teachers experience changes in the way they structure and plan their courses, organize course management, establish teacher presence, monitor student learning, and connect to their students (Baran et al. 2013). These changes require the development of unique online pedagogies for online teaching (Kreber and Kanuka 2006; Natriello 2005). Effective online teachers have common characteristics that guide the implementation of these pedagogies. They create the course content with their extensive knowledge base about the subject matter, design and structure the online courses carefully, work on knowing and understanding their students' profiles and needs, use measures to enhance student-student and student-teacher relationships, guide and scaffold student learning using online tools, evaluate students' learning and progress, and establish teacher presence using various tools (Baran et al. 2013). Effective online teachers have a more "extensive, complex, and flexible repertoire of concepts of teaching effectiveness, they hold more developed concepts of self-efficacy, they use wider range of criteria for self-evaluation, and they draw upon almost twice as many strategies for enhancing student learning" (Hativa et al. 2001, p. 700). Professional development programs for online teachers should integrate these effective practices to teachers' learning and address teacher transformation as well as teachers' shifting roles in online and mobile learning environments.

Professional development approaches need to address teachers' transformational learning for effective online teaching, while empowering them, promoting their critical reflection, and integrating technology into pedagogical inquiry (Baran et al. 2011). Professional development approaches can integrate teacher collaboration, content creation, sharing, and networked learning into online teacher learning platforms (Prestridge 2016). Other models may include action research projects that teachers carry in online platforms where they investigate an online learning problem, reflect on it, and engage in constructive dialogue with their colleagues (Prestridge and Tondeur 2015). Teachers' learning activities can involve critical reflection on their examination of personal beliefs and assumptions towards online learning, and support programs can help teachers engage in a dialogue about solving problems and making decisions regarding the design and implementation of online courses. Because several actors play critical roles in online course design, professional development programs can connect instructional designers, administrators, and technology experts with online teachers and help sustain communities of practices around successful online teaching (Holmes and Kozlowski 2015).

Professional Development for Mobile Learning

Mobile technologies have become more pervasive, affordable, and available among a wide range of age groups (Traxler and Kukulska-Hulme 2016). Their affordances for learning have been widely acknowledged and include mobility, access, immediacy, situativity, ubiquity, convenience, and contextuality (Kearney et al. 2012; Kukulska-Hulme et al. 2009; Sharples et al. 2009). Mobile learning has the potential to transform students' learning across multiple physical, conceptual, and social spaces. Teacher support and training regarding its effective use plays a critical role in mobile tools' integration into today's learning environments. Teachers need training and support regarding the advantages, challenges, and exemplary practices of mobile learning to make informed decisions in their teaching settings (Kukulska-Hulme et al. 2009; Schuck et al. 2013).

The definitions of mobile learning include common characterizations such as portability, authenticity, contextuality, social interactivity, and personalization (Kearney et al. 2012; Sharples et al. 2009; Stanton and Ophoff 2013; Traxler 2007). These concepts can be integrated into teacher professional development programs to promote teachers' meaningful learning with mobile tools. For example, the portability feature would allow teachers to receive and send information from different places, rather than a fixed professional development location. Teacher professional development programs could also take advantage of the authenticity feature by supporting teachers' authentic learning across contexts. Real time teacher observation and reflection activities can be conducted with mobile tools' different features such as tagging, video recording, collecting, sharing, and processing multiple forms of data (Çelik et al. 2018). Another feature, social interactivity, could help the formation of teacher networks and connect teachers with experts, mentors, peers, and their students. With advances in mobile tools' social features (e.g., social networking), teachers could engage in constructive and social learning processes (Traxler 2016). Finally, the personalization feature would help customize scaffolding based on teachers' learning paths (Klopfer et al. 2002). Teachers can control the pace and time of their learning and their learning activities can be tailored to their needs and environment with mobile devices' context-awareness features (Kearney et al. 2012).

Several strategies can be integrated into the professional development programs on mobile teaching, including: hands-on explorations of mobile technologies, developing mobile lesson plans, microteaching mobile lessons, enacting mobile lessons in classrooms, reflecting on mobile lessons, planning mobilized curriculum, and attending to communities of practice (e.g., Ekanayake and Wishart 2015; Mahruf et al. 2010). Professional development strategies can use mobile learning pedagogies to promote teacher collaboration and peer-feedback, allow reflection on teaching, help share classroom practice, and assess performance (Baran 2014). Teachers' understanding of the affordances of mobile learning can also be enhanced by modeling such pedagogies in professional development programs, helping teachers explore their content areas with mobile tools, connecting teachers with communities of practice through mobile tools, creating personalized learning experiences, integrating alternative assessment techniques to the professional development programs, and designing learning experiences using mobile tools for collaboration and teamwork (Baran 2014; Cushing 2011; Husbye and Elsener 2013; Kearney and Maher 2013; Kommers 2009; Shotsberger 2003).

Mobile tools' emerging affordances can transform teacher professional development practices with new features that provide mobility and learning across different contexts, experiences in simulated and augmented classroom environments, and connectivity to different communities and audiences (Fritschi and Wolf 2012). With more tech-savvy teachers entering teacher education programs, professional development programs can meet their learning needs by integrating these platforms into professional development environments and modeling good practices. For example, teachers can investigate the use of mobile devices for enhancing classroom practices. These practices include: connecting teachers with mentors and teacher educators via mobile tools to share feedback on their teaching (Cushing 2011), promoting their reflections through microblogging and e-journaling on mobile platforms (Schuck et al. 2013; Shotsberger 2003), providing real-time coaching (Kommers 2009), and implementing self and peer-assessment practices (Chen 2010). When teachers experience mobile tool integration in their professional development programs, they may begin to use such tools in their own teaching practices (Husbye and Elsener 2013). Such exemplary uses can enhance teachers' self-efficacy and attitudes towards integrating mobile learning pedagogies in their future classrooms (Burton et al. 2011; Price et al. 2014).

With a focus on mobility of learning, learner, and technology, Schuck et al. (2017) used the "third space" metaphor to illustrate learning across diverse contexts that is facilitated by mobile learning. The third space metaphor is useful in rethinking teacher learning that happens in different dimensions, such as formal, informal, virtual, public, asynchronous, global, and local contexts. The emergence of new mobile features holds promise for examining contextualized, authentic, situated, personalized, and collaborative teacher learning environments (Burden and Kearney 2016). Professional learning communities, for example, can be formed via mobile learning platforms to immerse teachers in the pedagogical inquiry while sharing their stories with other group members, giving feedback to each other, sharing expertise, and evaluating teaching practices (Schuck et al. 2013). Such investigations of teacher learning and education would contribute to discussions on future teacher competencies and necessary conditions for teacher preparation. The effective design of professional development settings for mobile learning requires concentrated effort in meeting the challenges, such as limited support, technical difficulties, accessibility issues, limited experience, and lack of curricular connections. To date there is limited literature about strategies for teacher education programs designed specifically with mobile learning pedagogies and theoretical frameworks (Baran 2014). Recent research has emphasized the barriers and challenges teachers face while using mobile tools for teaching and learning (Burden and Hopkins 2017) and developed mobile learning scenarios for teacher education (Burden and Kearney 2016). Future research should investigate professional development models specifically designed for mobile learning.

Professional Development Strategies

Challenges were noted previously in this chapter regarding teachers' slow transformation of pedagogies with technologies in their classrooms such as lack of time, limited resources and technology infrastructure, and lack of support (Al-Senaidi et al. 2009; Xu and Meyer 2007). Yet, a range of professional development and support programs (e.g., workshops, stand-alone courses) implemented to meet these challenges have had limited impact on teachers' adoption of online and mobile technologies in their classrooms, because they failed to answer teachers' unique needs in their authentic contexts with overemphasis on teaching about technology (Koehler et al. 2004). Current trends favor adopting professional development models that address teachers' unique needs and goals and include peer-learning and learning by doing activities within learning communities (Ertmer 2005; Georgina and Hosford 2009). The following models will be illustrated in this chapter with their focus on teacher transformation and teacher change in professional development programs for online and mobile learning: mentoring, professional learning communities, and design-based learning.

Mentoring

Professional development programs need to target teachers' individual needs and provide them opportunities to reflect on their existing knowledge, concerns, and practices and immerse them in collaborative learning activities (Ng 2015). As a possible solution, mentoring programs can be integrated into teacher learning practices to provide customized, contextualized, and timely solutions to teachers' needs regarding the transformation of their pedagogical practices with online and mobile technologies.

Mentoring has traditionally been considered as a relationship intended to develop the skill and knowledge of others and influence personal and organizational development (de Janasz and Sullivan 2004; Hansford et al. 2004). Mentoring programs aim to provide teachers with one-on-one working opportunities with a mentor to encourage their learning about, and practice of, technology integration. Mentoring approaches have paired students with faculty members, graduate students with online instructors, online faculty members with graduate students, and experienced faculty members with less experienced ones (Baran 2016, Gabriel and Kaufield 2008; Koehler et al. 2004; Larson 2009). The one-on-one working model between a mentor and a mentee revealed several benefits for the participating teachers including increased confidence in using technologies, transformed teaching practices, and enhanced learning communities (Chuang et al. 2003; Gabriel and Kaufield 2008). Academic, professional, pedagogical, and technical benefits were also noted for participating mentors (Baran 2016). Learning community, compatible match, rewards, sustainability, celebration of accomplishments, and technology support are considered as critical elements of technology mentoring programs (Thompson 2008).

Recent research has revealed strategies that are critical to the success of technology mentoring professional development programs: (a) determining needs, (b) exploring technologies' affordances and limitations, (c) scaffolding, (d) sharing feedback, (e) connecting technology, pedagogy, and content, and (f) evaluating outcomes (Baran 2016). Success factors included motivation, meeting challenges, the nature of the mentoring relationship, communication channels, and support (Baran 2016). Mentoring programs can support the adoption of online and mobile technologies into teacher practice by meeting the challenges of traditional professional development models that are disconnected from teachers' actual teaching practices. Considering teachers' needs for immediate support and help, professional development models may target learning new online and mobile technologies, implementing mobile and online pedagogies, sharing best practices, providing mentors to the teachers if needed, and supporting learning communities. Acknowledging the mutual learning process for both mentors and mentees, educational institutions can adopt mentoring programs that promote shared responsibility, mutual benefits, accountability, reciprocal learning, and shared vision that contribute to the success of mentoring experiences.

Professional Learning Communities

Teachers' technology adoption is a "complex, inherently social, developmental process" (Straub 2009, p. 641). Professional development programs should go beyond show-and-tell models and focus more on the inclusion of peer and community centered learning that is designed around shared expertise, ongoing dialogue, and pedagogical problem solving in learning communities. Learning communities play critical roles in the adoption of mobile and online technologies. For example, research found that "collegial learning groups were strong enabling actors that contributed to experimentations with technology, cross-fertilization of ideas, problem solving and, continuing dialogues on the topic" (Samarawickrema and Stacey 2007, p. 325). Teachers who belong to both formal and organized social networks and collegial learning groups as well as informal groups adapt better to web-based teaching environments (Baran et al. 2013). Creating learning communities with a focus on peer-observation and peer-evaluation may extend and sustain the conversation regarding effective teaching in mobile and online learning environments (Rovai and Downey 2009). Professional learning communities may also help teachers get support on teaching methods and provide psychological and emotional support regarding the problems experienced with mobile and online teaching (Lee 2001).

Learning communities are critical to teachers' adoption of online and mobile pedagogies in their classrooms as they negotiate practical issues while collaborating and reflecting on their individual work with other teachers and challenge assumptions regarding effective teaching with online and mobile technologies (Zellermayer and Margolin 2005). Teachers' participation in learning communities can help them socially construct their knowledge through peer-observation, peer-evaluation, and informal networks (Samarawickrema and Stacey 2007). Professional development programs can also include collaborative working teams, communities of practice, group discussions, and collegial learning groups. Teacher support and training programs may immerse teachers into community of practice (CoP) environments or professional learning communities (PLC) to promote their conversation regarding the use of mobile and online learning in different contexts. These environments can help teachers share best practices, exemplary applications, challenges, and solutions. Mentor or support systems can also be integrated into these environments (Herro et al. 2013).

Teachers in online and mobile learning environments need to update their technological pedagogical knowledge constantly to adapt to the changing needs of learners. Professional learning communities designed around sharing innovative and best practices can help teachers follow recent developments in their field. The tools integrated into such environments can include online and mobile tools that support teachers' collaboration and create knowledge networks around exemplary mobile and online teaching practices (Gunawardena et al. 2009). These tools may include wikis where teachers reflect on their methods, share feedback and professional thoughts, provide specific and immediate feedback to each other, and construct a professional identity while collaborating with other mobile and online teachers who share similar expertise (Albion 2008; Hutchison and Colwell 2012; Samarawickrema et al. 2010). Teachers' professional learning should be sustained over a period of time (Guskey 2000). Social networking tools can support online and mobile teachers' continuous learning giving them a space for sustained interaction. These networks may promote the way teachers share their stories and encourage them to initiate teamwork and collaboration with other teachers after the professional development programs.

Design-Based Learning

Design of classroom activities, learning experiences, and assessment strategies are common practices in teachers' professional lives. Design activities are used in teacher training programs as a way to actively involve teachers in examining the relationships between and among content, pedagogy, and technology (Koehler et al. 2004). Within professional development contexts, teachers explore solutions to online and mobile technology integration problems within design teams (e.g., Jang and Chen 2010; Koehler et al. 2007). Recent research has identified design-based learning principles that can be used in teacher education and professional development programs to facilitate teachers' understanding of technology integration in action (Baran and Uygun 2016). These principles included brainstorming of design ideas, design of technology-integrated artifacts, examination of design examples, engagement with theoretical knowledge, investigation of information and communication technology (ICT) tools, reflection on design experiences, applying design in authentic settings, and collaboration within design teams (Baran and Uygun 2016). Professional development programs may integrate such design activities into their models and encourage teachers' engagement within contextual, situated, and authentic learning design experiences regarding the use of mobile and online technologies in their unique contexts. Design-based learning activities give teachers active roles in redefining and solving problems, examining learners' needs, and exploring the affordances of mobile and online technologies.

When teachers are engaged in design-based learning activities, they present solutions to ill-structured educational situations within online and mobile learning environments. Working on authentic design challenges, teachers can explore the connections between their content, pedagogical approaches, and the affordances of mobile or online technologies. Teachers can work together and develop solutions through their interactions with other design team members. This kind of collaboration helps design team members engage in a joint discourse on effective mobile and online technology integration (Baran and Uygun 2016). Once teachers design these artifacts within teams, they may then apply their design in their authentic contexts and bring their teaching experiences back to the design conversation to participate in a collaborative group reflection process. Reflecting on their mobile and online learning design experiences, teachers can identify difficulties they encountered and conduct self- and peer-assessment of their own learning and development (Angeli and Valanides 2009; Mouza et al. 2014). Professional development programs can use design-based learning to promote teacher agency and dialogue as teachers explore the potentials of emerging pedagogies for mobile and online teaching.

Recommendations

Recent conceptualizations of teacher professional development focus more on the study of teacher learning from the situative perspective (Borko 2004; Cherrington 2017), which examines teacher learning in individual and social learning contexts including teacher practice within classrooms, communities, and professional development courses and programs (Borko 2004). In this respect, four key elements are identified: "(a) The professional development program, (b) teachers as the learners in the system, (c) the facilitators who guide teacher learning, and the (d) professional development context" (Borko 2004, p. 4). Putting teacher change to the center, teacher professional development for online and mobile learning environments can include these elements to help teachers' transformation for successful online and mobile teaching. A professional development model that focuses on teacher learning and new findings of the learning sciences would be effective in transforming teachers' online and mobile teaching practices. Several recommendations are presented to enhance teacher professional development programs for mobile and online learning.

Prioritizing Teachers' Individual Needs

The quality of online and mobile learning environments is strongly correlated with how the professional development approaches respond to teachers' needs, interests, and beliefs about learning. These needs should be addressed from the orientation phase when teachers are prepared to teach in online and mobile learning environments until the implementation and evaluation phases when they are supported through various channels. Teachers need to be equipped with information about the institutional culture, policies and procedures, online and mobile student characteristics and needs, online and mobile pedagogies that they can employ in their particular teaching contexts, recognition methods for quality work, and ways to develop a sense of collegial spirit among the online and mobile teaching stakeholders (Rovai and Downey 2009). Prioritizing teachers' individual needs and targeting professional development programs to their concerns, motivations, and contexts would enhance effective adoption of online and mobile technologies into learning environments.

Providing Support at the Teaching, Community, and Organizational Levels

Professional development models should "handle multiple personal aspects – cognitive, affective, and contextual" (Straub 2009, p. 642), as well as organizational aspects such as support at the teaching, community, and organizational levels (Baran and Correia 2014). Professional development models that consider support at these levels are critical to teachers' acceptance of, and participation in, online and mobile learning environments. Successful teaching in online and mobile learning environments is considered as the result of the complex interplay between personal, pedagogical, contextual, and organizational factors within education institutions. Therefore, by recognizing the importance of supporting teachers for teaching at various levels (e.g., technical, pedagogical, organizational), a holistic professional development approach is recommended (Baran and Correia 2014). In the holistic approach, the relationships between the community, teachers, and the organization would be considered and the support programs would follow an integrated structure to promote effective mobile and online teaching.

The support and recognition at the organization level were stated as the critical motivational factors of teachers' commitment, sustained interest, and participation in online teaching (Cook et al. 2009). When teachers see online and mobile learning as academically respected, rewarded, accessible, and flexible within their organizational culture, they will be more motivated and confident to teach within online and mobile learning environments. A positive organizational culture towards mobile and online learning would motivate and sustain teachers' participation.

Promoting Pedagogical Inquiry with Mobile and Online Technologies

Professional development programs that target successful mobile and online teaching need to support teachers' pedagogical inquiry as they reflect on the affordances of mobile and online technologies, the pedagogical strategies in these platforms, content transformations, and student learning in their authentic teaching contexts. Professional development programs can target the program and support content to each teacher's individual needs and competencies. Rather than having a solely technological focus, programs can help teachers transform their existing pedagogical methods to these platforms and explore new pedagogical potentials of mobile and online technologies, restructure their content within mobile and online environments, and examine student perspectives and learning within these platforms. Pedagogical inquiry is a key element in professional development and support programs that address teacher transformation. Transformative ICT professional development (Prestridge 2010) is one example that can be used to enhance teachers' online and mobile learning practices. Putting reflective process at the center, the model includes three professional learning elements: Investigation, reflection, and constructive dialogue (Prestridge 2010). For example, teachers can investigate new online and mobile learning pedagogies, engage in written and verbal reflections individually and within groups, and participate to the constructive dialogue with colleagues or peers as they critically discuss what is happening in online and mobile learning environments, and stimulate new ideas (Prestridge and Tondeur 2015).

Examining Teachers' Learning with Mobile and Online Technologies

Research on mobile and online learning should investigate teachers' learning with mobile and online technologies. Online and mobile environments hold potentials for enhancing teachers' learning with their new affordances of anytime-anywhere learning. Professional development programs can be supported with online and mobile learning that extend teachers' learning spaces (Burden and Kearney 2016). Mentoring programs, for example, can integrate e-mentoring or mobile-mentoring approaches. Personal learning networks can be established on mobile and online platforms to support knowledge exchange between teachers. Other advantages of mobile and online tools can be integrated into teacher learning environments to extend the time and space for learning (Kearney et al. 2012). For example, recent affordances for mobile tools (e.g., location awareness, augmented reality) can be used to create personalized, situated, contextualized, and authentic teacher learning settings.

Ensuring the Continuity and Sustainability of Teacher Learning

Teachers' successful transformation to online and mobile learning environments requires a sustained and systematic effort on implementing professional learning models. Professional development programs need to take measures to sustain the continuity of teacher learning (Dede et al. 2009). Establishing collegial learning networks, mentoring programs, and allocating resources to measure and track teacher learning over time would contribute to the long-term impact of these professional development models. Creating communities of practice on mobile and online platforms and supporting teacher interaction with the help of these environments could help teachers share best practices, receive immediate help and feedback, and encourage their sense of belonging to a group of like-minded professionals.

Examining the Impact on Student Learning

Professional development programs for mobile and online teaching can integrate data regarding student learning to the design of content and pedagogies of professional learning activities (Fishman et al. 2003). Collaboration with researchers would help design and implement research needed to measure student and teacher learning, and the effectiveness of teaching with online and mobile technologies in different contexts (Mouza 2009). Individual and contextual factors that impact student and teacher learning could also be investigated to gather evidence of the success or not of these programs. Collaborating with other stakeholders is another important success factor in this process. For example, teachers should be in constant communication with instructional designers, instructional and technology support centers, and other related staff to make informed decisions regarding effective use of mobile and online learning environments.

Conclusion

Professional development is a complex process, which requires the study of teachers' learning and transformation of their knowledge, beliefs, and attitudes into practice (Avalos 2011). New approaches to professional development for online and mobile learning shifted the focus from stand-alone teacher development programs to customized, anytime-anywhere, on-demand, and collaborative learning models. Such models grounded on teachers' pedagogical transformation include mentoring, professional learning communities, and design-based learning. Focusing on teachers' pedagogical inquiry, professional development can engage teachers in reflection, problem solving, and professional dialogue about teaching in online and mobile learning environments (Prestridge 2016). The field of research on professional development for online and mobile learning is relatively young, and literature needs more robust research on the impact of programs on online students' learning. Programs can benefit from research on newer conceptualizations of teacher knowledge required for effective teaching in mobile and online environments.

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Section VI

The Role of Leadership for Information Technology in Education

Section Introduction: The Role of Leadership for Information Technology in Education

31

Sara Dexter

Abstract

Leaders are essential for schools to realize the full potential of how IT can support teaching and learning. This section addresses how IT leaders might use their authority and expertise to foster IT integration through routines and tools to directly influence the role IT plays in schools, and exercise indirect influence by engaging, preparing, and supporting other leaders and teachers to contribute to the IT use in a school.

Keywords

IT Leadership · leadership · School's IT environment

Leadership for IT in education means influencing how school personnel work individually and collectively to use IT as means to support instructional ends. The focus of this section is what IT leaders can do to accomplish this and the conceptual frameworks and knowledge that can undergird those practices. Taken as a whole, this section provides IT leaders with guidance for leadership practices as well as new ways to frame their work.

In the first chapter (▶ Chap. 32, "The Role of Leadership for Information Technology in Education: Systems of Practices"), Dexter describes a *model* for leadership and then relates the empirical support for IT *leadership practices* in terms of the model's three leadership functions: setting directions, developing people, and developing the organization. The research base for IT leadership is not deep, and thus the chapter points to how we can draw upon the broader fields of educational leadership, teacher professional learning, and the organizational sciences

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for further guidance. The subsequent chapters then support how IT leaders can leverage that knowledge base to direct their efforts.

▶ Chapters 33, "A Distributed Leadership Perspective on Information Technologies for Teaching and Learning," and ▶ 34, "Leaders Fostering Teachers' Learning Environments for Technology Integration" describe how distributed leadership and learning design perspectives can guide IT leaders. In ▶ Chap. 33, "A Distributed Leadership Perspective on Information Technologies for Teaching and Learning," Halverson explains how we can consider leadership in terms of *what* tasks are taken on by *whom*, and *how* to intentionally coordinate the work of a group of leaders. He describes IT leadership in terms of its current concerns of infrastructure, policy, pedagogy, and culture and points to the affordances educators and students might realize by instead organizing a vision for IT in terms of the affiliations, expressions, collaborative problem-solving, and circulations characterizing IT usage outside of schools.

In ▶ Chap. 34, "Leaders Fostering Teachers' Learning Environments for Technology Integration," Howard, Curwood, and Scott urge leaders to take a learning design perspective when creating a school's learning culture. They characterize as *sensemaking* teachers' learning to integrate in light of their students, the curriculum, and the school's expectations, goals, and policies for IT, and argue that leaders can enhance it by integrating teachers' independent and informal learning with the typical formal learning experiences.

A series of mini-chapters finish out the section, in which authors present a set of tools and iterative processes IT leaders might use to set directions, build relationships, and develop people, or redesign the organization. Each author presents what the tool or process is, why leaders should use it, and how they might incorporate it into their leadership practices. Together they convey an action research orientation that can help IT leaders continuously improve how IT enhances teaching and learning.

The first three mini-chapters are particularly well suited to support leaders in setting directions. McLeod presents a variety of *frameworks* a leader might use to plan for future vision, goals, or performance expectations, or evaluate those already in place, to thereby bring greater coherence to a school's IT environment. Nash presents *design thinking* as a process that leaders can use to find solutions for persistent IT problems, while keeping the concerns of users front and center. Tschannen-Moran and Hofer describe how the *appreciative inquiry* process helps an organization focus on its strengths as a basis for setting directions for IT.

The last two mini-chapters each describe a process to use in iterative fashion to create new leadership routines that can support continuous progress for developing people and redesigning the organization. Laurillard (▶ Chap. 38, "Teaching as a Design Science: Teachers Building, Testing, and Sharing Pedagogic Ideas") describes a particular approach to engage a school's teachers in thinking of their craft as a *design science,* which complements the Howard et al. chapter. She argues that such an approach allows for the rapid innovation and exchange among teachers that is demanded by IT. Eddy-Spicer then discusses how *improvement science through networked improvement communities* can engage school personnel in iterative cycles of improvement.

The Role of Leadership for Information Technology in Education: Systems of Practices

32

Sara Dexter

Contents

Abstract

Information technology (IT) leadership requires that school leaders understand both how IT specifically serves as a means to an instructional end and how to create the conditions that foster such uses. Driven by leaders' technological leadership content knowledge (TLACK), the system of practices for IT leadership presented here suggests how leaders act to in turn influence teachers' knowledge and practices to foster student learning with IT. It is suggested that this system of practices encompasses setting directions for IT uses, building relationships and developing people to succeed with that vision, and developing the organization to support school personnel's efforts towards those ends.

Keywords

Educational leadership · Distributed leadership

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What Is a System of Practice for Leadership of IT and What Should It Encompass?

Leadership is often defined as exerting influence to facilitate a group to collectively use processes to act together to identify and accomplish shared goals (Leithwood 2012). But information technologies (IT) in and of themselves often do not specify their exact use and are, in fact, often described as "just a tool." Therefore, IT leadership requires that school leaders understand both how IT specifically serves as a means to an instructional end and how to create the conditions that foster such uses.

Although school leadership has been shown to be second only to teaching in its influence on students' learning (Louis et al. 2010), and so its potential contribution to successful IT implementation in schools is clear, there has been a dearth of research on how to effectively lead IT implementation in schools. Recent comprehensive reviews of the literature located only 116 empirical pieces on the topic in ERIC over the last 20 years (Dexter et al. 2017; Dexter and Richardson 2017). A recent review of empirical models of factors influencing teachers' integration (Petko et al. 2018) concluded that school-level influences do indeed matter in terms of teachers' uses but that there is little agreement about their component parts.

Fortunately, the broader field of school leadership offers far more evidence-based research on leadership practices that positively impact students' learning, which provides insights that can be used to guide both practice and research in the field of IT. Indeed, a recent systematic review of key leadership practices identified many overlapping concepts and sources of agreement in the three most comprehensive models of effective school leadership proposed over the past 40 years of empirical work (Hitt and Tucker 2016). The most recent of those models (Leithwood 2012), based upon a large-scale study of how leaders positively impact student learning (Louis et al. 2010), indicates that successful leaders employ practices that set directions, build relationships and develop people, and develop the organization to foster this work. Altogether, the literature in school leadership suggests a cascading model in which learning affects practices, beginning with the leader and moving to teachers and finally students, as illustrated in Fig. 1. As reflected by bullets in Fig. 1 regarding what leaders must know about each step in this process, leaders must not only learn and employ their own effective practices but also ensure that the school as an organization is set up to nurture and support the new directions for teaching that may grow from their and their teachers' learning.

This chapter addresses this series of influences upon student learning as a theory of action I'll discuss here as an IT leaders' *system of leadership practices*. Viewing IT leadership as comprised of sets of practices shifts the emphasis from the competencies or dispositions of individual leaders, such as the principal or head of school, to actions that actually influence IT integration, such as the ways tools, routines, and structures are employed to support teachers' learning and instructional practices. This focus on practices also emphasizes the situated and social context of IT integration, which demands that leaders work with each other and through relationships with teachers to respond flexibly to situations in ways that can be learned and

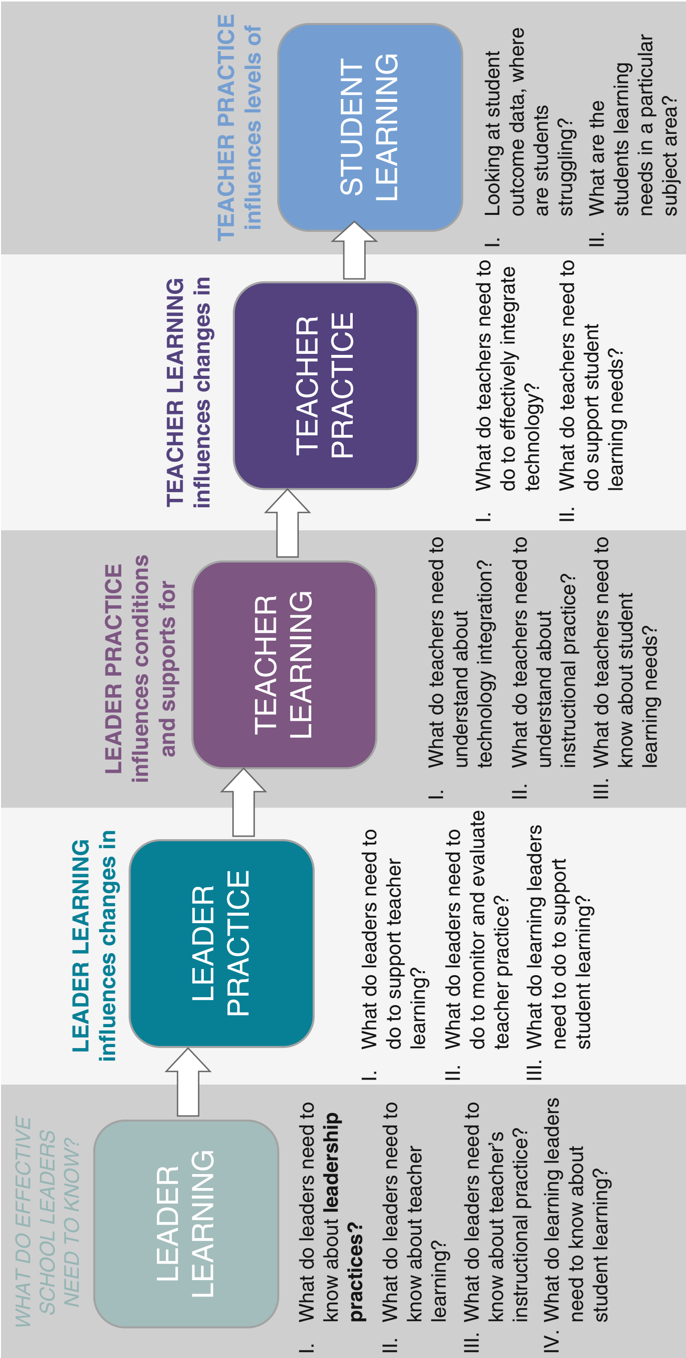

Fig. 1 Theory of action regarding the leadership of IT

improved with effort (Leithwood 2012). A system of practices is a set of actions that are combined to accomplish complex goals, such as the classroom-level integration and school-wide implementation of IT. (See also the discussion of distributed leadership in ▶ Chap. 33, "A Distributed Leadership Perspective on Information Technologies for Teaching and Learning" by Halverson.)

As Fig. 1 illustrates, a system of IT leadership practices encompasses leaders' understanding of and influence upon teachers' knowledge, which in turn influences teachers' own systems of instructional practice and thus students' learning. The knowledge that undergirds leaders' systems of practices includes how to create, appropriate, or marshal the school-level tools, routines, and structures to accomplish this synergy, which has been called *leadership content knowledge* (LCK) (Stein and Nelson 2003) and viewed as analogous to teachers' *pedagogical content knowledge* (PCK) (Shulman 1986). Stein and Nelson define LCK as an administrator's ability to "know strong instruction when they see it, to encourage it when they don't, and to set the conditions for continuous academic learning among their professional staffs" (2003, p. 424). Thus, an effective system of leadership practice for IT is one that builds teachers' knowledge of how technology combines with their PCK to foster students' learning of content, which many refer to as TPACK (Mishra and Koehler 2006), and enables teachers to be able to act on their TPACK by providing them with organizational support to integrate IT and ongoing opportunities to deepen their skills and understanding. Presumably, leaders' technological leadership content knowledge, or T-LCK, would drive their IT leadership. This chapter will refer to the leaders' knowledge that undergirds their system of IT leadership practices as TLACK, to ease pronunciation and thus communicating about this knowledge base for future research on it and to promote it in leadership preparation.

The most recent decade of research in the IT literature has identified a number of leader activities that should be included in a system of practices for the effective leadership of IT and, to a lesser degree, the TLACK needed by leaders to support these practices. To shape this discussion of an effective system of practice for leadership of IT, I have adapted the model provided by Leithwood and colleagues (Leithwood 2012; Louis et al. 2010) and suggest that successful IT leaders' TLACK allows them to carry out three key functions. First, IT leaders must know what strong instruction with IT looks like in order to set directions for its integration; second, they must know how to develop people to cultivate those uses, in order to ensure they are adopted; and finally, they must know how to set the conditions for continuous adult learning in order to redesign the organization to support IT integration.

Leadership Practices That Set Directions for IT

Following this model, setting the direction for IT integration requires that leaders develop a shared vision, create shared meaning around that vision, determine expectations and monitor progress, and continue to communicate the vision and goals. The practices these goals might entail when applied to IT are depicted in Fig. 2.

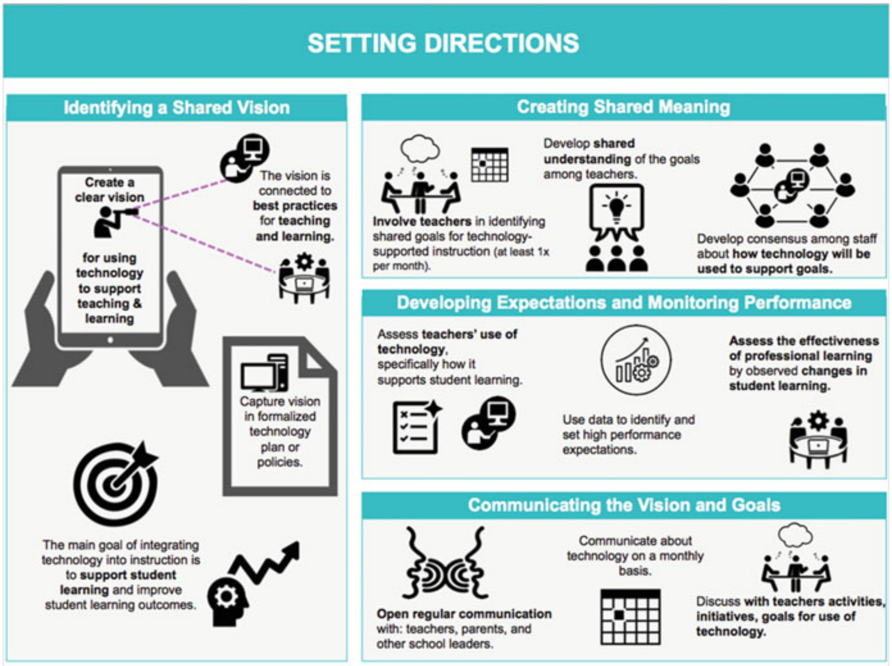

Fig. 2 Leadership practices that set directions for IT integration

Standards and policy discussions of IT and case studies from throughout the world have found that a coherent vision for the use of technology for teaching and learning is an important source of direction for a variety of decisions about staffing and other support related to IT integration (Dexter 2011; Tondeur et al. 2015; Vanderlinde et al. 2010). A leader's vision for IT will determine, for instance, the distribution of IT resources among teachers or students, such as where computer labs are placed, or which grade levels or subject areas receive IT devices. Vision also drives decisions about the nature and number of support personnel and thereby influences the expertise and authority of the leadership. Just as leaders' practices derive from their notion of what they want to accomplish, those in turn shape teachers' understanding of what the IT is to be used for. As researchers have shown, "a shared vision on education influences all decisions made by the schools in the subsequent steps of ICT policy planning," affecting which IT-supported instruction "will be prioritized, how new ICT activities will be implemented in the curriculum, and which concrete policy actions need to be taken" (Vanderlinde et al. 2010, p. 444). (For a discussion of how school leaders might use technology integration, leadership, or organizational support models and frameworks for instructional improvement, see ▶ Chap. 35, "Technology Integration, Leadership, and Organizational Support Frameworks for Instructional Improvement with Information Technology" by McLeod.)

A leader's knowledge base, or TLACK, will obviously influence not only the nature of that vision but the detail and foresight it might encompass (Tondeur et al. 2015;

van Niekerk and Blignaut 2014), including where and how to focus teachers' efforts (Anthony 2012). Such school-level cultural characteristics as innovativeness, supportive leadership, and goal-orientedness have also been shown to be associated with greater IT planning, support, infrastructure, and usage by teachers (Tondeur et al. 2009). At the level of individual school leaders, significant correlations have been found between a principal's transformational leadership style and his or her own computer use (Afshari et al. 2008), and consequently how they serve as a champion for IT and operationalize IT and promote its use to teachers (Dexter 2011). Given that research has shown that the mere presence of technical, collegial, and school-level support for IT and teachers' personal use of IT may not lead to integrating twenty-first century learning and communication activities in the classroom (Rutkowki et al. 2011), leaders' vision does appear to play a moderating role in leveraging investments in IT.

Because vision is an aspirational statement about a long-term effort, the leadership literature has explored the intervening steps and processes through which that vision is brought to fruition by specific, short-term goals shared by the leaders and teachers in a school. The degree to which those goals are shared by the teachers and leaders has been characterized by Petko et al. (2015) in a typology of top-down, bottom-up, complementary (both top-down and bottom-up), and optional. Their investigation found that although the teachers at complementary schools, where "district initiatives, school leadership and teacher involvement go hand in hand (p. 55)," integrated IT slightly less often than those in bottom-up schools, they were more satisfied with their support environment and their students used IT more often because their schools had more IT resources and more teachers involved in learning about IT. This most effective top-down, bottom-up complementary approach thus suggests how leaders might develop expectations, monitor performance, and communicate the vision and goals:

> The ICT adoption typically started out with a small group of teachers that gained increasing support from colleagues as well as from the head of school and school administration. Bottom-up processes were supported as a testbed to orient top-down steps. Both bottom-up and top-down processes were seen as steps going hand-in-hand with each other in order to achieve a common goal. (p. 51)

While the IT leadership research literature on this issue is scant, these results are consistent with case studies that indicate that effective school leaders use local data to make decisions about IT staffing and infrastructure (Vanderlinde et al. 2010) and make regular updates to IT plans as a means of monitoring their progress (Ritzhaupt et al. 2008) and that teachers report principals' encouragement and keeping up with their progress as a positive influence on their ongoing IT integration efforts (Wong et al. 2008).

To summarize, the current IT literature suggests that identifying a clear vision and shared goals is a vital aspect of conveying to teachers that they should integrate IT and why, but it provides little insight into specific practices for communicating expectations and monitoring performance. Case studies and some correlational studies, however, point to how necessary it is for leaders to have adequate TLACK to support those decisions, and the broader fields of educational leadership and teacher education offer more guidance in these areas. See, for example, Laurillard's (▶ Chap. 38, "Teaching as a Design Science: Teachers Building, Testing, and Sharing Pedagogic Ideas") chapter on design sciences in this handbook.

Leadership Practices That Develop People

To help teachers and staff develop the skills and practices necessary for integrating IT, the Leithwood (2012) model suggests leaders must give attention not only to building the knowledge base of teachers as a group but to addressing teachers' individual needs and harnessing their unique strengths, and to serving as models and leading by example. See Fig. 3 for examples of practices related to these needs.

As studies have consistently shown, teachers' learning must be nurtured with ongoing support from staff and opportunities to learn that strengthen both teachers' belief in the value of IT and their pedagogical skills for integrating it into the classroom (e.g., Ertmer and Ottenbreit-Leftwich 2010; Inan and Lowther 2010; Pan and Franklin 2011; see also the section *Professional Learning and Development of Teachers*, in this handbook). According to the broader professional development literature, "leadership plays a key role in supporting and encouraging teachers to implement in the classroom the ideas and strategies they learned in the PD" (Desimone and Garet 2015, p. 252). Although quantitative models studying the

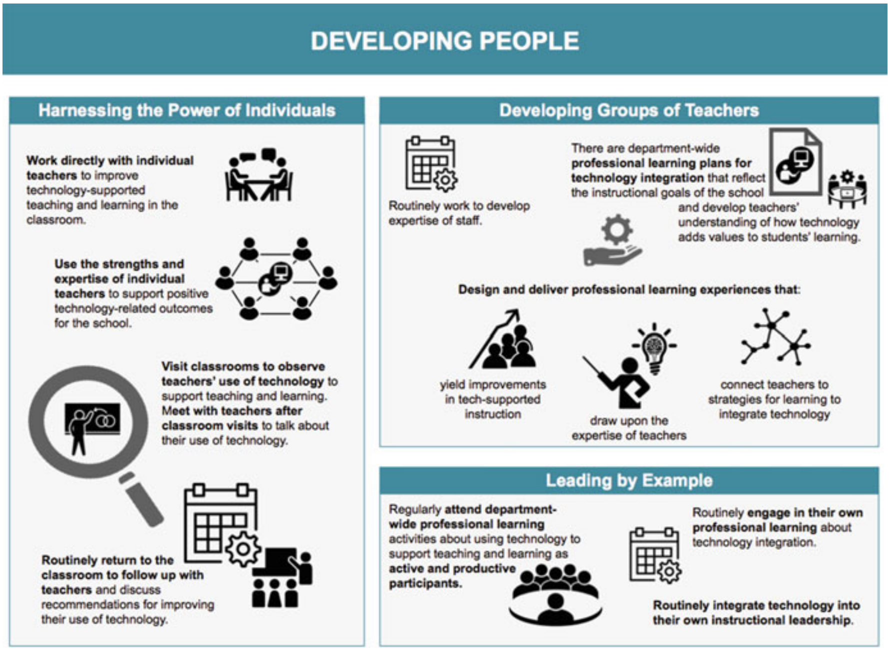

Fig. 3 Leadership practices that develop people

relationship between teachers' learning and their IT integration are few, they all concur that school-level support is essential to success and encompasses leadership practices that set direction, support people, and develop the organization. (For a discussion of these studies, see Petko et al. 2018.)

Studies have identified a number of specific design features – content focus, active learning, coherence, sustained duration, and collective participation – that leaders can employ to create effective learning opportunities for teachers to learn how to integrate IT (Desimone and Garet 2015, p. 252). By identifying specific matrixes of hardware, software, and instructional design strategies for different content areas, for instance, leaders can target the most appropriate tools to introduce to particular groups of teachers (Courduff and Szapkiw 2015). Focusing professional development activities on the highest yield interventions and resources to support student learning within a content area has been shown to maximize teachers' investment of time and resources and increase the likelihood they will find the learning relevant (Jones and Dexter 2014). The literature suggests that formal professional development should be structured to first allow teachers to learn pertinent tools and then to work together on curriculum integration, such as through weeklong residential sessions (Allan et al. 2010), ongoing collaborative design teams (McKenney et al. 2016), long-term collaborations among teachers across a series of workshops (Stevenson et al. 2016), or action research (Schrum and Levin 2013). By making clear the connections between these development activities and ongoing school improvement efforts and by grouping participants into communities of practice to foster ongoing informal collaboration, for example, based upon shared content areas, or grade levels, or common planning time, school leaders can increase the likelihood that teachers are actively engaged with sufficient time to take up and incorporate new instructional practices into their repertoire (Jones and Dexter 2014, 2016).

How leaders staff their support for teachers can also influence the nature and frequency of teachers' opportunities to plan IT-supported instruction. Whereas IT support staff based outside the school tend to provide instructional help for teachers' integration via planned classes, in-school staff can provide teachers with more frequent integration support through co-teaching classes or one-to-one coaching (Dexter et al. 2009). By distributing the leadership and support for IT integration strategically throughout grade levels, content areas, or the school building, leaders can also help develop teacher leaders who can provide school-level guidance for the initiative (Sheppard and Brown 2014) or peer coaching (Stroud et al. 2014).

While studies that focus on teachers' IT integration consistently emphasize the importance of providing sufficient support for professional learning for teachers, studies of leadership for IT frequently draw attention to the similar importance of supporting leaders' learning. Research has demonstrated that leaders' level of knowledge about IT is linked to their ability to address, assist with, manage, direct, and motivate teachers' IT integration (Beytekin 2014; Polizzi 2011; Stuart et al. 2009; van Niekerk and Blignaut 2014). To best support teachers' implementation of IT, according to Gerard et al. (2008, 2010), school leaders themselves need access to inquiry-oriented environments among peers to learn what constitutes strong instruction with IT for a variety of content areas and what impact IT will have on curriculum materials and student assessment.

As indicated in Fig. 3, effective leaders also recognize the importance of acknowledging and providing for individual differences and needs when creating opportunities for teachers to learn how to integrate IT. The pace and content of the learning opportunities teachers need (Robertson et al. 2006; Stroud et al. 2014) have been shown to be affected by variations in their beliefs about the efficacy of IT to improve teaching and learning and attitudes towards IT (Courduff and Szapkiw 2015; Courduff et al. 2016; Stevenson et al. 2016) and by their general experience with or access to IT (Pan and Franklin 2011; Trust et al. 2016). Although the current literature offers few models to help leaders conceptualize how to approach this need to individualize teachers' IT learning in practice, the previously discussed strategy of forming communities of practice among teachers could be purposefully designed to support a variety of different teachers' needs, as could simply providing a range of opportunities and allowing teachers to choose where, what, or how to learn (Svendsen 2016). By differentiating support and beginning with the teachers most ready to start integration efforts, leaders can catalyze changes that ripple across a school or create pilots that develop expertise and develop teacher leaders (Stevenson et al. 2016).

Two additional models for providing differentiated support for teachers' professional learning about IT have recently emerged in the literature. The first is the concept of PLNs, or personal learning networks, which are formed online by teachers' choosing to pursue information and participate with other educators based on their individual interests and needs (Trust et al. 2016). While little is yet known about the impact of PLNs on teaching practices, Trust (2016) found that participants in one network were guided primarily by specific questions they were seeking to answer and assessed, tested, and curated the resources they found there to adapt them to their own implementation context, thus meeting their individual learning needs. IT leaders might introduce teachers to PLNs as a concept and then provide time or other resources to participate in them as another way of meeting teachers' individual professional learning needs.

A second possible model for attending to teachers' differentiated learning needs is the holistic model described by Jones and Dexter (2014, 2016, 2018), in which leaders extend support beyond the formal professional development mode of learning by also facilitating teachers' independent and informal modes of learning with peers. Examples of such leadership activities would include designing information flow among the three modes of learning; modeling and creating a climate for learning exchange and collaboration; and providing digital tools, information sources, or collaboration sites to encourage give-and-take among peers and empower learning. Teachers seamlessly switch among the three modes as needed, and if school leaders recognize, support, and promote learning activities across all three modes, they generate synergies that will meet teachers' individual needs while also aligning teachers' learning efforts with organizational learning goals.

Although IT studies do not yet provide adequate evidence to make definitive claims regarding the impact of leading by example, the third dimension in Fig. 3, the persuasive appeal of leaders "walking the talk" is conceptually sound and has been shown to resonate with educators, as it does in other realms of life. In the case of this teacher, for example, attesting to the motivating role a school leader can play, "The principal played a crucial role and she leads by example in that she integrates ICT in her lessons (Tondeur et al. 2015, p. 575)."

To summarize, the IT literature is emphatic that leaders must support teachers' professional learning but does not yet provide a good deal of guidance as to how to do so. As with setting directions, the evidence base regarding IT leaders' practices for developing people consists primarily of case studies and some correlational studies that describe leaders' actions broadly, without clear indications of the TLACK needed by IT leaders. The broader fields of teacher education and professional learning offer more guidance in these areas, as discussed in this handbook in Howard et al. (▶ Chap. 34, "Leaders Fostering Teachers' Learning Environments for Technology Integration") and Prestridge and Main (▶ Chap. 28, "Teachers as Drivers of Their Professional Learning Through Design Teams, Communities, and Networks").

Leadership Practices That Develop the Organization

To develop the organization's capacity to support teachers' integrating IT, the third set of practices identified in the leadership model employed in this chapter focus on building a collaborative culture within and beyond the school and structuring the organization and allocating resources to encourage such a culture and facilitate integration. Practices supporting these efforts are illustrated in Fig. 4.

A collegial and collaborative climate at a school has been shown to positively mediate teachers' uses of technology (Scribner and Bradley-Levine 2010; Wong et al. 2008) by influencing how teachers make sense of IT and in turn the nature and extent of their uses of it (Cho and Wayman 2014). As noted earlier, this has been shown to be particularly the case when teacher-based "bottom-up" input into IT decision-making is combined with leaders' "top-down" efforts (Petko et al. 2015). Although the current literature in the field provides limited guidance about practices that leaders might use to build a collaborative culture for IT, it suggests that they might establish the means for teachers' exchange through a shared cloud-based server space or web-based apps for collaboration or through regular meetings of committees, communities of practice, or other decision-making structures that include expectations for teacher-to-teacher exchange or requests for input (Dexter 2011; Jones and Dexter 2014, 2018). Another suggested strategy is using shared curriculum development as a means for building collaborative cultures about IT. Leaders, for instance, might use open-ended processes like weekly or monthly scheduled meetings for exchanging ideas of interest within the community of teachers or outcome-oriented processes such as curriculum writing teams with schedules and deliverables (Allan et al. 2010; Wong et al. 2008).

Because the support environment for IT in a school is predictive of its teachers' integration of IT in their teaching practices, numerous researchers have investigated ways school leaders can actively create and coordinate teacher support (e.g., Divaharan and Ping 2010; Inan and Lowther 2010; Petko et al. 2018; Stevenson et al. 2016; van Niekerk and Blignaut 2014; Wong et al. 2008). At a school level, for

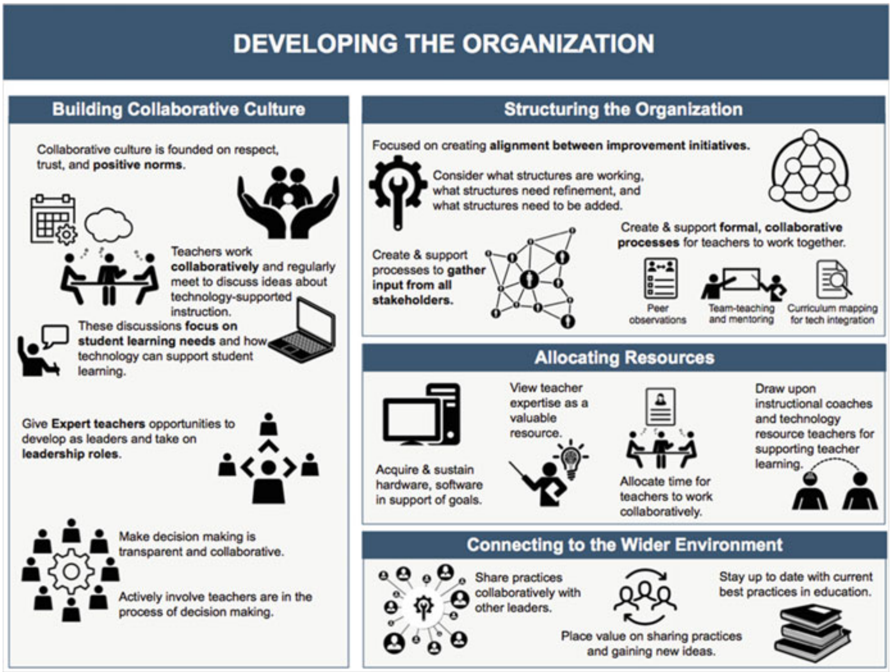

Fig. 4 Leadership practices that develop the organization for IT integration

example, this might include providing instructional support and coaching staff who are then included in the school leadership team's decisions for IT and expected to attend department or team meetings to strategize with teachers about high-yield uses of IT and work one-on-one on classroom implementation. Teacher supervision or evaluation and annual school improvement planning can then include or refer to such uses of IT as part of a school-wide strategy.

While the dimension of allocating resources is often thought of in terms of providing IT hardware and software, the number of IT devices and access to the Internet in schools have so increased that the IT leadership literature published since the last edition of this handbook rarely mentions the lack of IT as a factor limiting teachers' integration. Instead, the recent literature stresses that leaders' responsibility for resource management must include budgeting to ensure the timely repair, refreshing, or updating of IT and distributing it equitably and with regard to school mission and vision (Devolder et al. 2010; Oliver et al. 2012; Levin and Schrum 2013; Vanderlinde et al. 2010). Researchers have also identified acquiring and allocating resources for teacher collaboration time and instructional and technical support staff as critical to successful IT integration (Courduff et al. 2016; Dexter et al. 2009; Vanderlinde et al. 2010). Altogether, the literature regarding leaders' allocation practices has emphasized the importance of creating enabling conditions for integration, removing barriers to implementation, and managing IT as a resource important to achieving the aims of teaching and learning.

Another perspective often employed in leadership studies is the notion of distributed leadership, which recognizes that the ways in which multiple people work together to accomplish work are coordinated through routines and tools (see also ▶ Chap. 33, "A Distributed Leadership Perspective on Information Technologies for Teaching and Learning" by Halverson, in this handbook). By conceptualizing IT support personnel as a part of the group of leaders who are working together to accomplish goals for IT use, leaders can better identify and empower the specific ways they serve as communication linkages among school personnel (Hiltz and Dexter 2012; Sheppard and Brown 2014; Vanderlinde et al. 2010) and better position these support staff members to be viewed as IT leaders by teachers (Dexter et al. 2009; Scribner and Bradley-Levine 2010). Incorporating teacher leaders into the leadership team can further ensure that the classroom context, student learning, and curriculum concerns are considered in the design of the school's IT support system (Robertson et al. 2006; Scribner and Bradley-Levine 2010; Staples et al. 2005; Tondeur et al. 2015).

Currently, the available research provides more support for the importance of IT leaders' efforts to develop the organization through teacher collaboration and aligning the organization and its resources to the IT vision than through connecting to the wider environment, although the latter is occasionally mentioned in passing. Again, the evidence for IT leadership practices that can help develop the organization for IT integration comes primarily from case studies and to a lesser extent correlational studies using survey research. The broader field of educational leadership, however, offers additional guidance in specific approaches related to this domain; see, for instance, the chapters on design thinking (▶ Chap. 36, "Leading Information Technology via Design Thinking" by Nash), appreciative inquiry (▶ Chap. 37, "Appreciative Inquiry: Building on Strengths for Integrating Information Technology in Schools" by Tschannen-Moran and Hofer), and improvement sciences (▶ Chap. 39, "Improvement Science Through Networked Improvement Communities: Leadership of Continuous Improvement with, of, and Through Information Technology" by Eddy-Spicer) in this handbook.

Conclusion

Although most studies of IT integration have focused on how teachers influence its use in the classroom, the few studies that have offered a comprehensive model of influences or examined other contextual factors agree that teachers' IT integration is both directly and indirectly influenced in significant ways by the actions and support of school leaders. Although the IT-specific literature is sparse, theoretical models and empirical studies from the broader field of leadership studies offer useable insights and can help suggest and refine future research in IT integration, particularly quasi-experimental or experimental designs to identify generalizable and causal leadership practices.

Several future directions for research are suggested by the leadership practices and leadership content knowledge models highlighted in this chapter. In particular, these models indicate a need to more clearly understand factors that facilitate leaders' abilities to set directions for IT integration that will improve student learning, to develop teachers' TPACK, and to create the organizational conditions that will support teachers' ongoing success in integrating IT. Furthermore, as noted earlier, the existing literature provides almost no insight into what should constitute IT leaders' knowledge base, or TLACK. Currently, for instance, we know almost nothing about whether TLACK builds inductively from leaders' specific experiences with IT or can be deduced from their broader leadership experience and transferred to their IT leadership. A more comprehensive and deeper understanding of both IT leadership practices and the TLACK that drives them would allow existing and aspiring IT leaders to more effectively focus their learning and efforts.

Having models and conceptual frameworks helps the community of scholars who study a field discuss it and discern its interplay of relationships. Scholars of IT who learn of and use the models and frameworks proposed here and in other chapters in this section can build bridges to related fields of study to catalyze insights for the next generation of research in IT.

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A Distributed Leadership Perspective on Information Technologies for Teaching and Learning

33

Richard Halverson

Contents

Abstract

This chapter considers how distributed leadership can describe and explain the role of K-12 school leaders in supporting technologies for teaching and learning. Distributed leadership is uniquely suited to describe how schools lead for technological innovation. Spillane et al's. (2004) model of distributed leadership emphasizes a task-focused approach to describe how multiple actors engage in leadership work. This chapter will consider the range of tasks that define school leadership for technology. This work recognizes the considerable range of tasks in which leaders currently engage to implement new technologies within schools. However, from another perspective, schools are situated in a much broader world of technologies such as social media, video gaming media distribution, and production which are redefining what counts as teaching and learning outside of schools. Because leaders are responsible for creating environments that best advance learning opportunities for all students, the chapter describes both what

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currently counts as a learning technology task for leadership as well as a consideration of which tasks are on the horizon for technology work in schools.

Keywords
Distributed leadership · Instructional technology · Digital media and learning · Connected learning

Introduction

This chapter considers how distributed leadership can describe and explain the role of K-12 school leaders in supporting technologies for teaching and learning. Leadership establishes and maintains the conditions that support the core practices of an organization (Spillane et al. 2004). When considering school leadership for technology, the role of leaders is to make it possible for educators and students to take advantage of the range of affordances offered by contemporary information technologies to advance learning.

Distributed leadership is uniquely suited to describe how schools lead for technological innovation. Distributed leadership is often thought of as a way to think about the social arrangement of leaders for teaching and learning (Bennett et al. 2003). To be sure, leading for technology is in large part a matter of defining and sharing practices among and across actors in the instructional context. Distributed cognition theory also emphasizes the role of the *tasks* enacted by actors across contexts of practice (see, e.g., Hutchins (1995). *Cognition in the Wild*. Boston: MIT Press). Spillane, Halverson, and Diamond's model emphasizes this task-focused approach to describe how multiple actors engage in leadership work. Distributed leadership describes how leaders use tools to redefine the tasks that constitute what is possible (and impossible) in schools.

This chapter will consider the range of tasks that define school leadership for technology. This work recognizes the considerable range of practices in which leaders currently engage to implement new technologies within schools. However, from another perspective, schools are situated in a much broader world of technologies such as social media, video gaming media distribution, and production which are redefining what counts as teaching and learning outside of schools (for a discussion of how technologies are transforming learning outside of schools, see Ito et al. (2013). *Connected Learning: An Agenda for Research and Design*. Irvine, CA: Digital Media and Learning Research Hub; Jenkins et al. (2007). *Confronting the challenges of participatory culture: Media education for the twenty-first century.* MacArthur Foundation Digital Media and Learning White Paper Series. http://newmedialiteracies.org/files/working/NMLWhitePaper.pdf and Barron et al. (2015). *The Digital Youth Network: Cultivating New Media Citizenship in Urban Communities*. Cambridge: MIT Press). Because leaders are responsible for creating environments that best advance learning opportunities for all students, our analysis addresses what currently counts as a learning technology task for leadership as well as a consideration of what is on the horizon for technology work in schools.

Distributed Leadership Framework

Spillane and colleagues describe distributed leadership as a theory that seeks to explain how leaders establish the conditions for supporting and improving core organizational practices. They seek to understand leadership in terms of the key tasks supported by networks of people and tools. From the Spillane et al. perspective, distributed leadership draws on the theoretical sources of distributed cognition to explore how actors, artifacts, and tasks together define and engage in the situation in which practice unfolds:

- The *task* is a discernable unit of action engaged in by actors and supported by the context.
- The *social* distribution of practice refers to how tasks are shared, obstructed, and constructed across multiple actors over time. These actors can receive tasks given from outside their context of action (e.g., requirements to implement a policy) or can design tasks locally to support core elements of their work.
- The *situational* distribution of practice refers to the artifacts (such as tools, language, and routines) that mediate task engagement in a given context. In schools, some of these artifacts are inherited as elements of the local context (e.g., the school calendar); others are imported into the context as guidelines for action (e.g., standardized tests); and still others are designed locally to address community concerns (e.g., professional learning plans).

Together, these concepts of task, social, and situational distribution explain how practice unfolds in real time.

Distributed leadership adopts these concepts of task, social, and situational distribution to explain the work of leaders. The distinctive role that leaders play is to support the core practices of the organization. For example, leaders engage in hiring, training, and evaluating educators; providing resources and training to improve performance; and adopting and designing assessments of core organizational practices. In schools, leadership tasks are defined around the support and improvement of teaching and learning. School leadership involves tasks such as establishing a focus on learning and learners, monitoring teaching and learning, building professional capacity of staff, acquiring and allocating resources, and building a safe and effective learning environment for all students (Halverson and Kelley (2017). *Mapping leadership: The tasks that matter in school improvement*. Jossey-Bass: San Francisco CA). Distributed leadership analyses of these tasks illustrate how leaders build structures and resources to improve core organizational practices (Diamond and Spillane 2016).

Applying the Spillane et al. perspective to how leaders frame and support the tasks of technology leadership identifies the tasks necessary to draw the wide range of technologies in and out of schools into the core practices of teaching and learning. While there is a significant body of research available for how leaders support current technologies in schools, there is relatively little research on the direct role of school leadership for bringing the affordances of new media technologies into schools (▶ Chap. 32, "The Role of Leadership for Information Technology in Education: Systems of Practices" by Dexter and Richardson). The argument presented here brings together conventional leadership research on technology with work from other fields of technology development to outline an agenda for where leaders should currently focus as well as where they can focus next.

A Task-Based Distributed Approach to School Technology Leadership Research

Anderson and Dexter (2005) have shown that effective leadership for information technology is a significant predictor used by teachers and students in schools. There is considerable research that documents the leadership tasks for designing and supporting technologies for student learning, professional development, and data systems in schools (see, e.g., Anderson and Dexter (2005). School technology leadership: Its incidence and impact. *Educational Administration Quarterly, 41*, 49–82; Tan (2010) School technology leadership: Lessons from empirical research. Proceedings from the 2010 Annual ACSILITE Conference. Sydney. http://www.ascilite.org/conferences/sydney10/procs/Seng_chee_tan-full.pdf).

Leaders who successfully engage in the work of improving teaching and learning take a system-wide perspective on the nature of the tasks and the range of the partnerships required. Tan's (2010) review of international research on technology leadership identified four task domains necessary to engage in successful leadership within and across schools: *infrastructure*, *organization structure and policy*, *pedagogy and learning*, and *school culture*.

Infrastructure refers to building and maintaining the technical capacity for information technologies to support teaching, learning, and school operations. Infrastructure includes selecting, purchasing, and maintaining hardware and software systems as well as developing the professional capacity to assess, monitor, and improve technical resources. In recent years, an important aspect of technical infrastructure is the development of capacity to collect and disseminate standardized testing data for school improvement. Investment in these technologies are sparked by the requirements of policies that press schools to develop the capacity to generate and use student outcome information to make decisions about school management, teaching, and learning.

The ability to use these data has led to large-scale investment in information management and communication tools. In the 2000s, local and national education leaders around the world began to invest in data systems to collect and track accountability data to assess school performance and to make information visible to communities. By 2010, 99% of US public school districts had student information systems, 77% had data warehouses, and 64% had curriculum management systems (Means et al. 2010). By 2014, the global market for management and information technologies had swelled to a $1 billon industry (Herold 2014). Over time, schools came to realize that standardized test data alone had limited value in guiding instructional decisions. During the 2000s, schools began to invest in interim assessment tools that would use computer-adaptive testing technologies to provide instant, standards-based feedback on student learning. Technology leaders not only must be able to select the appropriate tools to enhance teaching and learning in schools but must also design technical infrastructure to coordinate how these tools interact with one another and with users in increasingly sophisticated technology systems.

One area where schools are investing in technology infrastructure is to provide data-driven decision-making support for students with special needs. In the USA, the development of specialized technologies to support individualized education program (IEP) requires educators to use data to develop customized learning plans for students. Programs such as Response to Intervention (RtI) aim to identify students before they begin to struggle and to assign students to appropriate instructional support systems (Batsche et al. 2006). RtI programs use data for universal screening in order to guide students toward different tiers of learning support to address student learning needs prior to assignment into special education. Similar data-driven programs have been developed for behavior management and discipline (e.g., Positive Behavior Interventions and Supports (PBIS)). Contemporary technology leaders use these intervention and support models to build systems to organize data acquisition, distribution, and recording systems to track how students fare in these kinds of information-rich instructional environments (new approaches to analytics can provide the same kinds of insight for the kinds of technology support needed by different types of teachers. Graves and Bowers found four categories of technology-using teachers: *dexterous* teachers able to move between systems and tools, *assessors* interested in using technologies for measurement, presenters who use technology to complement instructional delivery, and *evaders* who seek to sidestep technology use. For more detail, see Graves and Bowers (2017) Toward a Typology of Technology-Using Teachers in the "New Digital Divide": A Latent Class Analysis (LCA) of the NCES Teachers' Use of Educational Technology in U.S. Public Schools, 2009 (FRSS 95). *Teachers College Record*).

Taken together, standards-based planning and data-driven instructional supports result in sophisticated information networks organized around diagnosing student needs and diagnosing student outcomes. These systems are increasingly integrated into the core practices of teaching and learning in schools and provide powerful tools for educators to better understand student needs and the outcomes of instruction.

Organizational and policy change refers to the governance and partnership models that oversee the design and implementation of technical capacity in the school. Technology planning is a central leadership task in this area around the world. A sampling of planning documents includes:

- Singapore's Masterplan coordinates information technologies for teaching and learning across the nation. The core components of the plan include (a) building the capacity of school leaders, (b) integrating instructional technologies across the curriculum, (c) encouraging innovative technology practices in schools, and (d) ensuring ethical and responsible usage of technologies (Singapore Ministry of Education 2014).

- A UNESCO sub-Saharan Africa report emphasizes the preservice training in the effective use of information technologies for teaching and learning in the classroom through teacher training and a variety of in-service and virtual learning opportunities (UNESCO IICBA 2016).
- A European Commission report calls for investment in technology infrastructure and training in schools. The report claimed that between 20% and 50% of learners use digital texts, games, or virtual learning environments and only 20–25% learn in classrooms with technologically skilled teachers. The Commission sponsors frameworks for technology development and innovation, tools that support the development and measurement of digital literacies, and spaces to support the sharing of open education resources (European Commission 2017).
- The US Department of Education (2017) National Technology Plan Update describes key tasks necessary to engage in successful planning for technology leadership. The authors emphasized the role of establishing a vision for the use of technology in the school, to develop funding models for sustainability and leading for equitable access to learning technologies.

These plans suggest local and regional leadership engage in a variety of tasks to design and enact broad agendas for technology and learning:

- At the national and regional level, policy makers and school leaders are called to focus on providing broadband access to all school districts and to consider initiatives that put computation technologies in the hands of all learners. Legislators and state agencies need to provide funding and increase support beyond technologies that measure the results of schooling and move toward technologies that support teaching and learning in and out of classrooms, including learning management systems, communications tools, and computer-adaptive teaching and learning tools.
- At the district and school level, educators are called to collaborate on articulating a vision for equitable access and uses of technologies for learning, building the capacity for assessment technologies, and providing professional development for teachers on data literacy and on effective technology uses for standards-based instruction.
- At the classroom level, teachers and learners are called to integrate information technologies into everyday teaching and learning practices, including computer-adaptive learning and assessment tools. Classrooms need to provide greater access to opportunities for personalized and blended learning and need to participate in distributed, virtual communities that extend the walls of the classroom to access relevant professional and learning resources.
- At the community level, schools are urged to develop communication strategies that meet the information needs of all members of the community as well as using learning technologies to allow families to access and participate in student and classroom learning opportunities, to support families in the active uses of technologies by early learners in home environments, and to develop plans to safely share information with relevant community partners.

Data security and digital citizenship. The distributed nature of technology systems makes them increasingly vulnerable to hackers both inside the community and around the world. Because school data systems distribute identifying information about minors and families, and typically lack the resources necessary to invest in state-of-the-art security tools, education institutions need to plan to collaborate on sharing best practices for ensuring secure data systems. The US's National School Boards Association's 2017 report distinguishes between data privacy practices that ensure the confidentiality of student and teacher information and data security practices that protect the data system from internal and external attacks. The report recommends that each school develop a data governance plan to oversee the "data life cycle" through the collection, storage, protection, usage, sharing, and retiring of information (National School Boards Association 2017).

Digital citizenship has emerged recently as an important organizational issue for schools. The ability of the Internet to connect learners across communities around the world requires the establishment of shared standards for interaction. Open access to information has led to the need to teach students and teachers how to engage in online information exchange and interaction as twenty-first-century citizens. For example, communities such as E-Twinning have provided virtual opportunities to learn norms for digital interaction for over 2 million learners from 38 countries to collaborate on classroom and professional learning projects (Cassells et al. 2016). Digital citizenship should also focus on issues of social media interaction within schools with attention to issues of cyberbullying and helping learners to use social media as a resource for leaning (Espelage et al. 2012). Orchestrating interaction around these key tasks helps to organize technology planning around the habits of mind and practice expected of educators and students in schools.

Pedagogical and learning change describes the work of technology leaders to advance the practices of teaching and learning in schools. This work involves providing professional learning opportunities for staff and faculty, selecting and supporting virtual learning and learning management tools for classroom instruction, and assembling relevant instructional support technologies for learning outside of the classroom.

Designing technologies for pedagogical and learning change involves the assembly of systems designed to address a variety of learning needs in schools. For example, contemporary school leaders often engage in the provision of learning management systems to support teaching and learning. The global market for learning management systems is expected to grow from $5.2 billion in 2016 to a $19 billion in 2022 (Learning Management System Market (Distance Learning, Instructor-Led Trainings and Others) for Performance Management, Content Management, Communication & Collaboration and Others Applications: Global Industry Perspective, Comprehensive Analysis and Forecast, 2016–2022. https://www.zionmarketresearch.com/report/learning-management-system-market). In European higher education markets, open-source tools based on Moodle continue to dominate (http://www.micromarketmonitor.com/pressreleases/europe-learning-management-system.html), while in the K-12 world, platforms such as Google Classroom (http://www.prnewswire.com/news-releases/google-apps-for-education-anticipated-to-reach-110-million-users-by-2020-300107878.html) are being used in classrooms around the world. Professional development tools such as ETIPS provide case-based guidance for educators to plan and support technology-rich learning environments (http://www.etips.info). The market for testing and curriculum tools such as benchmark assessment systems and digital instructional content has grown dramatically in recent years as well. In addition, specialized platforms for special education (https://www.rti.org/sites/default/files/brochures/ict_ed_training.pdf), computer-adaptive learning (https://www.edsurge.com/research/special-reports/adaptive-learning/software), and individualized learning (http://www.edweek.org/ew/articles/2016/03/07/facebooks-zuckerberg-to-bet-big-on-personalized.html) are being used more widely in schools. Professional learning opportunities should be organized around research in technological pedagogical content knowledge (TPACK) that guides educators through the tools and tasks that best represent a subject area (Voogt et al. 2013).

Many schools have turned toward personalized learning as a model for taking the practices of data-driven learning supports to the student level. A recent Education Week review (2014) synthesized a variety of recent personalizing learning to define four key features:

- *Competency-based learning progressions* that define trajectories of content for learners and provide ongoing, formative assessment toward learning
- *Flexible learning environments* organized around the needs of students
- *Personal learning paths* that customize activities to learner motivations and goals
- *Learner profiles* to capture the progress students make toward learning goals

Personalized learning encourages teachers to work with students to develop learning plans for *each* student, instead of *types* of students. This shift requires leaders to implement new kinds of technologies, such as Google Classroom and learning relations management systems, which enable students to participate in data-driven instructional decision support. As an aspect of personalizing learning, schools are implementing a variety of computer-adaptive curriculum systems that provide a standards-based trajectory of curriculum units customized to demonstrate student abilities (for a discussion of the varieties of computer-adaptive learning systems, see Pugliese 2016. Adaptive Learning Systems: Surviving the Storm. *EDUCause Review*. http://er.educause.edu/articles/2016/10/adaptive-learning-systems-surviving-the-storm). Computer-adaptive curriculum packages, based on technologies developed in cognitive tutoring research, allow educators to link assessment to learning plans for students.

Cultural change describes the work of technology leaders to focus the use of information tools on supporting and advancing opportunities for teaching and learning. This work involves modeling appropriate work practices for collaboration and use of information tools by school leaders and staff, providing occasions for collaborative design with technologies for teachers and students, and developing a suite of tools (such as websites and social media) to communicate the progress and mission of the school to community members and stakeholders.

Because new technologies are always being introduced, a number of researchers characterize change in terms of building a culture of innovation. In *Where Good Ideas Come From*, Johnson (2011) describes innovative contexts as sites of "liquid" social and intellectual capital in which actors who share loosely related agendas share insights across areas of expertise to spark new insights in their fields. Leaders interested in creating this form of liquid capital in their schools can create opportunities for professionals with different forms of expertise to learn from one another. Liquid capital environments provide dynamic contexts that invite people to adapt the ideas of colleagues to new purposes, cultivate promising hunches, and set up conditions for serendipity.

Unfortunately, there is abundant evidence that the promise of information technologies is often unfulfilled. Peck et al. (2002) found that technology initiatives seldom improve teaching and learning across the organization. Without significant attention to pedagogical and cultural change, information technologies can simply be used to reinforce existing instructional practices, rather than acting as a force for change. Fletcher (2009) notes "When leaders are clueless about technology and the impact it can have in classrooms, they are powerless to change their school or district into one that provide tech enabled instruction for students" (p. 22).

Clearly, the work specified by these task domains goes considerably further than the positions of technology coordinator or principal. Anderson and Dexter (2005) found that the work of technology leaders across the school has a direct impact on quantity and nature of technology use for teaching and learning in schools. Often creating cultures of innovation requires a distributed perspective in order to establish new norms and routines of practice across the school. Christiansen and colleagues (2006) use the term "disruptive innovation" to describe how advances in one area of a market can overturn status quo practices in other areas. Creating Johnson's liquid networks requires strong, informed leadership to create connections, build collaborations, and find new opportunities for innovation. From a distributed leadership perspective, engaging in system-wide tasks such as *infrastructure*, *organization structure and policy*, *pedagogy and learning*, and *school culture* can help reshape the conditions that can thwart the work of isolated educators and school leaders.

Social Distribution of Technology Leadership Tasks

Effective technology leadership is socially distributed across the organization. At the district policy level, Turner (2014) found that superintendents created subject matter expert teams and arranged collaborative design meetings to develop and implement district-wide technology initiatives. Penuel's (2006) review of one-to-one computing initiatives suggested that drawing teachers together in collaborative design work has a better chance of improving practice and creating opportunities for student learning. Research on technologies implemented to support special education (Zorfass and Rivero 2005), learning management systems (Dagada and Mungai 2013), and virtual schooling (Abrego and Pankake 2010) all emphasize the role of leaders to intentionally distribute work across networks of subject matter professionals and community members to realize the potential of information technologies in schools.

A socially distributed leadership perspective on these core tasks reveals variation in how educators engage in technology leadership. Spillane (2006) described three idea forms of social distribution: collaborative, collective, and coordinated. A *collaborative* approach describes the ideal situation of technology planning in which leaders charged with technical, logistical, instructional, and resource allocation work together to achieve a coherent plan. A *collective* approach might describe the distinct roles that leaders play in enacting a technology-driven learning plan. For example, educators might collectively agree to implement a digital citizenship curriculum that requires each person to engage in a separate role across subject areas to reinforce norms of twenty-first-century learning across the school. A *coordinated* approach describes the operation of a large-scale learning technology system where the instructional technology staff monitor infrastructure and security issues; educators handle the day-to-day student-technology interactions; business leaders acquire and allocate necessary human and material capital resources; and formal leaders make the case for the value of the system to internal and external audiences.

Ideally, these levels of activity are coordinated so that information generated from each level is shared across levels to monitor system breakdowns. Of course, in practice, there are many ways for these systems to malfunction and for the resulting work to be disconnected from effective practices in teaching and learning. Bauer and Kenton (2005), for example, found that technologically adept teachers struggled to adapt their skills to the quality of the technology infrastructure available in their schools. The work of Peck et al. (2002) illustrates the limited reach of technological innovations to reshape everyday classroom routines; and Warschauer and Matuchniak (2010) contrast the promise of instructional technologies at the system level and how actual classroom practices tend to reproduce race, class, and gender inequities. System breakdown signals how errors are not noticed or not acted upon by actors at other levels of the system. A socially distributed leadership perspective enables observers to follow task enactment across multiple levels of action in order to identify areas for supporting best practices (for a discussion of how following information pathways allow for the identification of breakdown in distributed systems, see Hutchins (1995)).

Leading for Twenty-First-Century Learning

In upcoming decades, the leaders will face new challenges of integrating emergent learning technology tasks into everyday practices of teaching and learning (the following section draws on a paper that describes how technology leaders can bridge participatory cultures into schools: Halverson et al. (2016). *Participatory Culture as a Model for How New Media Technologies Can Change Public Schools* (WCER Working Paper No. 2016-7). Retrieved from University of Wisconsin–Madison, Wisconsin Center for Education Research website: http://www.wcer.wisc.edu/

publications/working-papers/). Collins and Halverson (2009) identify these emerging practices as “seeds of a new system” that serve to draw on the generative world of social, consumer, and entertainment to outline possible areas for growth in learning technologies.

It might seem strange to label users as learners in these kinds of contexts. After all, playing video games or hanging out in Reddit does not resemble a typical school experience. However, the information-rich contexts of these environments are changing what we mean by learning in the everyday world. Google Maps users learn how to navigate unfamiliar spaces; fantasy sports players learn how to predict the outcomes of players and sporting contests; and hearthstone players learn which virtual card decks are popular among experts. Users develop favorite sources of information, such as Facebook, Twitter, or Spotify, for social interaction and entertainment. New media technologies put unprecedented power for learning in everyone’s hands. To take advantage of these powerful learning tools, technology leaders in schools will need to create new opportunities to drive learning in schools.

Bridging the potential of these learning opportunities into the lives of teachers and learners creates significant challenges. Twenty-first-century educators and students learn to participate in learning communities in and out of schools, but the barriers for working across the divide are quite high. Issues of student identity and safety, as well as network security, present the initial obstacles for ready integration. The interest-based learning goals that define entertainment and social media communities threaten the tight controls over the content of student learning in schools as specified by standards and accountability policies. In many classrooms, an uneasy truce exists between the technologies that thrive within the schools and the technologies that engage interaction outside the school (Halverson and Shapiro 2013).

Henry Jenkins and his colleagues (2007) developed the idea of participatory cultures to capture the kinds of social learning interactions that emerge naturally around new media technologies in the wild. Participatory cultures begin with the idea that gaming, making, writing, and fan cultures are social learning communities. They propose four aspects of participatory cultures: *affiliations*, *expressions*, *collaborative problem-solving*, and *circulations*.

Affiliations describe the interest-driven aspect of participatory cultures. Members choose to affiliate with a group first to learn more about the topic and then to guide others in participation. Affiliations admit members based on interests and, over time, often inspire members to acquire new interests. Players of a certain game, for example, hear about the release of a similar game through affiliation, which leads them to play the new game. Affiliations typically include members with a differing ability levels whose expertise becomes a community resource for mentoring and the induction of novice participants. Over time, novice members come to serve as guides for the next generation of new users.

Technology leaders in schools interested in designing for affiliations could look to examples such as *maker spaces*, which are “informal sites for creative production in art, science, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products” (Sheridan et al. 2014). Opening up school libraries, for example, as maker spaces can invite students and teachers to tinker with 3-D printers, circuit design, knitting, or craftmaking as a place for multiage expertise within the school. School leaders can repurpose common-use spaces to support interest-based exploration; and use making activities to support bridges to disciplinary learning in science, social studies, computation, and the arts.

Expressions define learning as creating products that matter to the affinity group. Expressions include products such as videos, games, and critiques (Halverson 2012). In schools, conventional assessments typically take place after the learning has happened and are not meaningful in contexts apart from the learning task. For example, a math test happens after the learning has occurred, and the test in itself has meaning only in rating the performance of the student. In participatory cultures, learners demonstrate membership by making expressions that are critiqued and approved by the community.

YouTube communities provide a model for how expressions lead to authentic assessment. YouTubers watch the work of others on the way toward developing interests. Full membership requires providing feedback and guidance to new members through critique as well as making products (in this case videos) valued by the community. School leaders can look to YouTube communities as inexpensive examples for how to support technologies that build student interests and authentic audiences into daily practices. Many schools already have multimedia capstone projects designed to draw together aspects of the student's education experience across disciplines. Using expression communities as a model can point toward viable pathways for technology leaders to organize teaching and learning around real-world learning opportunities.

Collaborative problem-solving defines learning as exploring open questions in the company of other interested inquirers. Participants in collaborative problem-solving cultures work together to coordinate inquiry toward solving unknown questions, distributing knowledge across the community, and then specifying the next set of questions on the horizon.

School leaders interested in providing opportunities for students to engage in collaborative problem-solving can turn to citizen science. Citizen science communities coordinate engagement in basic science research by connecting experts who set the terms of the inquiry with amateurs who collect, and sometimes analyze, data to address the question. There are thousands of participants of all ages engaged in hundreds of citizen science projects – ranging from bird census data collection (http://eBird.org) to planet mapping (https://www.planethunters.org) and from protein folding (http://foldit.org) to Zika viral infection tracking (http://www.citizenscience.us/imp/). School leaders interested in building collaborative problem-solving into their schools could consider working with teachers and community members to integrate citizens-science projects as opportunities for learners to engage in collaborative problem-solving.

Circulations describe how knowledge and relationships flow through interest-based communities. Schools, of course, are places where knowledge and relationships readily circulate. However, they are also bounded by place and limited to the kinds of expertise resident in the institution. Virtual circulation networks allow members to access knowledge and build relationships anywhere. Participants who engage in multiple networks learn how to interact with people from different backgrounds and interests and can come to acquire new interests through joining a wider range of networks. Circulations have across-network benefits as well. Participants in multiple networks can bring solutions from one community to address the problems of other communities (for a discussion of how circulations in knowledge communities spark innovation, see Johnson (2011). *Where good ideas come from*. New York, NY: Riverhead Books).

Most people already participate in thriving circulation networks. Bringing some of these networks into schools can help to expand the boundaries of school-based networks. Pinterest, for example, has been co-opted by millions of teachers as a professional development and lesson circulation network. Teachers from around the world use Pinterest to find and exchange instructional resources. When teachers pin a board to their collection, this opens an opportunity to learn about everyone who pins on the new board and allows teachers to expand their professional network beyond the school community. School leaders interested in expanding circulations within the school can consider leveraging communities like Pinterest to extend the reach of the school network.

Affiliations, *expressions*, *collaborative problem-solving*, *and circulations* provide design guidelines for school leaders to infuse existing school communities with new opportunity. Leaders can get a head start by experimenting with robust, ready-made participatory cultures that already include millions of learners engaged in self-sustaining communities. However, building on this potential will require school leaders to expand the distribution of leadership beyond the range of conventional actors within the school. Consider, for example, how a community like Pinterest challenges the control of professional learning from a school-based leadership perspective. Distributed leadership networks that take advantage of new media communities will need to rethink the boundaries of the school and what counts as an educational resource.

Conclusion

A distributed leadership approach to technology leadership describes the tasks and the tools necessary to support teaching and learning in schools. In the first part of this chapter, the discussion considered the key tasks and social distributions of practice involved with implementing technologies that support contemporary standards-based learning practices in schools. In the second part of this chapter, the discussion highlighted possible communities and practices that leaders might use to bridge the learning affordances of entertainment and social technologies into the lives of teachers and learners in schools. Schools need twenty-first-century leaders who can work in both worlds to build single, coherent vision around the tasks that matter in using technology to guide teaching and learning.

Fortunately, there are robust models available to guide leadership practice toward this coherent vision of integrated technology systems. The connected learning framework (Ito et al. 2013), for example, is a collaborative research and development project that brings together academic, social, and recreational computing into a vision of future schooling. Mimi Ito and her colleagues define connected learning in terms of:

- *Peer-supported* environments that allow colleagues to interact around contributing, sharing, and responding to their work
- *Interest-powered* spaces that bring together members who share a passion for learning around a common topic
- *Academically oriented* initiatives that guide learning toward outcomes and that count toward advancement in formal education settings
- *Production-centered* spaces that provide access to the kinds of tools that allow making and expression as evidence of learning
- *Openly networked environments* that draw on technologies for assessment, tracking performance, and supporting collaborative and productive work in locally designed information ecologies
- *Increasing accessibility to knowledge and learning experiences* that create pathways to the resources and relationships that support collaborative inquiry

Blending social, interest-based, and academic goals into a common learning space provides a model for technology leaders to connect learning across the organization to advance opportunities for all learners.

Of course, drawing the potential of both contemporary learning technologies as well as new media technologies presents a significant reframing of the work of technology leaders in schools. The expansion of this work requires formal technology leaders to work with colleagues to form networks of professionals who can advance the potential of learning technologies across the organization.

- At the school level, leaders need to create cultures that permit educators and learners to adapt the power of new technologies to existing practices.
- Special educators, school psychologists, and data analysts need to explore information resources that can fit technologies to learner needs and to assess how new tools advance learning outcomes.
- Educators need access to the variety of tools that can form both standards-based and new media learning environments.
- Learners and families need guidance on how to integrate learning tools available outside of schools into the everyday work of schooling.

School leaders are responsible for assembling technology environments that improve teaching and learning. The distributed leadership perspective focuses attention on the key tasks of this work, which involve bringing together the tools for instruction, assessment, creativity, and interaction into a common space so that all teachers and learners can get access to high-quality and high potential learning environments. Models like participatory cultures or connected learning, as described in this chapter, can provide a framework to guide the new work of school technology leaders to name the tasks and to coordinate the work of leadership at multiple levels in order to fulfill the promise of contemporary technologies for learning.

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Leaders Fostering Teachers' Learning Environments for Technology Integration

34

Sarah K. Howard, Jen Scott Curwood, and Kelli McGraw

Contents

Abstract

This chapter addresses how school leaders can support teachers' professional learning and technology integration through a learning design perspective. Through this perspective, teachers engage in sensemaking to enact policy through teaching and learning. This can afford an authentic and contextualized approach

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to teachers' professional learning. To do this it is necessary for school leaders to create a culture of learning and experimentation. School leaders can do this through fostering teachers' engagement in contemporary professional learning, such as developing personal learning networks and communities. These can be online or face-to-face in local schools, or a mixture of the two, formal or informal, and structured or unstructured. The chapter highlights that professional learning should be flexible and personalized to teachers' contexts. This is increasingly possible as teachers have access to diverse networks and communities, which support engagement with a wide range of professionals, resources, and experiences that may not be available in local schools. The chapter concludes with recommendations on how school leaders can employ a learning design perspective to create this includes opportunities for teachers to make sense of technology integration and experiment and continuously learn to support digital technology use in their school context.

Keywords
Professional learning · School leadership · Culture of experimentation · Learning design process · Technology integration

Introduction

Since the 1980s, availability of digital technologies in schools has consistently increased, but integration in teaching and learning continues to be inconsistent and not well understood (Perrotta 2013). This issue has been attributed to the complexity of integration and solutions being difficult to identify (Tallvid 2014). To better understand and improve technology integration, Educational technology research has tended to focus on factors of teacher practice. Specifically, teachers' level of confidence with and knowledge of information technologies (IT) and how school leaders guide teachers in technology use have been seen as ways to improve technology integration. As a result, signinficant federal and state educational resources have been put toward developing both teachers' professional learning and school leadership, but only minimal gains in improving technology integration have been observed (Ertmer and Ottenbreit-Leftwich 2010; Howard and Gigliotti 2016).

In this chapter, we consider a shift in the "problem" of technology integration to focus on how school leaders can support teachers' professional learning and technology integration through a learning design perspective. Usually, teachers' technology-related professional learning is viewed from the perspective of professional development about technology integration (Salomon 2016). A more authentic approach is to consider a *learning design* process through which teachers engage in sensemaking to enact policy through teaching and learning (Cobb and Jackson 2012). When teachers are engaged in a learning design, or sensemaking, process, they are evaluating, selecting, and integrating various resources and strategies to address policies, school expectations, and learning goals. This process of sensemaking can be conceptualized as a space for teachers to identify where they may want or need support. It affords more authentic and contextualized learning, which is responsive to teachers' and students' needs. A design perspective is able to embrace the complexity of technology integration and bring to the fore the interdependences of leaders' and teachers' roles in improving IT integration.

A design perspective is implied in key leadership functions of setting directions, developing people, and redesigning the organization (Louis et al. 2010), which encompass the numerous questions about how leaders might facilitate teachers' learning design processes. It has become increasingly difficult for school leaders to create a coherent and consolidated approach to professional learning to support and improve digital technology integration. In the current digital landscape, it is possible for teachers to access a wide range of opportunities, locations, resources or networks, in formal, informal, and/or independent spaces and networks (Jones and Dexter 2014, 2016), such that professional learning may be structured or unstructured, include face-to-face and online contexts, and be accessed from a range of resources that may not be visible or accessible to others.

In this chapter, we first explore some of the complexities of teachers' professional learning and technology integration design, the implications of these complexities in teachers' learning, and the role of school leadership in developing a school culture to support professional learning. This is followed by a discussion of the range of contemporary professional learning options and how different approaches facilitate teachers' technology-related learning and, finally, some consideration about how school leaders can foster contemporary professional learning and build up a culture of experimentation in schools to support technology integration.

A View of Technology-Related Professional Learning

Complex and wicked problems can be understood as those involving a large number of variables, which exist in dynamic, contextually bound, and interdependent relationships (Morrison and van der Werf 2016). These problems are enduring and often not easily solved. It is known that the classroom level, specifically teachers' practice, has the greatest effect on student learning (Muijs et al. 2014), but this relationship is complicated. A learning design perspective can bring out the complexities teachers experience when engaging with school and other educational policy: how, what, and why they are expected to change their practice. Teachers' confidence employing digital technologies can be addressed through more authentic and collaborative "on-the-job" professional learning (Zhang et al. 2017) and improved access to effective professional development (Ertmer et al. 2012). To support these two aims, school leaders should develop a culture of experimentation and learning to encourage teachers' use of ITs in the classroom (Howard and Gigliotti 2016). School leaders can then provide the necessary appropriate support and resources to facilitate technology-related change. To do this, it requires an understanding of the current landscape of teacher learning and technology integration.

Professional Development Versus Professional Learning

The terms *professional development* and *professional learning* are often used interchangeably, but we argue that they involve very different experiences for teachers, each with different roles in technology-related teacher change and implications for school leaders to support teachers' change processes. *Professional development* is used to connote the typical teacher learning experience: related to practice, often structured as a single session workshop with no follow-up and often leader-directed, but it may be online, blended, or face-to-face in or outside of the school setting. Traditionally, the most common form of professional development is the formal workshop, which includes institutes, courses, conferences, and other forms of training to acquire a skill or knowledge in some area (Desimone 2009).

In contrast, *professional learning* is used here to connote an active, collaborative, iterative, and ongoing process based on a teacher's personal interests, professional goals, and sociocultural contexts (Desimone 2009; Wei et al. 2009). Opfer and Pedder (2011) describe professional learning as a holistic approach which may include multiple systems: the individual teacher, e.g., their beliefs, personal experiences, and how these are enacted in classroom practice; the school, e.g., the context and support for teaching and learning, cultural beliefs, and norms; and the activity, e.g., learning activities, tasks, and practices in which the teacher participates. Jones and Dexter (2014) found that teachers learning to use technology may engage in formal, leader-driven workshops but then actively pursue additional learning experiences through informal or independent efforts, such as through collaborations with colleagues and pursuing resources beyond their school, because these other modes offer different affordances for their learning.

While technology-focused formal professional development has typically comprised workshops delivered in a traditional face-to-face format, they are increasingly delivered online and/or through a blended model, including both face-to-face and online components. Zhang et al. (2017) present an example of an increasingly popular blended professional development model, which has a strong focus on collaboration and social support over time. Teachers worked with a chief teacher and engaged in formal online group discussions, and they also designed, delivered, and video recorded a lesson in order to receive feedback. Results showed that teachers felt positively about the experience, but engagement and interactions in the online space were very limited. Participants felt constrained by time, a common issue with formal professional development, and could not participate in discussions to the extent they desired. Interestingly, the researchers suspected that teachers were initiating additional interactions offline, which is common in blended professional development models (e.g., Chen et al. 2009) and an important point for school leaders to note. Teachers will naturally work across all available spaces, which suggests natural movement toward combining leaders- and teacher-directed formal and informal professional learning, as Jones and Dexter (2014) found. Were school leaders to facilitate and support this combined learning across online and offline communities, it would enhance an apparently natural approach teachers often use and take advantage of affordances of different modes of learning (Jones and Dexter 2016) in terms of flexibility, immediateness, and trust in asking a colleague while affording the deeper breadth of knowledge possible in an online space.

As technology has developed, professional learning has increased in online spaces. Trust et al. (2016) outline how teachers are moving to online professional learning networks (PLNs) to access professional learning resources specific to their needs, when they need support and expertise beyond their local school. This reflects increases in independent and informal learning. The flexibility of these modes is particularly effective when learning about technology integration, where teachers are negotiating different tools in a specific school context (e.g., Howard and Gigliotti 2016). Combinations of formal, informal, and independent learning reflect the complexity of technology integration learning, of which school leaders need to be aware to appropriately support teachers' technology integration and change.

Technology Integration

Two of the most commonly studied factors in relation to understanding technology integration have been teachers' use of digital technologies and technology leadership in schools (Vanderlinde et al. 2015). More recently, how students use digital technologies to support learning has become a more pressing issue (Zheng et al. 2016). Therefore, improving how teachers use digital technologies in teaching and learning is of great concern. This is reflected in the current International Society for Technology in Education Standards for Educators (ISTE Standards for Teachers 2017), which call for teachers to be a:

- Learner – continually growing their practice
- Leader – seek opportunities to support student empowerment
- Citizen – inspire students to positively participate in the digital world
- Collaborator – work with students and colleagues to improve practice
- Designer – create authentic and learner-driven activities and environments
- Facilitator – support learning with technology for student achievement
- Analyst – understand and use data to support student achievement

The above are considered essential ways teachers should engage with technology. Research has focused on the scope and quality of teachers' professional development opportunities to increase technology use and the above practices to foster modelling, to access higher-order thinking, and to design better learning experiences for students (e.g., Ertmer and Ottenbreit-Leftwich 2010). Broadly, many of the reasons why teachers have not engaged with digital technologies in these ways are, to a certain extent, well known, but not well understood. Reasons typically include lack of time to plan with the curriculum, relevance of ITs to curriculum, confidence in using digital technologies, lack of support from leaders, and access to appropriate professional development (e.g., Howard and Thompson 2016), but teachers' values and beliefs are among the most significant factors (Ertmer et al. 2012). Tondeur et al.'s (2017) meta-aggregative review of qualitative evidence synthesized five key points about the relationship between teachers' pedagogical beliefs and technology use. First, the relationship between pedagogical beliefs and technology integration is bi-directional. Beliefs lead to actions, which can reaffirm beliefs. Second, pedagogical beliefs can also act as barriers to technology integration. This is often in the form of beliefs about lack of time, a focus on testing, lack of relevance in learning, etc. School leaders should take steps to identify and understand teachers' pedagogical beliefs and identify how these may fit with policy and school expectations of technology integration.

The third point highlights how school leaders can begin to take action to support integration. The research shows, once beliefs have been identified, it is necessary to address the multidimensional and even contradictory relationship among those beliefs and how this may affect integration (Tondeur et al. 2017). This can begin to make visible the complexity of teachers' beliefs, which can help school leaders identify which are the most pressing and need to be addressed in relation to professional learning. This leads to the final two points which highlight for school leaders that working with a better understanding of these beliefs can facilitate creation of a more supportive school context for professional learning. In the following sections of this chapter, we explore how school leaders may better support technology integration and learning through supporting teachers' adoption of a learning design perspective.

Understanding the Complexities of Professional Learning and Technology Integration

Engaging in flexible, accessible, and personalized professional learning supports teachers to adapt their teaching and technology integration in response to the rapidly changing social, cultural, and economic environments in which they and their students live and work (Desimone et al. 2013). While digital technologies have been heralded as a way to increase student engagement and achievement, they are also increasingly considered a critical component of teachers' professional learning. Given the importance of authentic and personalized experiences when teachers are learning about the integration of digital technologies, technologically supported professional learning provides the opportunity to "learn to use and use to learn" (Karpova et al. 2009, p. 35). In this section, we consider the complex nature of technology integration and professional learning and how it is shaped by new contexts, tools, and reforms – elements largely shaped by school leaders. Given that effective technology integration depends on intensive, accessible, and ongoing professional learning, it requires the support of school leaders to be successful. By grounding the discussion in a learning design perspective, school leaders can support teachers' sensemaking of technology integration expectations and, ultimately, change.

A Focus on Learning

Drawing on the concept of learning design, Cobb and Jackson (2012) outline three aspects of thinking about educational policy and school expectations that school leaders can employ to help teachers make sense of possible changes in their practice.

They propose that policy should be considered from the perspectives of what, why, and how. The *what* is identifying teaching practices that will support desired learning goals related to a policy or expectation. The *how* includes supports for learning specified in the policy or expectation. The *why* encompasses the rationale for support provided to fulfil the learning goals. "Policy" can be understood on a number of levels, from department and state mandates to school expectations and goals. In this discussion, we use it to mean any expectation on teachers that they will change practice and integrate technology in their classrooms.

By engaging from a learning design perspective, technology-related change can be understood from within teachers' subject matter and teaching and students' learning in relation to IT use. Spillane et al. (2002) assert that conventional accounts of why reforms fail do not consider the complexity of teachers' sensemaking processes. Critically, in the current landscape of technology integration, teachers are faced with technology-enhanced ways of learning that are unfamiliar and often challenge existing conceptions of teaching and learning. While authentic professional learning is considered highly complex, Ching and Hursh (2014) argue that "teachers' attitudes, intents, and confidence are still the most powerful factors influencing technology integration . . . even in the most supportive environments, teacher decision making is still key" (p. 73). This reflects Tondeur et al.'s (2017) finding that educational change initiatives requiring new teaching strategies must fit with teachers' existing conceptions of student learning.

In the past, connecting change initiatives, such as new educational policy, with teachers' motivations to learn has been difficult, particularly if monetary incentive is absent and participation is voluntary (Gorozidis and Papaioannou 2014). This can be minimized by approaching technology-related change from the learning design perspective. Engaging in sensemaking of policy from this perspective can provide the space for teachers' to process prior knowledge, values, and emotions as well as social, organizational, and historical influences on their interpretations and decision-making related to change (Allen and Penuel 2014). Moreover, it is important to identify that teachers participate in different groups within a school culture, some formal and some informal, that will each contribute to teachers' sense of belonging, values and beliefs, and motivation to learn and engage in change. Understanding of the complexity of school culture is particularly important as school leaders negotiate how they engage teachers in the use of new IT and changes in the learning environment.

The Question of Capturing Professional Learning

Professional learning, broadly conceived, extends beyond government-endorsed workshops or school-based initiatives to include self-directed and self-regulated (informal and independent) activities, which are often invisible to accrediting organizations and schools. A report from the International Academy of Education (Timperley et al. 2007) has argued that teachers have "very diverse professional learning needs arising from the specific demands that their particular students place on their teaching skills" (p. 12) and that these needs cannot be readily met by short-term, skills-focused professional development provided by an outside expert. Specifically, online and/or offline informal networks are a significant part of teachers' wider social systems and professional learning, and they offer teachers mentorship opportunities inside and outside of their local schools.

There are generally four motivations for teachers to participate in professional learning: gaining new skills to improve classroom practice, higher salary, career promotion and/or maintenance, and career mobility (Stout 1996). Initiatives focusing on technology integration tend to relate to the first of these motivations – gaining new skills to improve practice. However, if a teacher believes that they must be the sole expert in the classroom, they may be reluctant to integrate new digital tools or allow students to exercise agency related to technology. Teachers often feel shame if they are not willing or are uncomfortable to use digital technologies in both the classroom and their own learning and may be reluctant to ask colleagues at their school for support (Howard 2013). Seeking online support through a loose network of peers offers a safe place to explore. Moreover, for teachers in remote areas of the world, online contexts offer tremendous potential for professional learning, including reflection, communication, and collaboration. Not only does this afford access to new strategies, activities, and perspectives, but it also provides a space to share fears or frustrations that they are not comfortable with expressing to immediate colleagues (Jones and Dexter 2016; Trust et al. 2016).

The core features of effective professional learning experiences for school leaders to consider are content, duration, and active learning, which repeatedly emerge as aspects of teacher learning that improve teaching practice and promote student achievement (Desimone and Garet 2015). Professional learning should address specific areas of teaching, such as pedagogy, and should be targeted at the correct level to be effective and relevant to teachers' context. Activities need to occur for a sufficient duration, such as over the course of a school year, to allow enough time for implementation, evaluation, and reflection (Desimone 2009). Contrasted with passive forms of professional development, such as attending a lecture, active learning is linked to more positive outcomes for teachers, and it is most effective when learning is embedded in authentic professional work (Darling-Hammond 2013).

School leaders can nurture professional learning opportunities by fostering an active culture of experimentation and professional learning. To create a culture of experimentation, school leadership should:

- Make clear that technology integration, learning, and change are important
- Commit to learning and change as a school
- Make learning, change, and experimentation social
- Celebrate success and failure
- Make change visible
- Keep plans for change current and active but also flexible and responsive to needs of teachers and the school

Throughout this process, leaders should make opportunities for teachers to use the learning design approach to make sense of the "what, how, why" of changes in practice (Cobb and Jackson 2012). They can do this in part through encouraging teachers to engage with and experience a range of professional learning networks. This may include joining pre-existing networks or creating their own system of colleagues. These may include interacting with colleagues face-to-face, online, or a combination of both. Through these, teachers can be motivated to experiment with new practices and are more likely to persevere in learning (Trust et al. 2016). Where possible, it is vital that leaders involve teachers at each phase of implementation of a change initiative, from initial conception to classroom implementation. In a technology-related change process, this approach can afford important learning experiences for teachers as they negotiate change and design problems of technology innovation such as how new IT tools are used to foster new forms of learning, which may not be familiar to teachers. Leaders actively supporting teachers' engagement in processes of negotiating professional learning, through experimentation with new technologies and practices, may result in potentially less misinterpretation of learning goals and greater commitment to achieving desired school change.

With technology integration, a one-size-fits-all approach to professional learning is not effective. As noted by Tondeur et al. (2017), professional learning needs to be closely aligned with teachers' beliefs about IT in learning, learning objectives, students' needs, and school resources. When teachers participate in self-directed (informal or independent) professional learning, they may engage with the wider education community beyond their school on these issues; thus leaders' support and guidance need to be provided to keep the focus on the school's students' learning and learning goals (Jones and Dexter 2016). The difficulty is how, given the shear range of options, contemporary learning processes are captured and identified so other teachers and school leaders can all benefit from new strategies and learn how to engage in sustained professional learning. To consider this question, we take a look at some of the specific ways teachers are currently engaging in formal, informal, and independent professional learning.

Considering New Technologies, Tools, and Contexts

In the context of technology integration, ITs can both facilitate teachers' professional learning and support students' learning. With the growing accessibility of social media tools and online spaces, and the recent popularity of informal community-based meetings, teachers are engaging in professional learning in a variety of new ways. Technology, in this sense, is often related to both the product and the process of professional learning. These approaches are rapidly gaining momentum at a grassroots level. This is a new area of research, but some recent work has offered case studies considering specific popular online contexts, including Facebook, Twitter, Instagram, and Pinterest (e.g., Biddolph and Curwood 2016; Carpenter and Krutka 2015), as well as within community-based meetings, such as TeachMeets (e.g., Esterman 2013), in an effort to understand the different ways teachers interact on- and offline, and how these spaces afford professional learning. A common finding across the body of literature of note for school leaders is that teachers engage and interact in these spaces with educational purposes to support their practice. An underlying principle guiding teachers' choices in professional learning is the capacity to interact with other teachers.

Sustained interactions can be referred to as professional learning networks. There is no clear definition of a professional learning network (PLN), but they can be understood as "new spaces in which teachers may learn and grow as professionals with support from a diverse network of people and resources" (Trust et al. 2016, p. 17). Social media tools and online spaces offer teachers the opportunity to engage in PLNs relevant to their interests, aimed at improving their practices, and situated within a wider community of educators. Trust et al. (2016) highlight how teachers use a range of digital technologies and offline approaches. For example, one teacher states that they "participate in Twitter chats, read blogs, reflect and write/attend conferences and courses, talk to colleagues" (p. 20). Curwood and Biddolph (2017) found that English teachers using Twitter as part of their professional learning also engaged in reciprocal learning as they shared resources and ideas. Particularly for teachers in rural and remote areas, the availability of flexible and accessible online resources and communities is significant, as they may not otherwise have high-quality professional learning resources.

Digital PLNs, in this sense, offer both a pedagogical tool as well as a professional learning community (Ertmer et al. 2012). On a daily basis, teachers engage in problem-solving design issues relating to technology and pedagogy. They ask questions, collect multiple sources of data, engage in sensemaking processes, implement new practices, and consider how technologies and their teaching directly impact student learning. The natural affordance of PLNs as a sensemaking tool lends itself to the learning design perspective to support change. Research has in fact shown that teachers engaging in PLNs feel more empowered to ask questions in a change context (Ertmer et al. 2012). However, school leaders must also provide teachers with the time, space, and tools to engage in self-directed and digitally mediated professional learning (Jones and Dexter 2014, 2016). As outlined earlier, this approach encourages teachers to explore, experiment, and take risks to make sense of how digital technologies can support learning outcomes. Leaders providing time and space for teachers' learning and experimentation reaffirm to teachers that their learning is valued. Some specific strategies for school leaders to encourage may be engaging in action research, collaborating with colleagues and students, and/or joining an established online community. These practices can help teachers make sense of their beliefs about IT and about the relationships among teaching, learning, and technology. However, some other considerations must be made to implement a learning design perspective of change, supported by a culture of experimentation, and to foster sustainable technology integration at a school level.

Adopting Real Teacher Learning in Schools

Having established that technologically-focused professional learning is ideally constituted by an active, collaborative, authentic, and ongoing process based on a teacher's personal beliefs, professional goals, and contexts (Desimone 2013; Wei et al. 2009), we now turn our attention to the question of how teacher professional learning, specifically use of PLNs, can be supported in school settings. To do this, school leaders need to negotiate a range of tensions relating to learning about, with, and through technology, model inquiry, take steps to create a culture of experimentation conducive to teacher learning, and support innovative technology integration (Jones and Dexter 2016).

Learning About Technology: Some Tensions

Teachers' technology-related learning often features the language of "integrating" IT into teacher practice. Over the decades, authors writing about professional learning have argued that "it's not about the tools, it's about the pedagogy" and "pedagogy before technology." More recently, it has been argued that digital technologies should support meaningful, twenty-first century teaching and learning, "which enables students to construct deep and connected knowledge, which can be applied to real situations" (Ertmer and Ottenbreit-Leftwich 2010, p. 257). The intent of these declarations has been to counter previous leanings toward technological determinism, by positioning digital devices and online materials in a way that they may be used meaningfully to support learning. This also emphasizes the importance of "avoiding simplistic claims about impact, effect and technical causation" (Oliver 2011, p. 382). The aim is to have teachers, as part of sensemaking, consider, for example, why they should bother getting students to use a device for personal note-taking when a pen and paper would easily suffice and perhaps be more efficient.

Oliver (2011) acknowledges that moving beyond technologically deterministic accounts of technology in learning "does not mean [believing] that technology has no properties" (p. 382). IT integration objectives can ignore critical realities for teachers' professional learning, such as ways in which technology practices are changing the learning environment, including:

- Sharing learning in public spaces
- Collaboration in on and offline spaces
- New dynamics between students and teachers
- New digital and media literacies

With teachers' values and beliefs about digital technologies in learning being a key barrier to engagement with professional learning (Ertmer and Ottenbreit-Leftwich 2010), the tension between acknowledging the impact of technological change and contexts in which change occurs and learning is constructed is one that requires informed and reflective navigation by teachers and school leaders. Using the learning design framework, school leaders can work with teachers to address the "what, how, and why" of technology-related change. As part of this process, robust discussions about the relationship between technology and pedagogy should be encouraged, with a strong focus on learning goals. This should form part of making technology-related change as important, in a culture of experimentation and professional learning.

However, the extent to which external frameworks can be applied at the school level to frame teacher learning is another point of tension for educators. For example, conceptual frameworks such as the technological and pedagogical content knowledge (TPACK) model (Mishra and Koehler 2006) are one source that educators might look to for guidance on how to conceptualize the relationship between technology and pedagogy. The TPACK model can provide some explanatory potential in relation to teachers' use of technology. However, in regard to professional learning, there are problems with how the TPACK model compartmentalizes teachers' professional knowledge and IT knowledge and makes unnecessary distinctions made between pedagogical and content knowledge. Placing these components into categories presents an "attempt to reduce the complexity of education phenomena, and which are too often used to standardize practice" (Bulfin et al. 2016, p. 122). The tension that school leaders face between the explanatory and reductive powers of frameworks and standards is an area that requires attention in schools seeking to grapple with the complexity of teaching, learning, and technology integration (Phelps and Graham 2010).

Further, broad application of frameworks or highly structured reform in schools has the potential to be in direct conflict to the flexibility and personalization of professional learning. Critics of standards-based education reforms have expressed concern about compliance mechanisms and professional standards inhibiting inquiry-based learning by imposing control and prescription on teacher professional learning (Parr 2010). A prescriptive approach is likely to erode the professionalism and agency of teachers by intensifying teachers' work, emphasizing compliance and conformity, and reducing teacher control. However, this is not to say that frameworks or standards of practice do not have a place in professional learning. School leaders would want to consider how frameworks align with existing school strategic goals and initiatives. School leaders should discuss adoption of an explicit framework to support technology integration and change with their teachers, to determine if particular tools are appropriate for their beliefs about integration, teaching context, and learning goals (see also McLeod, ▶ Chap. 35, "Technology Integration, Leadership, and Organizational Support Frameworks for Instructional Improvement with Information Technology," this volume).

Models for Building Capacity and Personal Learning Networks

The disruptions caused by theoretical and practical tensions provide opportunities for teachers and school leaders to have conversations, question pedagogical assumptions, and think critically about professional discourses and learning. However, schools require a culture of trust that is open to risk and experimentation for such conversations to occur and lead to professional learning (Howard and Gigliotti 2016). Tensions relating to technology integration can be effectively negotiated in schools that are conceptualized as *learning organizations* (Opfer and Pedder 2011; OECD 2016), drawing on communities and networks as needed to learn individually and together.

The Organisation for Economic Co-operation and Development (OECD 2016) proposes an integrated model of schools as learning organizations. This model offers four transversal themes – trust, time, technology, and thinking together – underpinning these seven action-oriented elements (OECD 2016, p. 1):

- Developing and sharing a vision centered on the learning of all students
- Creating and supporting continuous learning opportunities for all staff
- Promoting team learning and collaboration among all staff
- Establishing a culture of inquiry, innovation, and exploration
- Embedding systems for collecting and exchanging knowledge and learning
- Learning with and from the external environment and larger learning system
- Modelling and growing learning leadership

These themes and elements highlight the values and processes that tend to be evident within schools that are transforming into a learning organization. This model constructs the learning organization as a broad community of practice, with student learning as the common learning goal and team learning promoted within the community around more specific areas of inquiry. A strength of the OECD model is that practitioners are acknowledged as existing within a socially situated environment – the school – but also explicitly encircled by a network of external connections such as parents, local community, and other schools in their network. The model highlights the importance of information flow between and beyond schools, which can be supported through the development of strong teacher PLNs, employing a range of learning resources. The range of resources and support structures available to teachers to support continuous, collaborative, and personalized learning should be promoted in the school as a valid and valued approach to professional learning. While individual teachers may participate in professional learning on their own, "access, support and encouragement to participate are heavily determined by the school" (Opfer and Pedder 2011, p. 393).

Further, the OECD model recommends that schools as learning organizations establish a culture of inquiry, innovation, and exploration. Such a culture of experimentation requires understanding the subcultures within a school and possible formal and informal leadership roles of those groups and networks (Howard 2013). Formal groups may be led by school principals and other administrators and assigned by disciplines, grade levels, or faculty room locations. Informal teacher-organized groups are more likely to be based on teachers' interests, values, practices, and beliefs about learning. How well school leaders are able to align formal and informal networks in schools will have implications for creating a culture of experimentation and learning. In both types of groups, leaders need to foster inquiry and experimentation.

An orientation toward inquiry and experimentation can empower teachers to take up professional learning that is in the service of contextualized and situated problems relating to learning goals. This supports the notion that technology integration is really about solving a learning or teaching problem. Identified leaders in both formal and informal networks can employ reflective questions to direct teachers in their cycle of design, enactment, and study to collect evidence of "what is going on" for their learners, producing design knowledge incorporating common examples, patterns, and principles (Könings et al. 2010). Such approaches expect educators to operate as experts and knowledge producers. As part of fostering a culture of experimentation, school leaders would encourage and support teachers to develop robust PLNs as resources for this work. Through this mechanism teachers can access a wide range of international resources to identify and address questions in their technology-related learning designs and problem solving.

It is also important for school leaders to recognize the costs of technology-related professional learning. Trust et al. (2016) argue that "cognitive, social, affective and identity needs" (p. 16) must all be met in order to develop "whole teachers." Some research in the area of teachers' professional learning describes how acquiring knowledge of technology happens in relation to developing discipline/subject expertise (Ertmer and Ottenbreit-Leftwich 2010). This intersection of disciplinary concerns and technological solutions is important, and it presents a space where frameworks, such as TPACK, can be useful in conceptualizing implications and effects of these intersections. There is also an important intersection between teachers' personal and professional lives in professional learning (Cameron et al. 2013). The impact of personally significant events on teachers' learning trajectories can shape their professional needs. PLNs can provide the specific support needed for teachers' learning at various career stages and the increased ability to choose learning opportunities with direct relevance to classroom pedagogy.

To complement teachers' individual PLNs, school leaders can provide space for teachers to develop formal professional learning communities (PLCs) within schools, with a focus on providing high-quality learning opportunities and integrating informal professional learning. Dexter et al. (2016) found that these different types of opportunities within learning communities can be fostered by school leaders. In fostering PLCs, school leaders should keep in mind the role of different community configurations. Diverse learning communities will have distinct characteristics, which may offer different affordances for technology-related professional learning. Vangrieken et al. (2017) identified three types of communities: formal, member-oriented with a preset agenda, and formative teacher communities, additionally commenting on the impact of top-down or bottom-up realization. Informal learning that is initiated by the teacher, rather than being imposed from above, is reported as more oriented toward specific learning needs as questions and directions arise from community members (Vangrieken et al. 2017) and thus could be better suited for technology-related learning for specific learning goals. In a digital and networked culture, the potential for locating new communities, shifting identities, and accessing current information is vast.

School leaders can create bridges to those possibilities through the opportunities they create in formal learning, where they "model high-quality, informal, reflective practices and support the sharing of independent learning" (Dexter et al. 2016, p. 1202). While online communities may be difficult to observe or measure, school leaders can actively bring the work teachers do as a result of online interactions back to the school setting to be reflected upon and discussed. To insure that flexibility and personalization are part of teachers' PLNs, school leaders must focus on valuing both online and offline communities for professional learning. As previously outlined in this chapter, teachers are already using digital technologies and community-based approaches to support professional learning and develop communities. By encouraging PLCs, school leaders can create a priority in the school culture for teachers to consciously expand their PLN, with an aim to include both virtual and everyday physical environments and interactions. In doing this, they can increase the diversity and possible number of "weak ties" available to teachers that can be accessed for information, actively building their PLN, and to tap into information flow.

However, some teachers may need support in employing this type of professional learning strategy. To support teachers, simple online strategies can be shared across the school, such as employing the use of event or topic hashtags, as seen in TeachMeet events (Esterman 2013) and Twitter chats (Biddolph and Curwood 2016). These are already overtly used by some schools and professional associations to create event back channels for sharing information and reflections with a wider network. Teachers are typically quite good at engaging physically. Fostering a mixed approach to learning, through combining online with the more familiar in-person networks in a school, establishes the cultural value of engaging and learning online. Through this approach developing strategies for information seeking, problem-solving, and reaching out into teaching and learning networks is valued. Importantly, school leaders' practices should encourage teachers' work improving learning, refocusing technology integration, and harnessing ITs to be in the service of learning.

Conclusion

As Zheng et al. (2016) state, "as activity shapes the value of tools, tools simultaneously shape the nature of activity" (p. 2). Researchers have called for a refocusing of technology integration, away from just using IT, to instead be grounded in learning. If the success and effectiveness of technology integration are going to improve, school leaders need to support and encourage teachers to conceive of technology integration and change from a learning design perspective. Critical to this work is that teachers also engage in relevant professional learning and experimentation that support this aim.

As discussed, teachers are already engaging in professional learning. Learning happens through a range of formal, informal, independent, and on- and offline modes, which each have different affordances and support different interactions.

However, the question for school leaders is how to harness these different activities into a coherent approach to professional learning to improve technology integration. As a learning organization, school leaders can take an approach of embracing grassroots practices and the complexity of technology integration. Much of teachers' informal and independent learning is difficult to see and thus even more difficult for leaders to support across a school. Rather than focusing learning on any one tool or approach, the idea can be to embed a priority of learning and networking within an identified school change or policy related to technology integration. In particular, prior research proposed the idea that new classroom innovations, including technology integration, will be more effectively executed by teachers if they are included in a design process and provided with time to plan and reflect on the process. School leaders can involve teachers in technology-related program and design decisions, problem-solving, and troubleshooting at individual and school levels. They can do this by supporting teachers to work collaboratively, drawing on PLNs, and working online and offline to develop technologically integrated learning designs, foster inquiry, and a culture of experimentation around change and learning. Teachers are more likely to dedicate their time and energy in making the planned changes, from which they can control and directly benefit, and changes are likely to be more sustainable.

While the complexity of technology integration has traditionally made it difficult to affect change across school organizations, this chapter has outlined ways in which school leaders can address technology-related change from a learning design perspective. The aim of this perspective is to help teachers make sense of changing their practice and prioritize a culture of experimentation and learning through digital technologies. The most critical component of this approach is continued dialogue between school leaders and teachers and to continue engaging in the "what, how, and why" of technology-related change. The one constant of technology integration is that the technology will change, its role in learning will shift, and how it is used will be adapted. By school leaders and teachers always returning to a learning design perspective focused on what is the change, how are we changing, and why, it is possible for a school to keep pace with how they are using digital technologies to support learning in their context.

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Technology Integration, Leadership, and Organizational Support Frameworks for Instructional Improvement with Information Technology

35

Scott McLeod

Contents

Abstract

Leaders for IT can use integration, leadership, and organizational support frameworks to guide their planning or assess current conditions. This chapter introduces a number of useful frameworks for leading IT, provides a rationale for their use, and suggests how to put them into practice.

Keywords

Leadership · Technology integration · IT · Administrators

An increasingly important but often challenging responsibility of school leaders is the need to facilitate effective IT integration within their school organizations. Compounding the challenge is the fact that preservice preparation programs and in-service professional development initiatives infrequently pay robust attention to school administrators' learning needs in this area (Dexter et al. 2016; McLeod and

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Richardson 2011). Fortunately, school leaders have a number of different IT integration, leadership, and organizational support frameworks available to them to help guide their instructional improvement work with classroom educators and students. School administrators and instructional coaches will find that different frameworks have different purposes and thus should be used in ways that best align with organizational needs and contexts. The sections that follow describe some of the available frameworks and offer suggestions for how they might be utilized by principals and other instructional leaders to improve building- and classroom-level IT integration.

What Are *Learning and Teaching* Frameworks for Instructional Improvement with IT, and Why Use Them?

The dominant IT integration model utilized by instructional technology researchers and faculty members is the Technological Pedagogical Content Knowledge (TPACK) framework. Extending the work of Shulman (1986), Mishra and Koehler (2006) noted that optimal IT integration occurs when educators operate at the intersections of their pedagogical, content, and technological knowledge. TPACK is useful as a mental model but is relatively ambiguous regarding guidance for instructional design and also is fairly unknown by PK-12 educators. The International Society for Technology in Education (ISTE) standards for students (ISTE 2016), teachers (ISTE 2017), IT coaches (ISTE 2011), and administrators (ISTE 2009) are more visible to PK-12 practitioners and are attempts to delineate the IT integration understandings and skill sets desired of educators. Similarly, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has outlined IT competencies for teachers (2011).

Taking a slightly different approach, Dexter's (2002, 2005) Educational Technology Integration and Implementation Principles (eTIPs) offered three principles that teachers should use to guide their instructional decision-making when considering the use of IT in the classroom. They were based on the premise that teachers acting as instructional designers must consciously plan for the use of the technology if it is to support student learning. The first principle is that learning outcomes should drive the selection of IT. The second is that IT should be integrated only when it adds value to teaching and learning. The third principle is that IT should assist in the assessment of learning outcomes; for instance, by making students' thinking visible or allowing educators to capture versions of students' work during its progress.

Moving beyond general principles, mental models, or standards documents that articulate stocks of knowledge or skill that educators should possess, three other frameworks have taken a hierarchical or staged approach to the assessment of educators' IT integration efforts. Puentedura's Substitution Augmentation Modification Redefinition (SAMR) framework (2006) – arguably the most well-known model in PK-12 circles – postulated that, at the Substitution level, technology merely serves as a direct tool substitute, with little to no functional change. At the Augmentation level, technology begins to offer functional improvement, and at the

Modification level, technology allows for significant task redesign. At the top of the hierarchy, Redefinition, technology allows for the creation of new, previously inconceivable tasks. Many schools are attempting to use the simple SAMR continuum to help teachers move their IT integration efforts beyond technological replication of traditionally-analog learning activities, instead striving to utilize the new affordances of digital learning tools to engage in instructional work that would be difficult or impossible without IT. The SAMR framework is similar to earlier work done by Hughes (2005) and Porter (2001). Hughes et al. (2006) postulated a three-stage transitional framework of Replacement, Amplification, and Transformation (RAT), rooted in both conceptual research and the authors' analyses of classroom observations and teacher interviews. Similarly, Porter's Literacy, Adapting, and Transforming (LAT) continuum noted that, at early stages, teachers are rooted more in IT tool learning or replicative learning but then hopefully move into more adaptive and transformative uses. Both the RAT and LAT frameworks collapse the often confusing middle two categories of SAMR (Augmentation and Modification) into a single, transitional stage (Amplification or Adapting) between replication and transformation.

Two popular IT integration frameworks from the United States, the Florida and Arizona Technology Integration Matrices, added a second dimension for educators' consideration (Arizona K12 Center 2010; FCIT 2007). The horizontal axis of the matrices resembles the three- or four-stage continuums of the SAMR, RAT, or LAT frameworks but instead is broken into five integration levels labeled as Entry, Adoption, Adaptation, Infusion, and Transformation. The vertical axis of the matrices articulates characteristics of the learning environment. These characteristics represent descriptions of students' learning that can be enhanced by educators' IT integration efforts:

- *Active* – students are active users, rather than passive recipients, of IT.
- *Collaborative* – students use IT to collaborate with others.
- *Constructive* – students use IT to construct deeper understanding and share with others.
- *Authentic* – students use IT to engage in meaningful, real-world work.
- *Goal-directed* – students use IT to plan, organize, and reflect on their learning.

An educator thus could use the matrix to assess where she is along each of the characteristics and decide, for instance, that she wanted to work toward the Infusion level of students' collaborative work rather than her present level of Adoption.

Several other frameworks have overlaid conceptions of student thinking and activity with IT integration. For example, Churches (2010) created a continuum labeled Bloom's Digital Taxonomy that attempted to identify IT tools and uses that correspond with the six levels of educational objectives identified in Anderson and Krathwohl's (2001) modified version of Bloom et al.'s (1956) original taxonomy. In Churches' framework, using IT tools for filming, animating, and blogging would be more likely to correlate with higher-order thinking skills, while using them for highlighting, searching, and bookmarking would be more likely correlated with lower-order thinking skills. The Levels of Teaching Innovation (LoTi) framework from Moersch (1995) articulated a continuum of eight levels of teaching innovation: Nonuse, Awareness, Exploration, Infusion, Integration (Mechanical), Integration (Routine), Expansion, and Refinement. Higher levels of the continuum correspond with higher levels of cognitive complexity of student work. The LoTi levels also embed movement of student activities from teacher-directed and practice-based toward student-directed and problem-based (LoTi Connection 2016). Finally, Kimmons (2016) extended the RAT framework in his PIC/RAT model by adding a second dimension of student activity, ranging from passive to interactive to creative.

What Are *Leadership and Organizational* Support Frameworks for Instructional Improvement with IT, and Why Use Them?

While many IT integration frameworks are focused closely on classroom-level learning and teaching, some of the IT leadership and organizational support frameworks focus instead on building-level or system-level support structures. These frameworks are particularly relevant for school leaders because they recognize that IT-infused classroom activities are embedded within surrounding organizational contexts that can foster or impede the success of what happens between teachers and students. For instance, the Apple Classrooms of Tomorrow (ACOT) framework (Apple 2008) was created nearly a decade ago to help superintendents and principals think about systemic supports that foster effective classroom IT usage. The ACOT framework identified six design principles for “21st century” high schools: Culture of Creativity and Innovation, Relevant and Applied Curriculum, Informative Assessments, Social and Emotional Connection, 24/7 Access to Tools and Resources, and 21st Century Skill Outcomes. These design elements are intended to work in concert to formulate new conceptions of learning and teaching by modern schools and educators.

The ACOT framework explicitly embedded one of the more visible organizational support frameworks, the list of “21st century skills” identified by the Partnership for 21st Century Learning (2007). The Partnership created a famous “rainbow” diagram in which Core Subjects and 21st Century Themes; Learning and Innovation Skills; Life and Career Skills; and Information, Media, and Technology Skills constitute the core learning outcomes needed by 21st century students. In the framework, these core outcomes should be supported by appropriate and relevant Standards and Assessments, Curriculum and Instruction, Professional Development, and Learning Environments.

An additional organization-level view is the list of 14 “essential conditions” identified by the International Society for Technology in Education (ISTE 2000). According to ISTE, the organizational conditions necessary to effectively leverage IT for learning are Shared Vision, Empowered Leaders, Implementation Planning, Consistent and Adequate Funding, Equitable Access, Skilled Personnel, Ongoing Professional Learning, Technical Support, Curriculum Framework, Student-Centered Learning, Assessment and Evaluation, Engaged Communities, Support Policies, and a Supportive External Context. Similarly, a list of “essential conditions” was created by the North

Central Regional Educational Laboratory (Lemke 2002), those of Vision, Systems and Leadership, Effective Practice, Educator Proficiency, Access, and Equity.

In the United States, the Texas Education Agency took a different approach with its Technology Immersion Model (TIM), noting six critical – and primarily technological – components of effective IT immersion: Hardware, Software, Digital Content, Online Assessment, Technical Support, and Professional Development (Hanover Research 2013). The latter two components are more oriented toward the human side of the organization rather than the technical. Finally, the Future Ready Framework (U.S. Department of Education, Office of Educational Technology 2014; Alliance for Excellent Education 2015a) postulated that school districts must align seven key categories – or "gears" – in order to ensure successful digital conversions for "future readiness": Curriculum, Instruction, and Assessment; Use of Space and Time; Robust Infrastructure; Data and Privacy; Community Partnerships; Personalized Professional Learning; and Budget and Resources. All of these gears must work together to enhance IT integration and robust student learning. Although they are configured and organized differently, all of these frameworks explicitly recognize that surrounding contexts have significant impacts on instructional success.

How Might School Leaders Use IT Integration and Organizational Support Frameworks?

School leaders have several options for utilizing these IT integration and organizational support frameworks. For instance, schools that wish to inform their organizational restructuring and professional development initiatives could use one of several assessments to gather data on their systems and staff. Older assessments include the enGauge survey (Lemke 2002) and the Learning with Technology Profile Tool (NCRTEC 1997). Newer diagnostics include ISTE's Lead & Transform Diagnostic Tool (ISTE 2014), the Vision K-20 survey from the Software and Information Industry Association (SIIA 2008), the Clarity Technology and Learning surveys from BrightBytes (2010), the Future Ready District Assessment from the Alliance for Public Education (2015b), the Principals Technology Leadership Assessment (Anandan et al. 2005), or the School Technology Leadership Assessment (CANLEAD 2017). Schools then could align their findings, for example, with the ISTE standards and essential conditions, the TPACK framework, or the Future Ready Framework to assess organizational capacity and individual readiness for IT-related change efforts.

Zooming in closer to the classroom, the easiest – and probably most prevalent – mechanism would be for a school to utilize one of the basic continuums (SAMR, RAT, or LAT) to try and spark internal conversations about moving IT integration to be less replicative and more transformative of existing pedagogical practices. Many school administrators, instructional coaches, and technology integration coaches are doing this work daily, blending particular learning technologies into their instructional conversations as appropriate. Schools that find the relative vagueness of the continuums to be insufficient to guide their work could utilize one of the more specific frameworks, for example, either the Florida or Arizona Technology Integration Matrix – or the LoTi framework – to add depth and context to their conversations.

Several researchers have created resources that help school leaders and classroom educators go even deeper in their implementation of the models and frameworks described here. For instance, Hofer and Harris (2015; see also Harris and Hofer 2009) have done extensive work to describe various grade-level and subject-specific IT-supported learning activities that support implementation of the TPACK framework. These instructional exemplars can help PK-12 educators more concretely visualize TPACK's potential influence on their instructional planning and design work and classroom integration. Educators possibly could use the Digital Bloom's Taxonomy alignment of digital learning tools to higher-order thinking skills in a similar manner.

Another resource that can be helpful to school leaders' IT integration efforts is the 4 Shifts Protocol (formerly trudacot) created by McLeod and Graber (2018; see also McLeod 2015). The 4 Shifts Protocol is intended to facilitate teachers' thinking about the instructional purposes driving their IT integration decisions. Educators are asked to reflect on and discuss sets of questions that are designed to help them shift their classroom lessons, units, and activities toward deeper learning, greater student agency, more authentic work, and richer IT infusion. Additionally, Hutchison and Woodward's (2014) Technology Integration Planning Cycle, which emphasizes seven key steps that classroom educators employ in effective IT integration, can help guide educators' thinking and practice. Finally, the online Educational Theory into Practice Software case-based learning platform (www.etips.info) allows school leaders and teachers to immerse themselves into rich, descriptive, electronic cases of school- and classroom-level IT integration (Dexter et al. 2008; Tucker and Dexter 2011). School leaders can practice applying key IT integration, leadership, and organizational support principles within "hypothetical but realistic K-12 school settings" (Tucker and Dexter 2011, p. 251) in order to improve their own IT leadership knowledge and skills.

Taken together, existing IT integration, leadership, and organizational frameworks can accommodate a wide diversity of school settings and leadership needs. IT leaders can use these frameworks – along with some concurrent assessments and implementation resources – to help further the IT-related instructional initiatives that are occurring within their schools and districts. School leaders that utilize these frameworks in thoughtful and purposeful ways for assessment and improvement should see meaningful and positive impacts within their school organizations.

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36 Leading Information Technology via Design Thinking

John B. Nash

Contents

Abstract

Design thinking is a solution-finding process that offers a user-centric approach to find new, previously nonexistent solutions to persistent challenges people face in the adoption and implementation of IT. This chapter explains what design thinking is, why it would be of use to leaders of IT, and how to put it into practice in the leadership of IT.

Keywords

Design thinking · Human centered design · IT · Instructional technology · School technology leadership · Leadership · Schools · Schooling · Principals · Leadership

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What Is Design Thinking?

Some call design thinking a creative problem-solving process (Liedtka et al. 2013). I think calling it a solution-finding approach is more accurate. IT leaders who practice design thinking are able to find new, previously nonexistent solutions to persistent challenges they face in the adoption and implementation of IT, and the solutions which they develop tend to stick. This is because design thinking is a process that integrates three key tenets of innovation success: "what is desirable from a human point of view with what is technologically feasible and economically viable" (Brown 2009, p. 3). It's an appealing approach as it represents a set of tools which can be applied to a vast array of problems (Brown, 2011).

While there are several flavors of design thinking discussed in the literature (Boland and Collopy 2004; Brown 2009; Hasso Plattner Institute for Design 2010; Liedtka and Ogilvie 2011; Meinel and Leifer 2011), all have some central common features. For illustrative purposes, we'll draw on an approach advocated by the Hasso Plattner Institute for Design (2010). The tenets are:

Empathize. Empathy is the foundation of design thinking (Hasso Plattner Institute for Design 2010). Design thinking is a process focusing on creating solutions for others. Thus, you must have an empathetic understanding of the needs of the people for whom you are serving (IDEO 2015). For instance, it may be the case that integrating IT is a policy imperative in a school, but the manner in which you unveil that process can be greatly enhanced by involving students and teachers in the process because they are, ultimately, the users of the change.

Define. To define is to use the empathy you gain from the previous phase and craft an actionable problem statement. Once one understands the needs of the users who will be impacted by your initiative, you must define, from the user's point of view, the precise challenge your initiative is supposed to solve. Say you are interested in integrating IT into instruction in your district. And suppose other neighboring school districts have implemented a one-to-one laptop program. Do you just jump on their bandwagon? No. Implementing a strategy in the same fashion as it's done in other districts doesn't mean it will meet the needs of your stakeholders. Therefore, you should define the problem regarding what you hope for and what could work for your stakeholders. This leads to an actionable problem statement upon which you can brainstorm, or ideate, solutions. For instance, "How might we enhance students' success at finding and solving complex problems in social studies and science through integration of technology."

Brainstorm. To ideate is to brainstorm. It's the portion of the design thinking process wherein a great many ideas are developed to address the specific need you defined in the previous step.

Prototype. Once you have a feasible idea that seems worth trying, the next step is to create a prototype of the idea so users can play with it. The main benefit of creating a prototype is to provide a situation where you can fail quickly and cheaply. Testing the prototype of a curriculum idea, or an online learning environment with, say, one class over a week's time will tell you if users like it, whether it's feasible, etc., without investing a lot of time and money up front.

Test. Testing tells you if your prototype was on the right track. It also tells you more about the intended users of your design. By testing a prototype of a curriculum or instructional technology, you are offered another chance to build empathy for your users' needs by observing them in context.

Why Is Design Thinking a Tool Leaders Should Consider for Implementation of IT in Schools?

The leaders of modern primary and secondary schools tend to emanate from graduate programs of educational leadership which imbue them with a level of professional expertise. The results are a double-edged sword. On one edge, their expertise and knowledge of the field are vastly expanded. However, as Hess (2013) notes, this can create a cadre of decision makers who are thought-constricted in that "those who have spent their career immersed in the rhythms of any profession come to regard its policies, practices, culture and routines as givens" (p. xiii). The way IT is integrated into schooling is no exception. There are too many educational leaders who come into their position believing there is only one solution to every problem. Leaders who fall into this camp possess, according to Boland and Collopy (2004), a decision attitude. Such leaders:

- Believe there only exist a finite set of alternative solutions to problems, mostly provided by outsiders (other schools, vendors, the literature)
- Assume it is easy to come up with alternatives to consider, but difficult to choose among them
- Assume that the alternative courses of action are ready at hand
- Are lulled into the belief that there is a good set of options already available, or at least readily obtainable
- Are trapped in a role as a passive decision maker, making the untenable assumption that the alternatives presented in advance include the best possible alternatives

Contrast this with leaders who describe as having a design attitude (Boland and Collopy 2004). These kinds of leaders:

- Work with stakeholders to develop custom solutions that are not known at the start
- Are concerned with finding the best answer possible, given the skills, time, and resources of the team
- Develop alternatives for local conditions, thus decisions about which alternative to select become trivial
- Take for granted that the initiative will require the invention of new alternatives
- Know that their stakeholders are best suited to say what their needs are and options are created based on those needs

- Are active designers of a team of decision makers who help develop alternatives that have not yet been thought of and are usually better

In essence, design thinking can add value to the way IT is adopted and integrated into students' learning by broadening the spectrum of possible solutions that are both more innovative and more tailored to student needs.

How Might School Leaders Incorporate Design Thinking into Their Leadership Practices?

What follows is an approach for how leaders can use of design thinking to support thoughtful school-wide adoption or implementation and classroom integration of IT. Since 2010, I have applied the tenets of design thinking to challenges faced by school leaders which fall into a broad category of student agency and IT. The idea of this effort is as follows: school leaders empathize with students (from all grade levels) to better understand their lives, and treat them as partners in the policy process, to better adopt and integrate IT for learning. This involves two things IT leaders rarely do:

1. Taking the time to empathize with students
2. Treat students as trusted partners in the policy planning and implementation process

Finding ways to empathize with students doesn't take as long as leaders may fear, but it goes beyond the hackneyed approach of student sounding boards principals tout, often comprised of safe, high-performing college bound students (Holdsworth 2000; Thomson and Holdsworth 2003). This involves purposeful selection of students from the margins, high and low, along with equally purposeful dialogue designed to elicit information which leads to unique and workable solutions to tricky challenges, like getting IT right.

Let me summarize how we do it, and I'll point you to a handout you can use to try it yourself:

1. Block out about two and a half hours on a particular day.
2. Identify around a dozen students to interview, picking firstly from the edges, or extremes. Therefore, one-third of the students you select should be on the high side of the continuum you're concerned with. These might be students who "fit the mold" or are typically thought of as being "ideal" for school. Then, one-third should be from the other extreme – those who may not always be a "fit" for school, or who struggle (or rebel) for one reason or another. Lastly, one-third should be from somewhere in between ("average" students). Then select a set of teachers and administrators who will interview the students. Create design teams

of three to four adults who are joined by one to two students (say, six to ten teams).

3. Conduct empathetic interviews with the students. There are many ways to gain empathy with another person, and a good way to do is by having a good conversation. I use a framework developed by IDEO (2011) called “Open Specific, Go Broad, Probe Deep.” Interviews take between 20–40 min.
4. Unpack what was said during the interview and prove to the students you heard them. In this phase, the adult interviewers take a few moments, in the presence of the students, to unpack what they heard and restate it to the student interviewees. The students indicate whether the interviewers “got it right.”
5. Codesign the problem. At this stage, the students become full members of the design team, or “codesigners.” Participatory codesign is a technique which enhances the likelihood solutions will stick by leveraging the insider knowledge of the user (in this case, the students). As a team, the members define the precise challenges that should be solved, based on constraints posed by the organization and the new empathetic understanding of the users.
6. *Brainstorm*. Using the challenge statement created in the previous step, usually framed as a “How might we...” question, team members develop scores of potential solutions in a matter of minutes. I press teams to develop 50 ideas in 6 min.
7. *Prototype*. Based on how fruitful the brainstorm was, teams harvest the brainstorm for one or two key ideas they’d like to prototype. Teams develop something to show the group, be it a model, storyboard, role play, or diagram.
8. *Get feedback*. The most promising prototypes are “shopped around” the school by teams asking for feedback from a broader set of stakeholders. The information obtained is used to improve the prototype and inform a decision on whether to take it to scale.

Try It Out

Here is a link to my workbook, “Improving School Tech with Student Agency via Design Thinking,” which describes the steps above and includes interview questions and team tips: http://dlab.us/it-designthinking.

Conclusion

IT solutions for teaching and learning have been a part of education for decades, and as a staple of schooling will likely remain a steady future investment. School leaders should seek a strong return on such an investment, in terms of both cost and student learning. Partnering with students, teachers, and others as codesigners, through design thinking, can lead to IT implementations which are more desirable, feasible, and viable.

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Appreciative Inquiry: Building on Strengths for Integrating Information Technology in Schools 37

Megan Tschannen-Moran and Mark Hofer

Contents

Abstract

Appreciative inquiry is both a philosophy and a process for fostering individual and whole-system change by focusing on strengths and what is going well rather than on dwelling on problems, gaps, or discrepancies. It provides IT leaders with a helpful lens to engender conversations and a shared vision to consider what IT efforts might uniquely support teachers and students.

Keywords

Appreciative inquiry · Technology integration · Innovation · Imagine · Design thinking

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What Is Appreciative Inquiry?

Appreciative inquiry is both a philosophy and a process for fostering individual and whole-system change by focusing on strengths and what's going well rather than on dwelling on problems, gaps, or discrepancies (Watkins et al. 2011; Whitney and Trosten-Bloom 2010). The thesis of appreciative inquiry is that by exploring and amplifying strengths, an organization can overcome the problems and gaps more effectively than by focusing on the problems directly. By inquiring into the dynamics that allow the organization whatever successes it currently enjoys, participants can amplify and build on those strengths. It builds collective efficacy and ignites the imagination of participants as to what might be possible in the future. The introduction and expansion of the use of educational technologies is especially well suited for the use of appreciative inquiry because of the heretofore unheard-of affordances and new possibilities that they make possible in schools.

Although it may seem counterintuitive to focus on strengths, especially if things are going poorly, there is a robust research base that attests to the effectiveness of this approach (Cooperrider et al. 2008). Developed three decades ago at Case Western Reserve University, Appreciative Inquiry has been used around the globe in arenas as diverse as international aid organizations, social services, major corporations, and the military, it is less well known in the realm of education. However, a fledgling research base in education has begun (Dole et al. 2014). Growing out of the tradition of action research, the practices of appreciative inquiry are undergirded by five interrelated principles (Watkins et al. 2011):

1. *The Positive Principle* asserts that there is real power to transform problems simply by shifting the focus to identifying, appreciating, and amplifying the strengths inherent in the situation and the people involved. So even if the initial motivation for considering the introduction of a new instructional technology is to remediate students who are falling behind, to close achievement gaps, or to increase the engagement of students who have mentally checked out, the positive principle suggests that investigating the most successful current practice will lay a more solid foundation for new initiatives than digging in to identify the root causes of those gaps or disengagement. If providing students with more opportunities for differentiation and extension activities is valued, then finding examples of where blended learning has been successfully implemented will foster the kinds of conversations that inspire teachers to expand on these practices. By bolstering the collective efficacy of teachers, this positive approach broadens thinking, expands awareness, builds resilience, bolsters initiative, and generates new possibilities. It helps to provide a meaningful purpose for considering how IT can support the collective vision of the school.
2. *The Constructionist Principle* asserts that positive energy and emotion are constructed when people have positive conversations and interactions. When conversations focus on problems and the underlying causes of discontent, people are likely come away feeling glum and discouraged, while interactions that focus on possibilities and a vision for a positive future leave people feeling hopeful and

energized. The PLAYDATE model (Magiera et al. 2013) for IT exploration for teachers is a good example of the constructionist principle in action. PLAYDATE is a different type of informal conference that provides a space for teachers in a local area to come together explore multiple educational technologies. Rather than offering structured sessions, keynote addresses, or even a schedule, PLAYDATE encourages teachers to play, tinker, and explore together. It provides a positive and playful way for teachers to discuss new ideas and approaches to integrating new technologies in their work.

3. *The Simultaneity Principle* claims that conversations and interactions become positive in new ways the instant we ask a positive question. A search for the root causes of problems often ends up identifying culprits, thereby initiating a barrage of finger-pointing and defensiveness that detract from the creativity needed to confront complex challenges. Asking about aspirations and possibilities generates a vision of a positive future, grounded in the strengths of the present. These positive conversations foster collective efficacy by directing attention to the things that teachers know and do well. Asking teachers to reflect on their most positive experiences with infusing IT to support their own or their students' learning cultivates greater openness to consider new uses than dwelling on frustrating or even disastrous experiences in the past.
4. *The Anticipatory Principle* asserts that positive questions and reflections flow from a positive outlook. In the absence of hope, it is hard to seek out, much less to celebrate, the positive. When we anticipate a positive future, however, we become more creative, resourceful, and resilient in looking for ways to bring that positive future into existence. The more concrete and real the image, the more yearning and movement it creates. When the educators in an underperforming school catch hold of a clear and compelling vision of the school as a vibrant learning community infused with new technological tools to support the learning and growth of their students, they cultivate a sense of optimism and an increased sense of collective efficacy in moving forward toward that vision.
5. *The Poetic Principle* invites us to become mindful of what adds richness, texture, depth, beauty, significance, and energy to life. Poets draw our attention to the simple, ordinary aspects of our lives in ways that imbue them with a sense of meaning and purpose. By focusing on the ways current reality is aligned with our core values and our sense of purpose, life becomes a work of poetry. A maxim from appreciative inquiry reminds us that "what we appreciate, appreciates." When we focus on problems, we see more problems. When we focus on possibilities, we see more possibilities. Appreciating the ways that new technologies have enhanced our lives in the past and in the present can foster the curiosity, openness, and courage to explore new more challenging technologies in the future.

Taken together, these five principles form the rationale for abandoning well-worn practices of examining the ways that individuals and systems are falling short of our aspirations, and to instead to focus our attention and energy on building upon the existing knowledge and strengths present.

Why Is This Something Leaders Should Consider for Implementation of IT in Schools?

In K-12 schools today, educational technologies are integrated with a variety of aims: to engage students in personalized and adaptive learning often designed to close the achievement gap; to help them develop twenty-first century skills; to enable students to explore problems through inquiry, and many more. Whatever the aims, it is important to remember that technologies are not neutral (Nye 2007). Schools are complex and interdependent ecologies, where the introduction of new variables influences the whole system (Nardi and O'Day 1999). Thus, the introduction of new technologies shapes the learning experience for students and teachers.

Instructional technology tools and resources are imbued with values and assumptions about teaching and learning. For example, personalized and blended learning models provide opportunities for students to learn at their own pace, place, and mode in ways that are difficult, if not impossible, in a traditional classroom (Means et al. 2013). Engaging students to grapple with real problems using analytical tools and data similar to that used by professionals creates a sense of authenticity and relevance for students (Jonassen and Hung 2015). In both of these models, however, there are foundational assumptions about teaching and learning. There are assumptions that through increased autonomy and relevance students will be motivated to do sustained rigorous work. There are assumptions about the role of teacher as facilitator – or activator – that fundamentally alters how teachers interact with and guide student learning (Fullan and Langworthy 2014).

What often is not taken into account with many of these IT-supported initiatives is the unique context, culture, and ecology of the schools in which they are operationalized. How do schools and districts initiate these new efforts? In some cases, new initiatives spring from lagging test scores or decreased student engagement. In others, there is what Papert (1987) terms a "technocentric" focus on the affordances of new technologies that can supersede a focus on larger issues related to teaching and learning. In many cases, these new initiatives are instigated and implemented in a top-down fashion that does not reflect the unique culture and potential of schools, teachers and students. Appreciative inquiry provides a helpful lens to engender conversations and a shared vision to consider what IT efforts might uniquely support teachers and students.

How Might School Leaders Incorporate Appreciative Inquiry into Their Leadership of IT

School leaders who marshal the principles of appreciative inquiry to guide their IT leadership in schools and districts are likely to experience a very different energy surrounding those initiatives than from more traditional top-down approaches. The Four-I cycle is one of several models of appreciative inquiry that can offer a productive and joyful way to connect instructional technology to the purpose and values of school (Watkins et al. 2011). In the section below, we offer the template of an appreciative inquiry exercise informed by design thinking principles (Brown 2009) that can be used in any context.

Initiate: Focusing on Strengths

The first I, *Initiate*, involves the choice to use a strengths-based approach to addressing an area of concern. In focusing on IT integration, it is equally important to make a conscious choice to put the shared vision for teaching and learning ahead of particular IT tools and resources. It is essential to agree at the outset to allow the appreciative inquiry process to drive the selection and focus for IT, rather than the other way around. For example, a new superintendent may express an interest in making a substantial financial investment in new IT tools in order to improve mediocre student outcomes. Before dashing out to the next technology expo, appreciative inquiry would invite the educators in this system to consider their hopes and aspirations for supporting student growth and learning and then design an inquiry into ways that those aspirations are already being enhanced by the IT currently in use. The clarity that will emerge from this inquiry will guide the planning for new IT initiatives tied to these aspirations rather than getting wooed by the razzle dazzle of IT that may be impressive but are not aligned with the most salient learning goals of the district.

Inquire: Sharing Uplifting Stories

After the decision is made to use a strengths-based approach, as well as the focus of inquiry, the next step is to design an interview protocol that will “map the positive core,” discovering instances of strength and success in the area of inquiry (Whitney and Trosten-Bloom 2010). Appreciative inquiry is a deeply participatory process that seeks to engage as many stakeholders as possible. Therefore, the second I, *Inquire*, begins with conducting paired interviews in which people interview one another about the focus of the inquiry. Rather than taking a group of district leaders to an offsite location to sit around a conference table to discuss the learning and IT needs of the district, school leaders, teachers, students, and parents are all invited to tell stories and explore the positive experiences they have had when IT enhanced their learning and growth. An interview protocol is developed to invite the exploration of those positive experiences in the past as well as the core values, generative conditions, and aspirations for the future. An example of such a protocol might be:

- Tell me about one of your best experiences of learning something new in which IT played a role. What were you learning and why was it important to you? What challenges did you face and how did you overcome them? What contributed to making that such a positive experience? Describe that experience in detail.
- When you are at your best, how do people, policies, or tools and resources in this school help you to learn and grow?

- What do you value the most about the learning environment in this school? In what ways are you able to contribute to the expression of that value in the life of this school?
- Imagine that you could transform teaching and learning in this school in any way you wanted. What would that look like? How might that change heighten the vitality and health of the school community? If you had three wishes for bringing your vision into being, what would they be?

If the appreciative inquiry is taking place in a face-to-face environment, when each pair has had sufficient time to tell and explore their stories as well as to appreciate one another's values and wishes, they join with two other pairs to form small groups. Each person then recounts briefly his or her partner's story, values, and wishes to the group. As the sharing unfolds, participants identify three to five themes that energized and enlivened them. These are shared with the large group and the themes are then grouped into similar meta-themes for the group as a whole. Colored dots may be used for each individual to indicate the three themes that most resonate or energize them. If the inquiry is taking place asynchronously online, and making use of technological tools to allow for the involvement of a larger number of people than could be gathered in one location, then after the paired interviews each partner might summarize their partner's stories, values, and wishes on a web form or in some creative way using other digital tools. These data would then be shared and analyzed for the most salient themes as a guide going forward.

Imagine: What If?

The next phase in the process, the third I, *Imagine*, participants may be invited to form groups around the theme that most energizes or inspires them. In this phase, each group develops creative images of what the school would look and feel like if it honored fully the themes selected and if the school were just as people desired. They convey those images through drawings, collages, music, or skits. Participants may be encouraged to use creative digital tools or other analog approaches. They then share those images with the group as a whole. Only after the groups have developed their creative images of the future, do they attempt to articulate them in a set of bold claims for the school, framed as though these new aspirations were already fully expressed in the school.

Innovate: Taking Action

In the fourth phase of the process, *Innovate*, small groups convene to design and plan action steps for moving the school closer to the beautiful, vivid images that participants developed in the *Imagine* phase. It can be helpful here to think smaller rather than bigger. Rather than trying to put major new IT initiatives in motion all at once, it can be more productive to consider small "hacks" to build momentum towards realizing the aspirations identified in the Imagine phase. In this way, it can be easier to take the first steps, reflect, iterate, and move the vision forward, one small step at a time.

As the planning progresses, participants designate the responsible parties for each action step, schedule activities, identify locations, and plan the logistics of getting things done. Strategies over which the team members have control are listed as Commitments. Strategies that require the involvement, permission, or resources from another party are listed as Requests. The process is not complete until all these logistics are captured in writing. Once the school has tried the suggested innovations, the process can begin all over again. It is an iterative, ever-evolving process of organizational learning, growth, and change.

Logistically, the four phases of the AI cycle could be completed in a day-long planning and development summit or across several shorter meetings over a longer period of time. The creative use of IT can allow for the participation of an even broader array of stakeholders than might be possible in a single event. Whatever the logistics arrangements, the *Appreciative Inquiry* process provides an inspiring and engaging way for educators and their constituents to engage in productive conversations to explore their visions for their schools and the role that IT can play in enhancing those visions. This process keeps the focus on the curriculum-based learning needs and opportunities. Instructional technology is then utilized to support those goals rather than to drive the learning experience.

Conclusion

We live in magical time in which technological advances make possible previously unimaginable feats. It is easy to get caught up in the razzle dazzle of technological tools and programs and to lose sight of the teaching and learning goals the technology is meant to serve. Investing the time and energy to imagine together how technology can support the collective aspirations of a school community can focus the positive energy of that joint attention and put the magic to work in service of our highest hopes and dreams.

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Teaching as a Design Science: Teachers Building, Testing, and Sharing Pedagogic Ideas

38

Diana Laurillard

Contents

Abstract

Approaching teaching as a design science encourages teacher collaboration, to harness the inquiry that goes on every day in classrooms and channel it into shared knowledge that could benefit the whole community of teachers. This chapter explains what teaching as a design science is, why leaders of IT should consider it when implementing IT, and how to put it into practice in their leadership of IT.

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Teaching as a design science · Pedagogy · Teacher collaboration · Learning design · Teacher professional development · Blended learning · Conversational framework · Learning designer · Pedagogical content knowledge · Design science · TPD · Online learning · Learning technology

What Is Teaching as a Design Science?

Educational researchers have tried hard to influence teaching, and with some success, but never with the resounding large-scale improvements that teachers and researchers all want to see (Morris and Hiebert 2011). In part, this is because pedagogic content knowledge development "is a complex process that is highly specific to the context, situation, and person" (Van Driel and Berry 2012). Teaching knowledge cannot be reduced to a set of guidelines or captured on video by "expert teachers." These techniques may help, but they do not assure improvement.

At the same time, our education systems could be seen as massive uncoordinated experiments, where every day, every teacher has the opportunity to try out and test new techniques and learn from their students what works and what does not. The idea behind "teaching as a design science" is to acknowledge this: to formalize and celebrate an approach to teaching that enables teachers to innovate, test, and share their teaching knowledge. If teachers were to share, test, and build on each other's learning designs, teaching would be a design science – "improving its practice, in a principled way, building on the work of others" (Laurillard 2012).

Seen as a *design science*, teaching can then harness the inquiry that goes on every day in classrooms and channel it into shared knowledge that could benefit the whole community of teachers.

It is certainly feasible. The next three sections show that teachers are already adopting a more collaborative approach to teaching innovation, and there are now digital tools and online communities to support this activity.

Teacher Collaborative Inquiry

Teacher professional learning is increasingly seen as a socio-constructivist activity that shifts the focus from *what can be done for teachers* to *what teachers can do for themselves* (Makri et al. 2014; Najafi and Clarke 2008; Van Driel and Berry 2012). The research shows that:

> teachers' learning is facilitated and sustained in communities that are collaborative endeavors, acknowledge and value participants with different levels of expertise, and focus on practice-related issues. (Najafi and Clarke 2008, p. 244)

To go beyond local endeavors to the community as a whole, Morris and Hiebert propose an approach to improving teachers' methods of teaching by creating and sharing artifacts or instructional products (Morris and Hiebert 2011). Such an approach enables understanding to be accumulated over time. Teachers and researchers create materials, try them out, and "feed the information from the trials back into the products"(Hiebert and Morris 2012).

This iterative process of collaborative sharing of scholarship-informed practitioner knowledge could be the key to reconfiguring teaching as a design science, because it addresses the challenge of teacher-led inquiry (Laurillard 2012). It helps teachers build their knowledge of teaching by encouraging them to engage in the production and continual improvement of ideas of value to the community. Teachers work in "design mode" (Hong et al. 2009), with a collective goal of innovation and knowledge advancement (Scardamalia and Bereiter 2010).

Teachers are not so much scientists – who try to understand how the world works. They are more like engineers – who try to make the world a better place. Like engineers, they use science, where it improves what they do. And like engineers, they use feedback, redesigning their teaching in the light of what happens in practice. "Design engineers" – the term suits what teachers actually do.

A recent report on 10 years of research on professional development of teachers emphasized the value of the collaborative sharing of practice in teacher networks and identified the importance of tools, especially digital tools, to support professional learning (Avalos 2011). Others suggested that "knowledge sharing" could transform educational institutions into "learning organizations" (Argyris 1994; Buckley et al. 2004). Collaborative teacher inquiry is a significant change in professional development because it means that teachers can move progressively from their teacher-centered thinking toward more student-centered actions (Butler and Schnellert 2012; Chang et al. 2015).

Teacher collaborative inquiry was recently advocated as policy for the profession in the USA (United States Department of Education (USDoE) 2014). However, unlike engineers, teachers have few tools to support professional learning their design work.

Learning Design Approach and Tools

Over the last 10 years, the development of digital tools to support teachers' use of effective pedagogy has been driven by the need to represent learning designs in digital form (for example, the Learning Designer (http://learningdesigner.org/) is a freely available online design tool for teachers), to make it feasible for teachers to share good pedagogical practice online (Masterman et al. 2013). The learning design approach to planning teaching and learning activities enacts exactly this kind of collaborative inquiry. It enables teachers to make their intuitive processes both visible and shareable (Ghislandi and Raffaghelli 2015) and encourages them to be more learner centered (Dobozy 2013). The digital form of learning design promotes high-quality learning activities and reduces the investment of design time (Agostinho 2006), because the design work is shared across the community.

However, these digital tools have not yet been widely deployed in the educational mainstream (Masterman et al. 2013). So while digital tools for learning design have become more sophisticated, allowing teachers to discuss, redesign, and reuse learning designs on the small scale, it is not yet clear how easily they can be adopted into the widespread daily practice of teaching and learning (Ghislandi and Raffaghelli 2015).

Online Teacher Communities

The potential for online technologies to support the development of larger communities of practice has prompted researchers to examine what they could do for teacher professional development (Lin et al. 2008; Matzat 2013; Zhang 2009), although they argue that the area is seriously under-researched (Dede et al. 2009; Schlager et al. 2009). Nonetheless, the evidence is slowly accruing that teachers value online communities for the exchange of ideas and links to resources (Duncan-Howell 2010; Rolando et al. 2014) and find that it encourages a more student-centered approach and the use of digital technology (Archambault et al. 2010; Vavasseur and MacGregor 2008).

The gradual shift toward the ideal of a widespread community for teacher collaborative inquiry is now transformed by the availability of massive open online courses (MOOCs). The pedagogic form of such courses is generally highly didactic for very diverse participants, but the platforms do also support discussion. Teacher development courses are more collaborative in nature and can achieve the significantly higher engagement of 30–40% of participants, in comparison with the modest 2–3% of most such courses (Laurillard 2016).

For the first time, therefore, there is a congruence between the digital tools to support the sharing of pedagogies, the digital platforms to orchestrate collaboration on the large scale, and the ambition for teachers to be able to engage in collaborative inquiry. For the first time, teaching is viable as a design science.

Why Should Leaders Consider Using This for Implementing IT in Schools?

IT in schools typically begins with implementing the hardware and software and with good intentions to support teachers in using it. However, the good intentions fade fast. A recent United Nations Educational, Scienticif and Cultural Organisation (UNESCO) review of IT in primary education showed that in national policies the distribution of funding resource between human capacity and technical capacity always favors the latter (Kalaš et al. 2012). This makes no sense. Teachers play the principal role in changing how effectively learners learn, and they need good solid support if they are to succeed in the difficult task of harnessing technology.

The argument for using the idea of teaching as a design science goes like this:

- Schools must adapt continually to their changing environment.
- Schools must innovate to keep pace with the requirements of their context.
- Rapid technology change means that teachers must use collaborative inquiry to manage the workload required for pedagogic innovation.

Who else is there to work out what the new pedagogies might be, and how to make optimal use of continual digital innovations? Who is better placed to discover what works? How can teachers be seen as anything other than a professional community of designers who build on each other's best ideas to make progress in the face of continual change?

Schools Must Adapt to a Changing Environment

School leaders are aware that their school – the curriculum and its teaching – has to develop in response to the changes in the very complex social-cultural-political-economic-technological-financial environment it inhabits. All these forces create pressures and constraints, against which the school leaders are trying to construct a forward-moving vision for their school and their students. Continual responsive development is necessary, but rarely funded.

Schools Must Innovate

Innovation moves forward when there is the opportunity for professionals to collaborate, exchange ideas, experiment, and share the results. This is the model we are familiar with in the world of scholarship and research, as well as in many fields in which professionals have to adapt fast to changing contexts, such as architecture, engineering, policymaking, and IT design. The organization of schools, the configuration of classrooms, the curriculum, and the pedagogies have all undergone change and development in recent decades, but despite the increasing focus of national policies on the use of IT in schools, it is not being used to support the most powerful forms of learning (Ertmer and O'ttenbreit-Leftwich 2010). To do this, it is essential that teachers:

- Are involved in the change and development process
- Have the opportunity to develop their own beliefs and sense of self-efficacy with IT
- Have strong support from professional learning and from the management and culture of their school (Association for Learning Technology (ALT) 2014; Ertmer and O'ttenbreit-Leftwich 2010)

Governments have made little provision for such activities, and the responsibility for this quite dramatic shift in school practice has been left to the schools themselves in most countries. International surveys show that digital technologies have not yet been fully integrated in teaching and learning (Organisation for Economic Co-operation and Development (OECD) 2016).

Teachers Must Collaborate to Innovate

Innovation is costly and inevitably increases workload in the short term, even if there is a planned payoff in the longer term. It is especially difficult for schools to innovate when both policy and technology change at alarming rates. IT can be highly effective, but it takes time to learn how to best use it and embed it in the curriculum.

Collaboration spreads the cost of innovation. It accelerates successful innovation, as each teacher builds on the work of others, and contributes to building community knowledge. This is the model for science and scholarship, orchestrated through peer-reviewed academic journals and conferences. Teachers must also be innovators now. They need their own tools and support mechanisms to accelerate and distribute the responsive innovation schools need, as the next section shows. This is what it means to treat teaching as a design science.

How Might School Leaders Incorporate the Idea into Their Leadership Practices?

Academic studies repeatedly demonstrate the need for teacher self-efficacy in IT and more teacher development, but school leaders receive little support for making this a normal part of the school workload. However, given the now near-ubiquitous presence of IT communications systems and design tools, there are more ways of lowering the threshold of innovation. This section suggests how IT can support not just students in collaborative learning but teachers as well.

One approach is to use the *Learning Designer*, a tool for teachers that mirrors the academic journal process, by enabling teachers to build on what has gone before, experiment, innovate, test, redesign, test, and publish. It can work well as a useful adjunct to meetings and discussions.

A related approach is for staff to do a relevant massive open online course (MOOC) together, as a way of keeping up-to-date with developments in blending digital learning with conventional class and homework activities.

A Tool to Support Learning Design

The Learning Designer is a digital tool that supports a pedagogical knowledge-building community by creating a constructionist learning environment for teacher development (Laurillard et al. 2013). (The tool is open and free to all on simple registration at http://learningdesigner.org.) As "teacher-designers" (Goodyear and Yang 2009), they can use a knowledge-building process, building on the work of others in the community, developing and testing their own innovative ideas, and then sharing the results with the community (Ferrell and Kelly 2006; Laurillard and Masterman 2009). Being online, the community has the capacity to reach all teachers wherever they are.

The pedagogy underlying the tool promotes the appropriate inclusion of the six types of learning operationalized by the Conversational Framework (Laurillard 2012; Laurillard et al. 2013), giving them feedback on their design. As they plan the sequence and duration and for each activity select the appropriate learning type, a pie chart displays a graphic of the current balance of their pedagogy across learning through acquisition, inquiry, practice, discussion, collaboration, and production. In this way it prompts the teacher to articulate an optimal learning design, i.e., a sequence of teaching-learning activities for a specified learning outcome. Their design then becomes a digital object which can be shared with other teachers, adapted to other's contexts (Zhang and Laurillard 2015), and exported as a Microsoft Word document, or a plan for implementation in a virtual learning environment.

An Online Collaborative Teacher Development Community

For scaling up the collaborative inquiry process, MOOCs now offer the kind of platform that succeeds in engaging teachers in discovering and experimenting with new forms of learning, such as blended learning – mixing IT solutions with conventional teaching, both in class and at home. (A MOOC on *Blended Learning Essentials*, for teachers, runs on the FutureLearn platform: http://bit.ly/28RNQpI and http://bit.ly/2cV2Od9.) For example, there are two courses on Blended Learning Essentials: Getting Started and Embedding Practice. Teachers in schools and colleges have been following them together, as a school-based group, for example, so they can discuss the ideas as they apply to their own context.

The Learning Designer is used in both courses, as well as in MOOCs run by other platforms, where it has been embedded as a form of collaborative exercise for the participating teachers. The evaluations so far show that teachers are excited by the tool and willing to share their ideas and to adapt others' patterns to their own context.

Leadership Practice

What can the school leader do? It is most important to demonstrate the value the school leadership puts on teacher professional learning, on innovation, and finding out how to make optimal use of digital learning. Teachers are very good at helping themselves and are happy to run the whole process, once it is endorsed by the leadership team. Here is one way to approach it:

1. Propose a collective focus on blended learning or digital learning as a way of tackling a challenge of interest to the teachers, such as student motivation, class behavior, difficult concepts, and skills. It should be an issue of interest to the teachers where pedagogic innovation could have an impact.
2. Decide which MOOC(s) to look at and when (search for "ICT blended digital learning" through Coursera (https://www.coursera.org/) and FutureLearn courses (https://www.futurelearn.com)) to fit with the plan.
3. Plan a sequence of collaborative workshops over a term, each around an hour or so, and the series of workshops could go through the following sequence of activities:

   (a) Identify the good challenge(s) to work on and describe what you hope to achieve through a new pedagogical approach and the groups who will work together to do this.
   (b) Use a session to explore the Learning Designer tool: sign up, go to the Browser screen, and explore the Education designs; click on one and review it in the Designer screen; experiment with changing the duration of some activities to see how the pie chart changes; click on Turn editing on, and edit the design by changing the text, adding/deleting activities within a segment, and teaching-learning activities (TLAs), changing times, learning types, etc.; and save and export as a Word doc or as the code for others to use.
   (c) Explore other designs to see how they use digital resources, and look at some of the reviews as well.
   (d) Use the ideas from the MOOCs to plan a session that defines the learning outcome you want to achieve and uses blended learning, where you add a resource to define the uniform resource locator (URL) students will use and plan the activity around how they will use it.
   (e) Exchange and peer review other groups' designs, and reflect on the feedback you give and receive to revise your design.
   (f) Test it out in class, and note what happens.
   (g) Discuss the results in the next workshop session.
4. Report back to a plenary staff session on where to go next on embedding digital learning as a way of addressing teaching-learning challenges and how best to work collaboratively across the school to do this.

Such a program of within-school innovation could build slowly but would put the teachers in the driving seat of change.

Conclusion

Innovation is essential for schools to flourish in the face of unpredictable changes in political, financial, and technological forces. Teachers are best placed to innovate, because they can understand and discover what their students need, what works, and how to mix the old with the new. But they have never had the support and trust of the education system that would enable them to develop the program of teacher collaborative inquiry that could drive forward the effective innovation we need. By reconceptualizing teaching as a design science, supported and orchestrated by the right digital tools, we could define a new vision for a teaching workforce able to innovate and adapt effectively.

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Improvement Science Through Networked Improvement Communities: Leadership of Continuous Improvement with, of, and Through Information Technology

39

David H. Eddy-Spicer

Contents

Abstract

Improvement science through networked improvement communities offers leaders of IT a systematic approach to quality improvement in education, which can be applied when implementing IT in schools.

Keywords

Continuous improvement · Organizational learning · Networks · Participative decision making · Educational change

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What Is Improvement Science Through Networked Improvement Communities?

Improvement science through networked improvement communities (NICs) is an emerging approach to quality improvement in education promoted by the Carnegie Foundation for the Advancement of Teaching (Bryk et al. 2015; LeMahieu et al. 2017; Russell et al. 2017). Quality improvement has a longstanding history in industry and, more recently healthcare, as a rigorous and systematic means of continuously improving organizational processes, practices, and routines with the aim of bringing about sustainable change to programs, products, and services (LeMahieu et al. 2017, p. 5). Improvement science shares with realist approaches to research and evaluation a central concern for "how and why does this work and/or not work, for whom, to what extent, in what respects, in what circumstances and over what duration?" (Westhorp 2014, p. 4). It shares with Action Research an emphasis on building proactive knowledge through practitioner-based inquiry and learning as the means through which answers to that question might be addressed. Improvement science through networked improvement communities differs from Action Research by employing systematic and rigorous approaches to using evidence to understand what has happened and could happen through integrating evidence-informed improvement strategies into ongoing work.

Improvement science as a systematic approach to quality improvement in education is rooted in the work of W. Edward Deming (1986), particularly as those ideas have been taken up in healthcare (Health Foundation 2011; Lewis 2015; Langley et al. 2014). The improvement science cycle of inquiry resembles other cyclical inquiry processes in related disciplines oriented to improvement in education (e.g., action inquiry cycle; action learning cycle). In improvement science, the cycle of inquiry or "model for improvement" (Langley et al. 2014, pp. 23–25) is characterized as a Plan-Do-Study-Act (PDSA) cycle.

The Carnegie Foundation is not the first to promote Deming's work in education (Holt 1993; Leonard 1996); but its approach is the most ambitious in terms of spread and scale of improvement. The Foundation turned to the work of Douglas Englebart (2003) on knowledge networks as a potential means of rapidly increasing the type and scale of change within and across schools and school systems. Carnegie's approach advocates promoting the scaling up of proactive knowledge through networked improvement communities (NICs), which (Bryk et al. 2015) characterizes as scientific learning communities.

The Foundation has supported a series of "proof of concept" initiatives as what is now called the Networked Improvement Science (NIS) concept has deepened and broadened. Initially, the Foundation provided direct support for several NICs, such as the Carnegie Math Pathways NIC, the Building a Teaching Effectiveness Network (BTEN), and the Student Agency Improvement Community (SAIC), a network of NICs, and most recently in its support of the development of NICs by others in the field of education. The efforts of the Foundation are now focused on what it terms "field-building activities," most notably in the creation of networks of educators in

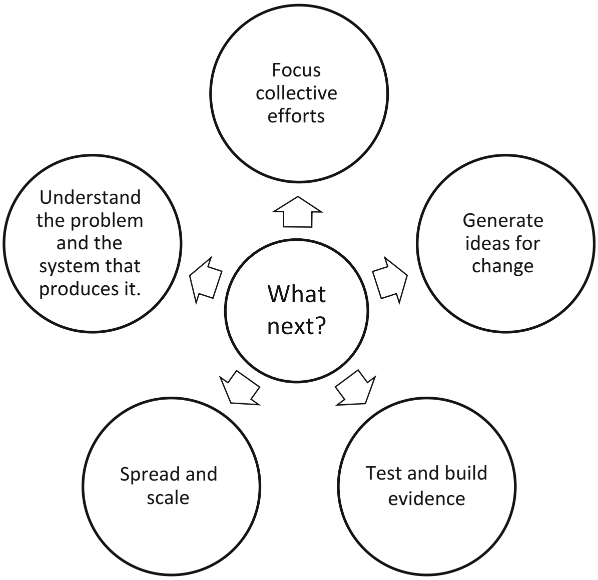

Fig. 1 Networked improvement science "Cheat Sheet" (Greenberg et al. 2017). (Used with permission © 2017 Carnegie Foundation for the Advancement of Teaching (CC BY-NC))

higher education who are designing and running courses and programs in improvement science for school leadership, the Carnegie Higher Education Network (HEN), and in support of higher education and school district partnerships through the Improvement Leadership Education and Development (iLEAD) initiative. Carnegie disseminates its approach through its annual Carnegie Summit on Improvement in Education and publications (Bryk et al. 2015; LeMahieu et al. 2017).

The aim of networked improvement science is to identify and solve problems. The systematic processes of improvement science enable practitioners to achieve this aim by focusing on high-leverage problems of practice (e.g., new teacher effectiveness, developmental math for community college students) and refining standard organizational processes and professional practices that might then be adaptively integrated across a wide range of organizational contexts (Mintrop 2016, p. 15). Associates at the Carnegie Foundation put forward an "Improvement Science Cheat Sheet" that encapsulates phases in an improvement process and corresponding tools and approaches (Greenberg et al. 2017) (Fig. 1).

The "hub and spoke" organization of this model, in contrast with the circular representation of the PDSA cycle, is to emphasize that improvement does not necessarily follow a linear path. Each phase begins with the central, animating question, "What next?" The typical trajectory of an improvement initiative would first involve understanding the problem and its root causes within a wider system. The other phases, however, need to be approached flexibly, and progress made contingent on what needs to be learned next to advance improvement efforts (Anna Kawar, 31 October 2017, personal communication). The phases are iterative and overlap in ways that respond to the learning needs of the improvement initiative.

The improvement science phases are distinct from other approaches to inquiry because of the six foundational principles they seek to cultivate and sustain:

1. Make the work *problem-specific* and *user-centered*.
2. *Variation in performance* is the core problem to address.
3. *See the system* that produces the current outcomes.
4. We cannot improve at scale what we cannot *measure*.
5. Anchor practice improvement in *disciplined inquiry*.
6. Accelerate improvements through *networked communities*. (Bryk et al. 2015, p. 2)

A common maxim in improvement work is that, “Every system is perfectly designed to get the results it gets” (Berwick 1996, p. 619). Donald Berwick, a leading figure in improvement science in healthcare, called this, “the central law of improvement” (1996, p. 619) underscoring the importance of the first three principles – emphasizing attention to the “user” experience in delineating problem focus and attending to variation in that experience to provide important insights into the system that produces the problem (see also ▶ Chap. 36, “Leading Information Technology via Design Thinking,” John Nash, this volume). The final three principles shift attention from clearly seeing systemic causes of complex and problematic outcomes to focusing collective efforts on practical and sustainable solutions. These also encapsulate the “science” of improvement by attending to systematic and rigorous inquiry based on practical measures. These measures are oriented towards practice improvement, not solely outcome indicators designed for accountability or data for research designed to increase disciplinary knowledge (Yeager et al. 2013). This step of evidence-based inquiry grounded in practice and the importance of clarifying one’s assumptions and testing those assumptions through the clear delineation of practical measures is brought to scale through social learning among teams involved in networked improvement communities.

Why Is Improvement Science a Tool Leaders Should Consider for Implementation of IT in Schools?

Improvement science through networked improvement communities offers a methodology for generating proactive knowledge that involves IT throughout the phases and in support of the principles described above. Technology has many potential roles in amplifying the leadership of continuous improvement in schools through improvement science, from the support role of facilitating rigorous approaches to exploring complex problems to the transformational role of scaling up change across many different organizations. IT offers leaders at all levels means of orchestrating interactions and engagement that hold the promise of generating proactive knowledge, the “alert and lively” use of knowledge that bends towards action (Perkins 2008, p. 3). Networked improvement science offers systematic processes that IT can amplify for accelerating individual and team learning and supporting larger-scale, context-sensitive approaches to organizational and system-wide learning (Bryk et al. 2015; LeMahieu et al. 2017).

One way of delineating the ways technology might amplify leadership of continuous improvement is suggested by the tripartite exploration of *effects with*, *effects of*, and *effects through* technology (Salomon and Perkins 2005). *Effects with* corresponds to the use of IT tools and IT-enabled processes to enhance the leadership of collective inquiry and knowledge-building. *Effects of* characterizes the ways in which technological affordances may support leadership even after their direct use. *Effects through* evokes a more transformational role in terms of reorganizing performance to enable a qualitatively different kind of leadership than would be possible without IT. The following provides a brief introduction to the tenets of improvement science through networked improvement communities and then examines in turn effects with, of, and through technology in terms of the leadership of continuous improvement through improvement science.

How Might School Leaders Incorporate This into Their Leadership Practices?

A crucial aspect of the leadership of continuous improvement is the orchestration of influence in the uses of IT throughout the inquiry process. Identifying how technology amplifies the leadership of continuous improvement entails understanding effects with, of, and through technology (see Table 1).

Effects with. . .

Effects with technology comprise the ways that leadership of continuous improvement relies on approaches that support systematic methods and tools for viewing systems and processes, gathering and organizing information, understanding variation, analyzing relationships, explaining variation, and overall project management (Langley et al. 2014, pp. 409–451). Leadership of continuous improvement hinges on ensuring improvement teams have access, skills, and support to use the necessary IT tools that are essential to this work. IT tools for data collection, analysis, and visualization are crucial in the initial phases of discerning collective focus on a specific problem of practice and the system that produces it and moving on to generating change ideas. These may be as simple as common word-processing and collaboration tools (e.g., Google Drive and Docs, Microsoft Cloud) that make possible the rapid accumulation and sharing of information. Many useful data and process visualization tools are available, such as the charting features of common spreadsheet applications. More specialized tools for visualization, such as Lucidcharts, support collaborative representation of retrospective and prospective causal analysis (e.g., cause and effect diagram, causal loop diagram, interrelationship

Table 1 Amplifying understanding of improvement science (IS) with, of, and through technology: Phases in the improvement science cycle of inquiry

IS "Cheat Sheet" steps	Effects with...	Effects of...	Effects through...
(1) Understand the problem and the system that produces it	Digital documentation and representation of problem focusing Data collection and analysis Collective analysis of data Communications	Synthesis and archive of learning journey Systematic documentation of historical variation	Collective meaning making around problem and system
(2) Focus collective efforts	Learning platforms that enable collaboration	Shared visualization of the system Representation of multiple perspectives	Seeing the system from different perspectives
(3) Generate ideas for change	Exploration of databases, repositories of information Use of collaborative online protocols	Collective discernment of improvement aim, drivers, change ideas	Collective meaning making and prioritization of change ideas
(4) Test and build evidence	Design and use of practical measures Shared protocols for testing	Explicit predictions Articulating and testing assumptions Collective meaning making around results	Building proactive knowledge around change ideas
(5) Spread and scale	Use of collaborative online platforms that enable widespread communication and distributed knowledge-building	Collective meaning making around variation in relation to context Identification of "positive deviants"	Support for adaptive integration of change ideas in varying contexts

digraph, driver diagram), system processes (e.g., flow diagrams), and event mapping (e.g., journey mapping). Similarly, online tools for concept mapping (e.g., Xmind, Padlet) are crucial for generating ideas and focusing collective efforts. A final vital area that enables leadership is that of collaborative project planning and management through tools such as Trello.

Effects of . . .

Leadership of continuous improvement builds on the enabling effects with technology described above to orchestrate meaning making between members of improvement teams and among improvement teams across a NIC. The products of visualizing the system through technology-enabled representations and generating change ideas through concept mapping serve as the substrate for the collective interpretation, evaluation, and meaning making that support the leadership of continuous improvement. Problem focusing and framing, as well as visualizing the system, are all enduring effects of analysis and visualization enabled by IT. In addition to supporting real-time, collaborative data representation and visualization, IT serves as distributed memory of the group's processes of meaning making through collective repositories of artifacts as well as historical archives. These enable leadership to build consensus around specific problems and improvement aims. Ultimately, the effects of shared meaning making through technology serve as means of generating sustainable, proactive knowledge around specific problems.

Conclusion: Effects Through . . .

Collaboration and knowledge-building technologies hold the promise of giving rise to qualitatively different ways of accelerating improvement through networked improved communities. NICs are predicated on the existence of a distributed infrastructure of technology that enables not only the rapid sharing of proactive knowledge from one location to another but also the accretion of proactive knowledge across diverse organizational contexts. In its current state, effects through technology are beginning to be evident as a result of amalgamating existing platforms for online, collaborative learning with the kinds of analysis and visualization tools described above. For example, High Tech High Graduate School of Education sponsors a number of Networked Improvement Communities and orchestrates the generation of proactive knowledge across distributed sites nationwide through a constellation of IT tools that include a homegrown collaboration platform, Google Docs, and a suite of online tools such as Padlet, Lucidcharts, and concept mapping software. A next generation of networked technologies for collaboration around improvement science initiatives is emerging. The University Council of Educational Administration Professional Development Network (UCEA PDN) is currently experimenting with adapting a networking tool for collaboration for its NICs (Dexter 2017). The Carnegie Foundation is also testing its own version of an online learning platform that aims to support the organization and leadership of NICs. These comprise a new generation of IT tools specifically designed for improvement science that require new forms of leadership and could enable a fundamental reorganization of the ways NICs operate and the scale and spread of improvement ideas.

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Section VII

Using Information Technology for Assessment: Issues and Opportunities

Section Introduction: Using Information Technology for Assessment: Issues and Opportunities

40

Mary Webb and Dirk Ifenthaler

Abstract

The use of IT-enabled assessments has been increasing rapidly, as they offer promise of cheaper ways of delivering and marking assessments as well as access to vast amounts of assessment data from which a wide range of judgements might be made about students, teachers, schools and education systems. In many countries in recent years renewed focus on assessments to support learning has been pushing against the burgeoning of testing for accountability. This introduction to the section presents an overview of the six chapters which examine issues and opportunities for using IT-enabled assessments to support students in their learning as well as providing for the wider needs of education systems.

Keywords

IT-enabled assessment · Analytics · Formative assessment · Automated assessment

Use of IT-enabled assessments has been increasing rapidly, as they offer promise of cheaper ways of delivering and marking assessments as well as access to vast amounts of assessment data from which a wide range of judgments might be made

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about students, teachers, schools, and education systems. In many countries, in recent years, a renewed focus on assessments to support learning has been pushing against the burgeoning of testing for accountability (Black 2015; Shute et al. 2016), which in some countries renders effective formative assessment practices almost impossible (Black 2015). Thus, a key challenge for IT-enabled assessment is to support a move toward IT-based assessment that can serve learners' needs as well as the broader needs of education for evaluation of institutions and systems (Webb et al. 2013).

In order to achieve the learning benefits that should accrue from IT-enabled assessments and especially developments in assessment analytics, teachers and students will need to be engaged not only in the production of new tools that visualize the information, for example, to help shape how the new tools provide the most useful and understandable information (Ifenthaler 2014), but also in the dynamic creation of meaning from the use of those tools in learning situations, for example, to create personal insights from the experiences as well as the reflections made possible by the new tools (Webb and Gibson 2015). Thus, by engaging teachers in these development processes, it will be possible to achieve the more extensive assessment literacy needed to take full advantage of opportunities provided by new and more diverse methods of assessment. It is envisaged that it may take many years for IT-enabled assessments to achieve their potential to support formative as well as summative assessment. In the medium term, the need is to integrate IT-enabled assessments where appropriate alongside more traditional methods including teacher and peer assessment. Assessment analytics has massive potential for improving learning but is important for all educators, including policymakers, to understand that decisions about the use to which assessment data is put are critical as they may have unintended consequences for assessment validity as well as for learner motivation (Gibson and Ifenthaler 2017).

In addition to embracing opportunities provided by IT-enabled assessment, schools need to address ethics and privacy issues linked to data-driven assessments. They need to define who has access to which assessment data, where and how long the assessment data will be stored, and which procedures and algorithms to implement for further use of the available assessment data (Ifenthaler and Tracey 2016). In this section, we analyze research evidence and examine theoretical considerations relevant to the opportunities and issues associated with IT-enabled assessment.

Webb and Ifenthaler present an overview of the range of different opportunities for IT to support assessment with a view to provide a vision for assessment design to move forward with designers, teachers, and learners working together to design assessments that support learning in the twenty-first century as well as the broader needs of education. In this shared endeavor, data can be collected and represented to enable learners and teachers to identify achievements, collate evidence of those achievements, diagnose needs, both cognitive and affective, and decide on suitable pedagogical approaches for enabling the next steps in learning. Webb and Ifenthaler review key theoretical issues related to assessment and examine new and potential approaches to assessment that are facilitated by IT as well as the challenges that these new opportunities create.

Van der Kleij and Adie review evidence for ways in which IT has been used in formative assessment, focusing specifically on digital learning environments, game-based assessment, classroom response systems, Web 2.0, and video feedback. Their analysis suggests that using IT as a platform for feedback provides opportunity to individualize feedback, increase student engagement, collect learning evidence for all students, facilitate reflective processes, and support self-regulated learning. Reported potential challenges to the utilization of IT include time restrictions, limited response formats, technical difficulties, access to evidence of student learning for teachers, and teacher knowledge and skills. A key finding is that, although innovations in technology have evolved considerably, many promising possibilities are not yet being exploited for the purpose of formative assessment. Most importantly, research demonstrates that it is not the technologies themselves but the ways in which they are used that impact on their formative potential.

Whitelock and Bektik review progress and challenges for automated scoring and feedback systems for large-scale assessments. Large-scale assessment refers to tests that are administered to large numbers of students, and are used at local, state, and national levels to measure the progress of schools with respect to educational standards. In order to have accurate and fair measurements, large-scale assessment systems need to include all available students, which means a high volume of students with large numbers of exams to be marked. The need for large-scale assessments and the high cost of manual marking and limited "turn around" time have led to developments, over some years, of automated assessment and marking. Whitelock and Bektik review the history and development of automated assessment systems using findings from empirical research as well as highlighting the theoretical considerations that emerge from such developments. In addition, they explore the practical aspects of developing such assessments with examples, including, the systems and tools available, the current capabilities of natural language processing (NLP) approaches and their limitations, ethical concerns, and future potential.

Shute and Emihovich focus on the scope for game-based immersive environments to assess problem-solving skills as an example of constructs that are typically very difficult to measure for a variety of reasons (e.g., lack of a clear and agreed-upon definition, psychological and/or statistical multidimensionality of the construct, subjectivity of scoring). Adding to the challenge of validly measuring problem-solving skill is that formal education settings tend to focus only on well-structured problems – those that have correct and incorrect answers. However, these problems tend to have little transfer to the real world. In short, there is a gap in the kinds of problems being assessed and taught in schools and those desired in workplace environments. However, game-based immersive environments, such as well-designed video games can be used to both measure and promote the development of problem-solving skills in formal education settings.

The increased availability of vast and highly varied amounts of data from learners, teachers, learning environments, and administrative systems within educational settings is overwhelming. Therefore, Ifenthaler, Greiff, and Gibson examine the challenge of how data with a large number of records, of widely differing datatypes, and arriving rapidly from multiple sources can be harnessed for meaningful assessments and for supporting learners in a wide variety of learning situations. They conclude with future directions in the broad area of analytics-driven assessments for teachers and educational researchers.

Lodge attempts to extrapolate from current developments to examine how the future of assessment might play out. New technologies afford possibilities for focusing assessment on learning as an ongoing developmental process, rather than on performance. There are prospects for assessing students continuously while they learn in a developmental way through the use of data and analytics. The resulting picture of student development will allow for a more holistic and systemic approach to assessment in the years ahead. Thus, the future is likely to entail more continuous, personalized forms of assessment that focus heavily on helping students to make better judgments about their own learning and development.

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Assessment as, for, and of Twenty-First Century Learning Using Information Technology: An Overview

41

Mary Webb and Dirk Ifenthaler

Contents

Abstract

IT-based assessment has been advancing rapidly, and its growth is set to accelerate with emerging opportunities for automatic data collection as well as increased possibilities of communication and interaction mediated by IT. In this chapter we aim to present an overview of the range of different opportunities for IT to support

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assessment. We identify and discuss challenges for moving toward a situation where IT-based assessment can serve learners' needs as well as the broader needs of the educational system for evaluation. We examine theories related to assessment more generally as well as specifically to IT-enabled assessment and review recent research and development. Scenarios for IT-enabled assessments may take many different forms, some of which hold much promise for supporting learning, but there are theoretical, developmental, technical, and human challenges to be overcome. Our vision is for IT-based assessment design to move forward with designers, teachers, and learners working together to design assessments that support twenty-first-century curricula and pedagogy. In this shared endeavor, we expect that data can be collected and represented to enable learners and teachers to identify achievements; collate evidence of those achievements; diagnose needs, both cognitive and affective; and decide on suitable pedagogical approaches for enabling the next steps in learning. We argue that open assessment resources provide a vehicle for enabling the large-scale developments that are needed to support the development of IT-enabled assessment across the broad spectrum of learning. Some of the more complex twenty-first-century skills of collaboration, problem-solving, critical thinking, etc. present particular challenges. We envisage that it may take many years for our vision to be realized. In the medium term, the need is to integrate IT-enabled assessments where appropriate alongside more traditional methods including teacher assessment.

Keywords
Formative assessment · Summative assessment · Self regulated learning · IT-enabled assessment · Feedback · Analytics

Introduction

The future of assessment faces major challenges including, perhaps most importantly, the extent to which assessments, when enabled by IT, can serve simultaneously the needs of learners and those of the enterprise of education (Bennett 2015; Gibson et al. 2012). In many countries, in recent years, a renewed focus on assessments to support learning has been pushing against the burgeoning of testing for accountability (Black 2015; Shute et al. 2016), which, in some countries, renders effective formative assessment practices almost impossible (Black 2015). Furthermore a strong focus on summative assessment for accountability can reduce motivation and disengage many learners (Harlen and Deakin Crick 2002). At the same time, the use of IT-enabled assessments has been increasing rapidly, especially in some developed countries such as the United States (Shute et al. 2016), as they offer promise of cheaper ways of delivering and marking assessments as well as access to vast amounts of assessment data from which a wide range of judgments might be made about students, teachers, schools, and education systems.

Scenarios for IT-enabled assessments may take many different forms, some of which hold much promise for supporting learning (Gibson et al. 2012). Thus, while much effort in institutional and national testing systems is focused on harnessing the power of automated systems in order to reduce costs and increase efficiency (Bennett 2015), a range of different assessment scenarios have been the focus of research and development, often at small scale (Stödberg 2012), for some years. IT-enabled assessments may involve, for example, a pedagogical agent acting as a virtual coach patiently tutoring someone and providing feedback in anything they would like to learn (Johnson and Lester 2016), scaffolding students to complete a task and measuring how much support they need (Ahmed and Pollitt 2010), an analysis of a learner's decisions during a digital game or simulation (Bellotti et al. 2013), students reviewing and commenting on each other's digital creations through an online discussion (Webb 2010), a multimedia-constructed response item created with an online animation and modeling application (Lenhard et al. 2007), students receiving remote asynchronous expert feedback about how they worked with each other via IT to solve a problem and communicate their understandings (Rissanen et al. 2008), an emotionally engaging virtual world experience that unobtrusively documents progression of a person's leadership and ethical development over time (Turkay and Tirthali 2010), or semantic-rich and personalized feedback as well as adaptive prompts for reflection through data-driven assessments (Ifenthaler 2012).

This set of vignettes begins to outline a broad range of possibilities that place IT in a variety of roles including a medium for communication, learning assistant, judge, test administrator, and performance prompt, practice arena, and performance workspace (Webb et al. 2013). However, according to Bennett's (2015) review of the evolution of educational assessment, from a paper-based technology to an electronic one, the current state of educational assessment is between a first generation focused largely on infrastructure building and the second generation driven by efficiency. It will be in the third generation of assessments, not driven by technology but focused on cognitive principles and theory-based domain models, that will enable assessments to serve both the needs of learners and those of institutions, and this evolution is likely to take many years (Bennett 2015).

In this chapter, we examine the implications for learning, learners, teachers, and other stakeholders of new technological developments and the developments in assessment possibilities that have ensued or are envisaged. In this endeavor, we discuss aspects of theory that have underpinned assessment in education more generally and may inform future developments with IT-enabled assessment, such as self-theories affecting motivation (e.g., Dweck 2000) and theories and models of pedagogy (e.g., Shulman 1986) and self-regulating learning. We also highlight areas of theory that are developing rapidly in response to challenges and opportunities presented for assessment by new technologies. Our aim is to provide an overview of this dynamic field and to outline the challenges for practice, policy and theory, and key questions for future research. We start by outlining the various types of assessment and the terminology in this area in order to set the scene and discuss areas of contention in the use of terms that can and have led to confusion.

Types of Assessment and Terminology

The nature of formative and summative assessment and the difficulties of characterizing their differences and interrelationships have been much discussed in the literature (Assessment Reform Group 2002; Bennett 2011; Black and Wiliam 2009; Harlen and James 1997; Wiliam 2011). In order to provide some clarification for teachers, the terms "assessment for learning" and "assessment of learning" were proposed to replace formative assessment and summative assessment, respectively (Assessment Reform Group 2002). In these more teacher-friendly terms, it is the purpose of the assessment and the use to which the findings are put that typically characterize the assessment (Assessment Reform Group 2002; Black and Wiliam 2009). Thus, assessments *of* learning are used to assess a student's learning at a particular point in time, usually at the end of a unit or course. A judgment will usually be made based on criteria, standards, or benchmarks, and the outcome may be used for accreditation purposes and entry to further courses and/or to inform decision-making regarding setting students into groups. On the other hand, assessments *for* learning have the formative purpose of supporting decision-making about the next steps in instruction. Thus, according to Black and Wiliam (2009),

> Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited. (p. 9)

This definition places formative assessment at the heart of learning and classroom practice. The emphasis on the improvement of learning together with evidence, from meta-analysis of research studies, that formative assessment improves learning with strong effect sizes (Black and Wiliam 1998; Hattie 2009) has led to a renewed impetus for assessment to support learning. Thus, the phrase "assessment for learning" has become used widely in both compulsory and post-compulsory education not only in Western cultural settings but also in Confucian Heritage settings (Brown and Gao 2015; Carless and Lam 2014; Cheng 2016; Lee and Coniam 2013).

However, making a clear distinction between assessments on the basis of their purpose has proved more complex. For example, one of the useful formative practices that emerged in studies with teachers was the "formative use of summative tests" (ref p. 31) in which, for example, students might engage in peer discussion and feedback activities focused on reviewing their performance on summative tests. Thus, there is a recognition that these definitions and characterizations of types of assessment are not yet sufficient (Bennett 2011; Wiliam 2011). One of the reasons for the lack of clarity is that the word assessment is used for both processes of gathering evidence and feeding back comments as well as a label for the judgment of results. Thus, there are at least four ways to think about assessment, all of which can be supported or enhanced by the use of IT (Webb et al. 2013) (see Table 1).

One perspective is of the formative process – learning from the feedback information provided by an assessment process. Another perspective focuses on the results, which may be evident, for example, in revised lesson plans or in targets set by students for themselves, of adaptations made to instruction based on an interpretation of the

Table 1 Four ways to think about assessment (Webb et al. 2013, p. 453)

	Process focus	Results focus
Assessment ***for*** learning	1. Feedback information	2. Improvement decisions
Assessment ***of*** learning	3. Degree of engagement with/understanding of process	4. Value judgments

evidence from the assessment. The third is the understanding of the assessment and the degree of engagement by students and teachers in the assessment process. The fourth is the value judgment of results which provides summative information based on the evidence. Perspectives 1 and 3 in Table 1 are crucial for assessment to be formative and can be either short-term learning processes involving "interactive regulation" during the vast numbers of minute-to-minute interactions in classrooms (Perrenoud 1998) or in longer-term processes involved in planning lessons, designing activities, and setting targets (Perspective 2). Perspectives 3 and 4 are essential for summative assessment. Perspective 3 is important for both formative and summative assessment because unless students engage with the process of assessment, the information generated will not be valid. Furthermore, if the students fail to engage with the feedback information, there will be no effect on their learning. Perspective 4, in particular, is where there may be significant conflicts between the formative and summative assessment purposes. Making value judgments may be important at key transition points for the purposes of grading, accreditation, setting, etc., but such processes impact on students' engagement with learning (Harlen and Deakin Crick 2002) as discussed later in this chapter.

Assessment *as* learning is a phrase that has crept into common use in education and reflects a renewed focus on the nature of the integration of assessment and learning. Key aspects of assessment *as* learning, which also supports the perspectives on assessment *for* learning outlined above, have been identified by Dann (2014) as the centrality of understanding the learning gap and the role of assessment in helping students and teachers explore and regulate this gap. Thus, feedback and the way students regulate their response to feedback (Perrenoud 1998) are critical for assessment *as* learning just as it is for assessment *for* learning.

Of particular interest for this book are the ways in which IT-enabled assessments can support the four perspectives that we have outlined. Therefore, in the following sections, using the framework shown in Table 1, we will examine how IT may support assessment now and in the future and what challenges arise.

Focusing on the Assessment Process: Feedback

Feedback is clearly essential for formative assessment, but feedback is not always useful for students' learning, and much research has focused on the nature of effective feedback. Thus, for example, Sadler in emphasizing the importance of the quality of feedback stated "we now realise we have to understand not just the technical structure of the feedback (such as its accuracy, comprehensiveness and appropriateness) but also its accessibility to the learner (as a communication), its catalytic and coaching value, and its ability to inspire confidence and hope" (Sadler 2010, p. 84). The challenge for IT-enabled assessment, however, is not only to deal with the subject matter but also to take into account a range of learners' characteristics. Sadler was referring to quality in relation to feedback as a particular piece of information. However, we have characterized feedback as a process, in line with Wiliam (2011), to emphasize the importance of feedback processes as part of a system, because unless learners make use of the information, it is ineffective. Therefore, feedback becomes part of a communication process between learners and between learners and the teacher thus placing emphasis on interaction. Such interaction may be mediated by IT systems thus increasing the range of opportunities for interaction that may support assessment. In these processes, IT systems can enable synchronous communication at a distance using text, voice, and/or video links or asynchronously at different times using a range of discussion boards and social media applications. Such processes are now widely used across many areas of education and have been harnessed specifically to support assessment in a range of studies (e.g., Coll et al. 2014; Webb 2010).

While IT systems can provide the media for increasing feedback opportunities, the major challenge remains of gaining access to the learner's understanding. Thus, as Perrenoud (1998) stated "one can only stimulate, reinforce, reorient, readjust or accelerate the pupil's mental processes, in the hope of modifying the learning processes. This intention can only be effective if a window is found into the cognitive system of the learner". The difficulties of understanding students' specific cognitive needs for feedback have meant that automated feedback systems have tended to be restricted to particular subject areas and topics where the subject matter renders diagnosis of errors and misconceptions relatively straightforward (Mislevy et al. 2003a). However, automated feedback systems are an area of rapid research and development, and current evidence is examined in detail in "Formative assessment and feedback using IT" (van der Kleij and Adie) in this assessment section of this handbook. The technical challenges and future possibilities are also examined in depth in "Progress and challenges for automated scoring and feedback systems for large-scale assessments" (Whitelock and Bektik), in this section of this handbook. Feedback processes are, of course, also challenging for teachers, and typically good teachers manage this by means of a teaching/assessment cycle which according to Black critically incorporates assessment at each stage of the cycle (Black 2012, 2015) as discussed later in this chapter. Therefore, when developing IT-enabled feedback systems, it is a matter of not only building on teacher and classroom practices but also looking for ways in which the interaction and mediation capabilities of IT can be harnessed to support more focused and/or timely feedback.

Focusing on the Assessment Results: Improvement of Decisions

The results of an effective feedback process will be (1) good teaching focused on students' needs and (2) students who understand or are coming to understand their own learning needs. This increased understanding is prerequisite for students to be able to self-regulate their learning and thus to achieve autonomy in learning. Self-regulated learning is generally regarded as desirable for learning especially for online learning. There is evidence of improved performance in online learning correlating with some aspects of self-regulated learning. For example, in a study of over 800 community college students studying an online course, effort regulation, one aspect of self-regulation, as measured by the Motivated Strategies for Learning Questionnaire (MSQL) was significantly related to performance (Puzziferro 2008). Furthermore, a study of nearly 5000 students on 5 MOOCs (Kizilcec et al. 2017) showed that the goal-setting and strategic planning aspects of self-regulated learning predicted attainment of personal course goals.

On the other hand, autonomous learning is often claimed as being enabled by the use of IT (Chang et al. 2015), so there is potential for synergy here between assessment purposes and IT use in the promotion of learner autonomy. At the same time, development of the theoretical basis of self-regulated learning has moved toward increasing focus on co-regulation, socially shared regulation, and the importance of peer interaction (Chan 2012; Järvelä and Hadwin 2013) as discussed later in this chapter.

Focusing on the Assessment Process: Degree of Engagement and Understanding

The importance of affective factors in accurate assessment and effective feedback processes has been recognized by many in recent years and has been supported by detailed studies (see, e.g., Ifenthaler 2015) but has not always been given the attention it deserves (Sadler 2010). Vygotsky identified the separation of cognitive and affective factors as a major weakness of traditional psychology since "it makes the thought processes appear as autonomous flow of 'thoughts thinking themselves' segregated from the fullness of life, and personal needs and interests, the inclinations and impulses of the thinker" (Vygotsky 1986, p. 10). The recognition that engagement and motivation are important for learning goes back at least to the time of Dewey (1913). More recently, analysis of large datasets such as PISA test results, for example, has shown that affective factors contributed significantly to achievement in science and mathematics (Ozel et al. 2013).

In classroom-focused research with primary teachers, Webb and Jones (2009) found that developing effective formative assessment required a culture change associated with a range of affective factors, such as mutual support for each other's learning and willingness to take risks as well as changing learners' expectations. This culture change necessitated substantive change in classroom practices and indicated the major challenges for teachers in establishing effective formative assessment.

Dweck's work on "self-theories" (Dweck 2000) has been particularly important in understanding students' belief systems that are important for assessment for learning. In summary, Dweck found that students with a learning orientation seek to develop their skills and understanding because they believe that they can achieve with sufficient effort. On the other hand, students who are oriented toward performance want to show their capability, and hence they shy away from more challenging tasks because they are concerned about failing.

Affective factors and engagement are equally important, in formal situations, where test anxiety is a significant concern for the validity of assessments. For example, a study of 50 fourth-grade students revealed a significant relationship between the students' levels of test anxiety, as measured by pulse rate, and performance on the New York State Standardized Science Test (Fulton 2016).

Given the importance of engagement for effective assessment and the evidence of affective factors influencing assessments, we will next consider the scope for IT-enabled assessments to support or hinder engagement in assessment. Ways in which IT-enabled assessment may promote or at least not hinder engagement include on-demand testing; background data collection enabling "stealth assessment" (Shute 2011) or "quiet assessment" (Webb et al. 2013); nonreactive assessment (Ifenthaler et al. 2010), which use traces in online learning environments; peer assessment supported through online discussions; as well as other more informal approaches.

Peer assessment is an active research area given the opportunities for IT-enabled peer interaction and the perceived potential for peer feedback to contribute to learning experiences in massive open online courses (MOOCs) (Suen 2014). Evidence of the value of peer assessment using IT is discussed further in "Formative assessment and feedback using IT" (van der Kleij and Adie), in this assessment section of this handbook.

Stealth assessment, coined by Shute (2011), is an approach to performance assessment by collecting and processing data from online activities automatically and unobtrusively while the students are interacting. While such an approach will enable the learners to focus on the activity rather than being concerned about the assessment, it also seems to take away learner control rather than encouraging learners to take responsibility for their learning and might also raise ethical issues. Therefore Webb et al. (2013) proposed an alternative approach described as "quiet assessment" in which students are well informed of the assessment process but can choose to carry on and ignore or "turn up the volume" in order to see a trace visualization of their performance and progress. Such quiet assessment requires methods of presenting such data in a meaningful way to students and teachers as well as a good standard of assessment literacy as discussed later.

Focusing on Assessment Results: Value Judgments

Recognizing students' achievements has always been an important element of education, and some judgments such as identifying appropriate courses for students and organizing groupings to support learning and teaching are clearly in students' interests. IT provides additional opportunities for making the necessary value judgments. For example, digital badges offer the opportunity to recognize learning anytime, not only in formal but also in informal learning environments (Mah et al. 2016). In addition to the recognition and bridging of learning inside and outside educational institutions, the main roles of digital badges in education include motivational effects, signaling of achievements, and capturing learning paths (Gibson et al. 2013; Jovanovic and Devedzic 2015). Digital badges not only recognize personalized learning paths; they also have an impact on learning and learning motivations. So far, there are few empirical findings concerning how badges exactly affect learner motivation. Abramovich et al. (2013) concluded, in their small-scale study of approximately 50 students using an intelligent tutoring system for mathematics, that patterns of badge acquisition differed according to the prior knowledge level of the learners and that different badge types affected different learner motivations. In another small study of the perceptions of badges by 38 participants in MOOCs, where badges have been promoted as a method of dealing with the assessment of large cohorts, learners reported a generally positive response to the role of badges but with a range of different opinions concerning their value for both formative and summative assessment and some doubts about how their value would be perceived by employers and colleagues (Cross et al. 2014). Further research is needed to determine whether and how badges can be designed to affect motivation positively and to overcome the potential negative effects of their emphasis on extrinsic motivation.

As mentioned earlier, the focus on value judgments in summative assessments can be counterproductive for learning owing to adverse effects on students' motivation (Harlen and Deakin Crick 2002). For example, the use of assessment data for making judgments about teachers, schools, and courses may not be in students' best interests if such judgments adversely affect teaching and students' motivation and self-esteem. Harlen and Deakin Crick's systematic review (Harlen and Deakin Crick 2002) revealed that high-stakes tests can result in changes to teaching to a transmission style that only caters for a limited range of students. Furthermore, a strong emphasis on testing produces students who are extrinsically oriented toward grades and social status rather than being oriented toward learning (ibid.).

Perversely, opportunities enabled by IT for assessments may have exacerbated the problems caused by the results focus on value judgments associated with high-stakes assessment by giving administrators access to large datasets and new ways of manipulating the data to produce reports highlighting trends, issues, etc. Consequently, administrators see opportunities to use the data for a range of judgments without being aware of the consequences of such actions. Unintended consequences of assessments can result in threats to validity. Current theories of validity in relation to assessment are associated with not the assessment instrument itself but the use to which it is put and validity as affected by how the data is to be used (Messick 1994). Thus, an instrument designed to measure students' performance with a view to supporting their learning may be seen as engaging and interesting by students who are supported and encouraged by the teachers to perform as well as they can. However, if the results of this assessment are later to be used for making judgments about teachers, the teachers may put pressure on the students and "teach to the test," thereby increasing students' anxiety and decreasing their engagement. In this way, the validity of the assessment is threatened, and students are not well served.

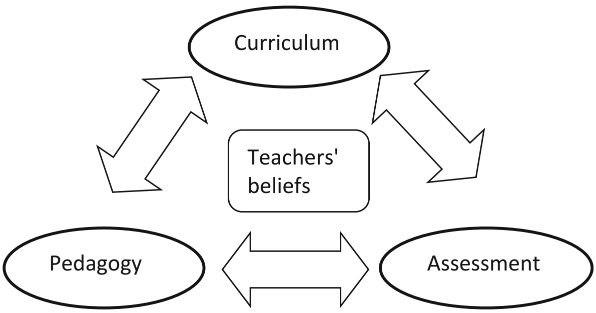
Assessment Within Learning Systems

As we have seen, assessment is closely associated with learning. In this section, we examine the relationships between assessment, curriculum, and pedagogy. A classic way of conceptualizing the relationship between curriculum, pedagogy, and assessment is in a triangular arrangement (see Fig. 1) with a push-pull relationship between curriculum, pedagogy, and assessment moderated by teachers' beliefs about learning.

Thus, where teachers believe strongly in the value of formative assessment and have sufficient freedom to implement their ideas, there will be a dynamic fruitful relationship between pedagogy and assessment perhaps to the extent of assessment becoming fully integrated into pedagogical practices. At the same time, the curriculum will inform pedagogical practices, and both pedagogy and assessment will determine how the curriculum is interpreted and delivered. However, where high-stakes assessments dominate, assessment can exert a controlling influence on pedagogy and may also influence the curriculum directly or indirectly through pedagogical practices which tend to focus on elements that are to be assessed. If the assessment is only able to assess parts of the intended curriculum, then the curriculum will become impoverished (Harlen and Deakin Crick 2002). Therefore, a key message indicated by the triangular push-pull relationship between curriculum, pedagogy, and assessment is that any changes in assessment approaches, including those based on technological developments, whether for formative or summative purposes, are likely to affect both curriculum and pedagogy. Summative assessment practices present a high risk to pedagogy as explained earlier. However, if summative assessment addresses curriculum goals comprehensively and well, then curriculum, pedagogy, and assessment can remain in a steady-state relationship in which all can change when necessary but they continue to support each other. Arguably formative assessment is always likely to support good pedagogy because both formative assessment and pedagogy focus on improving learning and their integration is an important goal.

We now turn to how pedagogical practices can integrate assessment. In commenting on the prerequisites for effective formative assessment and particularly feedback interactions, Perrenoud (1998) identified two levels of the management of learning processes: the first is the setting up of activities that provided opportunities

Fig. 1 A conceptual model depicting relationships between curriculum, pedagogy, and assessment



for learning based on curriculum requirements and the second is the interactive regulation which takes place within didactic situations (Perrenoud 1998). Perrenoud's explanation makes clear the crucial role of assessment information influencing key aspects of pedagogy. More recently Black built on Perrenoud's ideas and proposed a more comprehensive model of assessment in pedagogical practices (Black 2012, 2015) consisting of five stages with clear links between them and all involving assessment:

1. Clear aims: The first stage of planning
2. Planning activities: Setting up activities with the potential to achieve the aims
3. Implementation in the classroom
4. Review of the learning: Using informal assessments to check achievement
5. Summing up: Using assessment to guide decisions about the next stage of students' work

This model looks very similar to other models of pedagogical practice including Shulman's seminal model of pedagogical reasoning (Shulman 1986). However, there is a difference of emphasis. In Black's model the importance of assessment is emphasized at each stage. On the other hand, in Shulman's model, assessment must be assumed to take place since teachers' knowledge of the learners for which they are planning lessons is a crucial element in their pedagogical reasoning, but assessment is underemphasized. In addition to the central role of assessment at each stage, the links between all the stages are crucial because if any are broken, the whole system becomes broken (Black 2015). Furthermore Stage 5 is essential for planning the next step in teaching and learning, so the whole process is iterative.

A useful model for characterizing the particular roles of teachers and learners in the assessment elements of the pedagogical process was developed by Wiliam and Thompson (Black and Wiliam 2009; Wiliam and Thompson 2007) and later adapted to indicate the potential roles for IT as shown in Fig. 2 (Webb 2014). In this model as in Black's model of assessment in pedagogy, while the processes are numbered in an apparent sequence, the model is actually iterative as explained above (Webb 2014), and there are dynamic links between the processes which are essential for effective pedagogy. Roles for various types of IT have been identified as being supportive of each process.

Theories and Models of Self-Regulated Learning

As mentioned earlier self-regulated learning is enabled by self-assessment, and both of these aspects are important for learner autonomy and for supporting online and blended models of learning and assessment. Most theoretical models of self-regulated learning involve multiple components and phases (see, e.g., Pintrich 2000; Winne and Hadwin 2008). Thus, self-regulated learners have the potential to engage in continuous and concurrent regulation of metacognitive, behavioral, motivational, and emotional processes. Furthermore, they regulate these processes through a series of phases while performing a learning task. An increasing focus

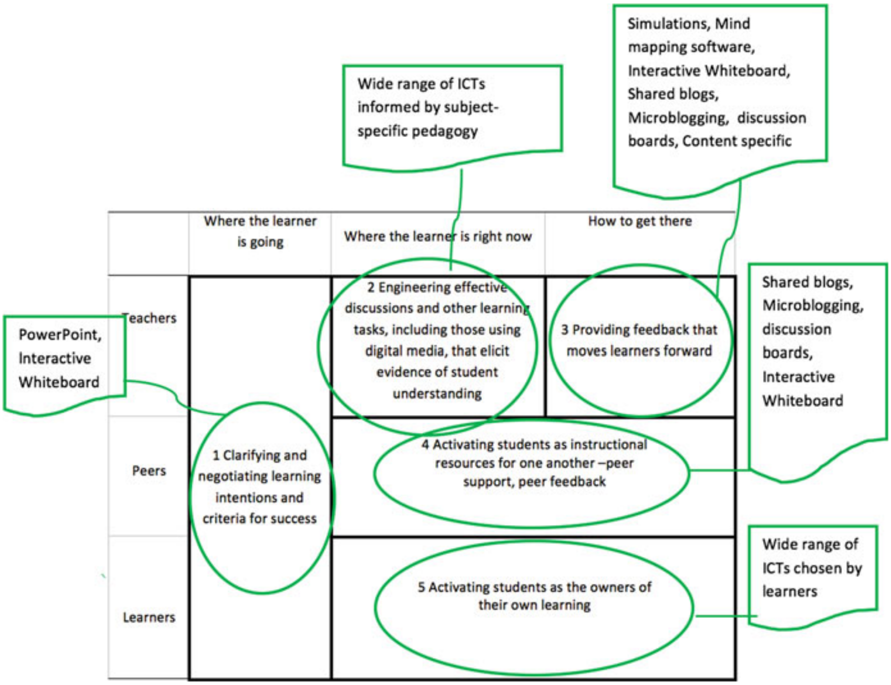


Fig. 2 Technologies in support of aspects of formative assessment adapted from a framework developed by Black and Wiliam (2009)

on collaborative learning places more emphasis on co-regulation or socially shared regulation of learning in which multiple group members regulate their joint activity in order to achieve a shared goal (Hadwin et al. 2010; Jarvela et al. 2008). Understanding of how groups regulate their learning and how these processes can be facilitated by teachers or technology is still building (Chan 2012; Ucan and Webb 2015). A detailed study of 14- to 16-year-old learning collaboratively suggested that the design of the activities at an appropriate level to challenge students and a positive socio-emotional atmosphere were crucial for enabling socially shared regulation not only of planning, monitoring, and metacognitive processes but also of social and emotional interaction (Ucan and Webb 2015). A study focusing on performance of teams demonstrated how IT-based systems can identify team-based performance on complex tasks on the fly as well as visualize the individual's contribution to the group of learners (Ifenthaler 2014).

Assessing Twenty-First-Century Skills

So far in this chapter, we have discussed theoretical issues relating to assessment, learning, and pedagogy. Furthermore, we have focused on **how** to assess, but another consequence of the digital age is the changing range of knowledge and skills that students need and thus a consideration of what to assess. Most frameworks of twenty-first-century skills acknowledge that new assessment frameworks are needed (Voogt et al. 2013). Typically, twenty-first-century skills or competencies comprise of a number of areas that have always been important but not always assessed adequately including collaboration, communication, citizenship, problem-solving, and critical thinking together with some newer aspects of learning including digital literacy, creativity, and productivity (ibid.).

Assessing some of these skills, especially social skills such as collaboration, has relied previously on teacher assessment and has often been difficult and hence underemphasized. More recently an IT-enabled approach to assessing collaborative problem-solving has been developed for the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) (PISA 2015) – see "Making use of data for assessments: harnessing analytics and data science" (Ifenthaler, Greiff, Gibson) in this handbook.

In summary, IT-enabled assessments are expected in the future to offer new powerful and reliable ways of assessing twenty-first-century skills, but the challenges are significant, and in the short and medium term, it will be important to make use of teacher assessment for these more complex skills (Gibson and Webb 2015; Webb and Gibson 2015).

In order to develop these new approaches to IT-based assessment, it is not only important to build on new technological capabilities but also to develop a theoretical base for designing assessments.

Theoretical Underpinning for Developments of IT-Based Assessment

Reviews and group discussions of global ICT and assessment since 2009 (Webb et al. 2013) have combined research-based findings with classroom observations of assessment practices (Black and Wiliam 1998) and evidence-centered assessment design (ECD) (Mislevy et al. 2003b) to conceptualize ways of enabling assessments to support a range of needs and purpose. The ECD framework has become quite widely used among designers of IT-based assessment as it makes explicit the interrelationships and substantive arguments among the main elements of the design and implementation: domain models, validity, assessment designs, and operational processes (Mislevy et al. 2003a). The framework has diagnostic capabilities and provides opportunities for stakeholders to view estimated competency levels, to examine the evidence on which these judgments were based, and to use this information for a variety of processes as appropriate (Shute 2011, p. 9). It is also the primary organizing theoretical framework for the PISA assessment of collaborative problem-solving discussed earlier. In order to move toward assessment systems that support learners and teachers as well as automating elements of the assessment process and hence making it more efficient, Webb et al. (2013) argued that the ECD approach needs to be combined with formative assessment frameworks outlined earlier in this chapter and that teachers and students need to develop assessment literacy.

Understanding and Engaging with Assessment: Assessment Literacy

The need for assessment-literate teachers, students, and parents has long been recognized (Stiggins 1995), but research suggests that years of predominantly external testing have damaged teachers' confidence and ability to design assessments themselves and to understand validity considerations (Black 2015). In order to achieve the learning benefits that should accrue from IT-enabled assessments, teachers and students will need to be engaged not only in the production of new tools that visualize the information (e.g., to help shape how the new tools provide the most useful and understandable information) but also in the dynamic creation of meaning from the use of those tools in learning situations (e.g., to create personal insights from the experiences as well as the reflections made possible by the new tools (Webb and Gibson 2015). This implies that teachers will need to develop their assessment literacy but these tools in themselves can and should be designed to support teachers in this development. Furthermore, reconceptualizing assessment design as a shared process involving teachers enables a focus on the purposes of assessment, with due consideration of validity, while at the same time considering the optimum ways of combining technology enhanced assessment with other methods in order to achieve those purposes. Thus, our vision is for a future in which technology supports teachers and students working together with technologies to understand their learning needs, move their learning forward, and develop evidence of their achievements. We believe that this vision can best be achieved by teachers working together with designers to design both assessments and learning materials as well as involving learners in these design processes wherever possible.

Addressing the Challenges of Assessment: The Promise of IT-Based Developments

We have already mentioned a number of IT-based developments that show promise in supporting twenty-first-century learning as well as the needs of educational systems. These developments include the use of a range of communication software tools to support teacher and peer feedback, quiet assessment to enable background collection of assessment data whose volume can be turned up to enable self-assessment, digital badges that may motivate students in informal learning as well as formal settings and are discussed further in "Assessing Problem-Solving Skills in Immersive Environments" (Shute and Emihovich) in this assessment section of this handbook, and automated feedback systems that are discussed further in "Formative assessment and feedback using IT" (van der Kleij and Adie), also in this assessment section of this handbook.

A promising current area of rapid research and development is learning analytics applied to large datasets that can enable the learning scenario and the actual performance of an individual or a team to be stored and analyzed in real time (Ifenthaler 2015). Intelligent adaptive algorithms for personalized feedback have been developed; however, only a few have been implemented in educational settings (Ifenthaler 2015) as discussed in "Making use of data for assessments: harnessing analytics and data science" (Ifenthaler, Greiff, Gibson) in this handbook.

Developing a suitably wide range of assessment instruments to enable the vision we have outlined here presents a considerable challenge, so finding a way of sharing and building on developments is also an important goal. Open educational resources (OER) are learning, teaching, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use and repurposing by others. Open assessment resources (OAR) include free automated formative assessments (and free support for semiautomated and fully human formative assessments) to advance the trend toward scale. In order to support higher level learning, we propose to focus the OAR on transferrable deep learning processes (e.g., collaborative problem-solving, creativity, self-regulation, metacognition) from specialized fields into broader contexts (Gibson et al. 2016) as discussed further in "Making use of data for assessments: harnessing analytics and data science" (Ifenthaler, Greiff, Gibson) in this handbook.

Conclusion

In this chapter, we have outlined current thinking in relation to assessment generally as well as the developing field of IT-based assessment in order to map the theoretical landscape and outline new opportunities. In this endeavor, we have shown that IT-based assessment is developing rapidly but is still at an early stage of development toward a goal of such assessments being based soundly on cognitive principles and theory-based domain models as well as taking account of affective factors in learning. Our vision is for IT-based assessment design to move forward as a shared endeavor where designers, teachers, and learners work in partnership to ensure that assessments match changing curricula, support learning needs, and provide data representations that are meaningful to learners and teachers, as well as provide information to policymakers where appropriate. Realizing this vision across the whole spectrum of learning is likely to take many years. As we move forward, it is important to recognize the need to combine various types of assessment in order to ensure that assessment addresses the whole curriculum and, in particular, some of the more complex areas to assess, such as twenty-first-century skills of collaboration and critical thinking, are not ignored. Thus, teacher assessment should be recognized as playing an important role, and the need for supporting and enabling peer assessment with and without IT remains. Important implications for learners of new opportunities for IT-enabled assessment of first that they not only may find new ways of learning, enabled by IT, both within school and outside but that their achievements in all these situations can be measured and recognized. In order to take advantage of these opportunities, learners need to develop skills in self-regulated learning, and teachers need to support them in this development. Furthermore, teachers have responsibilities to develop their assessment literacy and to become engaged in assessment design. For policymakers, it is important to facilitate a shared approach to assessment design in which all stakeholders participate to maximize the opportunities and consider the potential consequences of design decisions, including decisions regarding the purpose and use of assessments, for curriculum and pedagogy as well as for the validity of assessments.

We have identified a number of challenges for moving toward a situation where IT-based assessment can serve learners' needs as well as the broader needs of the educational system for evaluation at various levels. Thus, future research on IT-based assessment may focus on the following challenges:

- To what extent can the validity issues associated with using assessments from multiple purposes be overcome to enable needs of learners and of evaluation of education systems?
- How can assessment data be made accessible and understandable to all stakeholders?
- How can assessment data support stakeholders?
- How far can peer assessment and feedback replace or complement teacher assessment, and what are the social and cultural factors that need to be considered?
- Can we develop the synergy between the opportunities presented for autonomous learning through IT systems and the feedback opportunities presented by IT-based assessments?
- How can assessment information from distributed networks and unstructured data be directly linked to additional educational data collected within an institution's environment?
- What opportunities arise from the development of automated natural language processing (NLP) capabilities? The major challenge besides the development of real-time NLP is the validation of such algorithms and the link to quantitative educational data.

The chapters within this assessment section of this handbook address many of these challenges and open up additional issues which need to be addressed as educational technology is evolving rapidly.

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Formative Assessment and Feedback Using Information Technology 42

Fabienne van der Kleij and Lenore Adie

Contents

Abstract

Formative assessment including feedback to students on their learning is widely recognized as an effective means to support student learning. Research has found that the potential of formative assessment in improving student learning is often not fully realized in classroom practice. IT provides a possible solution for overcoming some of the obstacles when implementing formative assessment. This chapter reviews various ways in which IT has been used in formative assessment, focusing specifically on digital learning environments, game-based assessment, classroom response systems, Web 2.0, and video feedback. The results suggest that using IT as a platform for feedback provides opportunity

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to individualize feedback, increase student engagement, collect learning evidence for all students, facilitate reflective processes, and support self-regulated learning. Reported potential challenges to the utilization of IT include time restrictions, limited response formats, technical difficulties, access to evidence of student learning for teachers, and teacher knowledge and skills. One key finding is that although innovations in technology have evolved considerably, many promising possibilities are not yet being exploited for the purpose of formative assessment. Most importantly, research demonstrates that not the technologies themselves, but the ways in which they are used impact on their formative potential. Bringing together IT and formative assessment may open up the potential for moving from convergent forms of feedback to more open, divergent feedback practices.

Keywords
Feedback · Formative assessment · Classroom practice · Technology · Student learning

Introduction

Formative assessment is widely recognized as an effective means to support student learning (e.g., Black and Wiliam 1998). Feedback is a critical aspect of formative assessment (Hattie and Timperley 2007; Sadler 1989). Feedback in formative assessment refers to (i) insights into student learning provided to teachers and other stakeholders, and (ii) messages provided to students (by self, teachers, peers, digital devices, etc.) that are intended to directly influence their learning processes cognitively or metacognitively (Sadler 1989). Research has found that teachers and students do not necessarily fully engage with formative assessment processes, which in practice has resulted in disappointing outcomes. For instance, in the seminal work on feedback (e.g., Black and Wiliam 1998; Hattie and Timperley 2007), the importance of motivation in the feedback process is acknowledged in two ways: (1) feedback can motivate students to learn, and (2) students need to be motivated in order to use feedback to improve their learning. A recent review by Heitink et al. (2016) identified numerous prerequisites for the effective implementation of formative assessment in the complex reality of diverse classroom contexts. IT provides a possible solution for overcoming some of the obstacles when implementing formative assessment, such as providing timely individualized feedback on student learning in a way that engages learners.

This chapter evaluates the existing evidence of how IT has been used, and could be used, in formative assessment. The chapter commences with a brief overview of formative assessment and feedback to establish the conceptual framework in which the review is set. The following is a review of research into a range of IT tools and applications for formative assessment and feedback.

A Brief Overview of Formative Assessment and Feedback Research

There is a long tradition of feedback research in education, yet evidence on feedback effectiveness is often inconclusive (Shute 2008). Research has demonstrated that the most frequently used type of feedback by teachers is praise, which unfortunately has limited value for student learning (Hattie and Timperley 2007). More elaborated feedback has generally been found to be more effective than simple corrective information (Hattie and Timperley 2007; Shute 2008). Results from a recent review suggest that formative feedback needs to be specifically related to the assessment task and student performance, and should provide suggestions for improvement (Heitink et al. 2016). Such feedback can positively enhance students' motivation for learning and result in improved learning outcomes (Hattie and Timperley 2007).

Most of the research on feedback in formative assessment has been conducted from a cognitivist perspective, in which feedback has been conceptualized as corrective information that is transmitted by an expert teacher to a passive learner, expected to result in improved learning (Evans 2013). However, recent literature increasingly emphasizes the importance of active student involvement in formative processes. For example, Black and Wiliam (2009) identify that internalization of feedback by the student is necessary for feedback to affect cognition. Thus, feedback is facilitative rather than directive, and ideally takes place in dialogue. The student's active role in seeking feedback is emphasized. Feedback may provide suggestions for improvement, but ultimately students decide what to do with feedback and whether to act on it (Evans 2013). Furthermore, the importance of the learning context and students' levels of motivation for learning have long been recognized to be fundamental to students' engagement with feedback (Black and Wiliam 1998).

A critical goal of formative assessment is to provide students with skills to self-regulate their learning (Black and Wiliam 2009). ► Chapter 41, "Assessment as, for, and of Twenty-First Century Learning Using Information Technology: An Overview" (Webb & Ifenthaler), in this assessment section of this handbook, contains a discussion of how theories of self-regulated learning relate to formative assessment practices. Self-regulated learners can effectively generate and use internal feedback, provide feedback, and become increasingly less reliant on externally provided feedback (Butler and Winne 1995). Peer and self-assessment can play an important role in developing students' self-regulatory capacities (Black and Wiliam 2009; Wang 2011). In peer assessment, students take on the role of assessor and provide feedback to their peers, demonstrated to be valuable in developing students' sense of quality (Yu and Wu 2013). Self-assessment requires learners to be actively engaged in monitoring their own learning progress, and generates internal feedback to self-regulate (Panadero et al. 2016).

Feedback practices can be understood within a two-dimensional continuum (Fig. 1), ranging from asynchronous (with a delay) to synchronous (real time) feedback interactions, and convergent to divergent feedback.

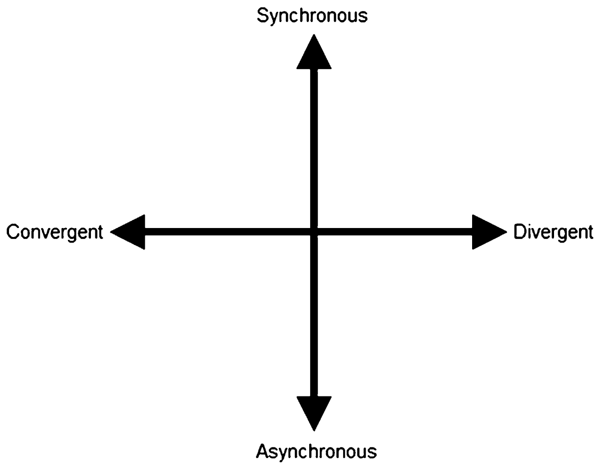

Fig. 1 Dimensions of feedback interactions

Torrance and Pryor (2001) first described assessment as convergent with reference to the practice of assessing whether students have met specific learning goals, where typically the teacher is the sole assessor. This notion extends to feedback interactions (Pryor 2015), in which convergent feedback describes that which addresses but does not go beyond prespecified learning outcomes. Convergent feedback describes those feedback instances where the focus is on detailing correct responses and specifically identifying where errors have occurred and how to correct these, thus closing the gap between current and desired performance (Sadler 1989). In contrast, Torrance and Pryor (2001) described divergent assessment as being exploratory in nature where students are given a chance to demonstrate what they can do beyond the bounds of curriculum. Thus, divergent feedback describes feedback that goes beyond prespecified outcomes and corrective information. Students, teachers, and peers engage in a feedback dialogue in which the student identifies the type of feedback they require to progress their learning, and students may also provide feedback to the teacher. Students are also actively participating as self-assessors, providing feedback to themselves that extends their individual and internalized learning goals. Divergent forms of feedback involve students as co-constructors of meaning in feedback interactions.

Digital platforms provide opportunities for feedback to be instantaneous and continuous. They also provide opportunities for asynchronous feedback through, for example, voice and video recordings that deliver personalized messages. The form of feedback as corrective or extending thinking may occur synchronously or asynchronously dependent on the application and learning focus. Figure 1 provides a framework to consider the form of feedback made available through the digital platform. The following section provides an overview of the various digital platforms in terms of the type(s) of feedback interaction they facilitate.

Formative Assessment and Feedback Using IT: Tools and Applications

Digital Learning Environments

In digital learning environments, feedback is often provided to students based on their correct or incorrect response to a task, either immediately or with a small delay. The potential advantages of the convergent and synchronous application of automating feedback in computer-based assessment have long been recognized. As early as the 1920s, Pressey invented the "teaching machine," a machine that included multiple-choice questions and informed learners of the correctness of their responses, also known as knowledge of results. The purpose of providing such feedback was to reinforce correct responses, consistent with a behaviorist perspective on learning. Perspectives on learning and the potentials of technology have evolved considerably since; however, the way feedback is provided to learners in many digital learning environments is still remarkably similar to those in the teaching machine (e.g., Cayton-Hodges et al. 2015). And although computer-based assessments have been programmed onto a variety of tools, such as computers or tablets, the presentation of assessment tasks and feedback is still very similar to traditional paper-and-pencil formats with simple response formats and feedback in the form of ticks and crosses (e.g., Faber et al. 2017).

Currently, much of the research into digital environments with automated feedback involves a static set of tasks that is completed by all students, similar to paper-based tests (van der Kleij et al. 2015). Innovations in psychometrics and technology have opened up possibilities to tailor the difficulty of tasks to the ability level of the learner, which has the potential to enhance the effectiveness of digital learning tools. However, a recent meta-analysis (Kuo and Wu 2013) in mathematics and science indicates that both formative assessment and adaptive assessment are underutilized in digital learning environments.

While much of the previous research has focused on closed answer item formats such as multiple-choice, IT offers possibilities for providing automated feedback on more complex task formats. Automatic essay scoring systems have been developed for student writing tasks, which when utilized in conjunction with teacher feedback, have been shown to reduce teacher workloads and increase students' writing persistence (Wilson and Czik 2016). However, automated feedback on writing by itself may not be very effective; a recent meta-analysis reported an average weighted effect size of 0.87 for adult-provided feedback compared to 0.38 for automated feedback (Graham et al. 2015). For additional discussion of this topic, see also ► Chap. 43, Progress and Challenges for Automated Scoring and Feedback Systems for Large-Scale Assessments" (Whitelock & Bektik), in this assessment section of this handbook.

Regarding the effects of feedback in digital learning environments in primary, secondary, and tertiary education, a recent meta-analysis (van der Kleij et al. 2015) found an effect size of 0.05 for knowledge of results, which means that it is essentially just as effective as no feedback. The meta-analysis found substantial differences between the effects of different methods for providing feedback, and highlighted the need to take into account the complexity of the learning to be achieved. When the aim is for students to memorize or understand material, providing them with knowledge of the correct response is generally moderately effective (overall $ES = 0.32$). In the case of more complex learning, where the learner is required to apply their knowledge and skills, *elaborated feedback* works best (overall $ES = 0.49$). Elaborated feedback includes information additional to knowledge of results, such as an explanation, strategic hint, worked out solution, or a reference to additional study material. This type of feedback includes elements of instruction and goes beyond the correctness of the learner's response (Hattie and Timperley 2007), which can help students identify *how* they can improve. Van der Kleij et al. (2015) found that elaborated feedback is particularly effective when it gives students hints or strategic information which stimulates students to think deeply about the task and their strategies, thus supporting self-regulation.

Intelligent tutoring systems provide a platform for the provision of elaborated feedback (Narciss 2013) or scaffolding to support next-steps in student learning. When used in this way, students receive subtle and gradual feedback to enable them to recognize and correct errors in knowledge and strategy, and use feedback in subsequent tasks. This use of intelligent tutoring systems for elaborated feedback has been found to establish the conditions for students to develop self-regulated learning skills. For instance, Narciss and Huth (2006) compared the impact of knowledge of correct response and "bug-related tutoring" feedback, which provides explanations for errors in addition to knowledge of correct response, in a sample of 50 German fourth-grade mathematics students. Students in the bug-related tutoring condition demonstrated higher levels of mastery indicated by correctly solving two similar mathematics problems, greater ability to self-correct errors, and improved academic performance from pretest to posttest. The research also reported enhanced student motivation levels in the bug-related tutoring condition: "The positive feedback effects on motivation are consistent with the view of current motivation theories which assume that mastery experiences resulting from successful task completion and the feeling of personal causation are crucial for developing positive perceptions of competence" (p. 319). Extending on these findings, a Taiwanese study in fifth-grade science concluded that the option for students to request hints as a guide toward correct responses increased achievement compared to knowledge of correct response (Wang 2008). In Wang's study, students were also able to ask the teacher questions asynchronously.

Several studies have explicitly explored the relationship between digital platforms and self-regulated learning. In a 2011 study involving 123 seventh-grade biology students, Wang examined the effects of five peer-supported self-regulation strategies in an e-learning environment. The strategies involved the use of answer notes to explain students' reasoning for choosing a particular response and the review of their peer's answer notes. Students who had access to the self-regulation strategies scored higher on a self-regulation behavior questionnaire compared to the control group who did not. Regulation feedback including questions relating to, for instance, task comprehension, strategy use, and reflection on the solution was the focus of another study involving 65 ninth-grade mathematics students in Israel (Kramarski and Gutman 2006). In this e-learning environment, it was found that knowledge of results plus regulation feedback was significantly more effective than knowledge of results only ($ES = 0.44$). Timmers et al. (2015) used a similar self-regulation feedback strategy in their study of information literacy involving 50 thirteen-year-old students in the Netherlands, but also included a self-assessment component. They found significant positive improvements in performance and strategy use in girls only.

The effects of self-regulatory scaffolds have also been examined in the context of biology learning in a hypermedia e-learning environment for 53 tenth-grade and 58 seventh-grade students in the United States (Azevedo et al. 2005). Students were assigned to one of three conditions: no scaffolding, fixed scaffolding, and adaptive scaffolding. In the fixed scaffolding condition, students received a list of goals to guide their learning. In the adaptive scaffolding condition, students could request digital guidance from a human tutor, who would, for example, help them "monitor their emerging understanding" (p. 392). Students in the adaptive scaffolding and no scaffolding conditions outperformed those in the fixed scaffolding condition in terms of knowledge gain. Moreover, students in the adaptive scaffolding condition demonstrated better self-regulatory strategies.

A limitation of the research into digital learning environments has been the focus on textual feedback, with the potential of multimedia being underutilized (van der Kleij et al. 2015). Ostrow and Heffernan (2014) found the use of video feedback increased student engagement. Their study compared video and textual feedback in a digital learning environment for 139 eighth-grade mathematics students from the United States. The video feedback demonstrated a researcher reading a feedback message and referring to a worked solution on a whiteboard, while the textual feedback conveyed the same information. Students in the video condition spent more time engaging with feedback than students in the text only condition and completed subsequent mathematics problems more quickly. While the provision for students to ask questions and respond to teacher feedback was not an aspect of this study, it is an area requiring further consideration if feedback is to promote self-regulatory skills, dialogue, and deep engagement. In addition, researchers have called for systems that provide opportunities for classroom-integrated technology that informs the teacher of how students are engaging with the task (e.g., Faber et al. 2017). Further research is required into online systems that provide a range of feedback for both the teacher and the student while increasing the opportunity for dialogue about feedback and learning.

Gaming elements have often been incorporated into digital learning and assessment environments to enhance motivation or engagement (e.g., Wang 2008). The following section considers the form of feedback that game-based digital platforms may provide to teachers and students.

Game-Based Formative Assessment

Game-based digital platforms through their design can offer challenge and an element of play that motivates students to participate in formative assessment

(Wang 2008). In primary and secondary classrooms, tablets are popular devices for educational games. However, research (Cayton-Hodges et al. 2015) has found that although the majority of applications claimed to be game-based learning environments, in many instances, the assessment components were presented as explicit tasks that interrupted the gaming experience. Assessment tasks were usually presented in multiple-choice formats. Some exceptions included rich interactions using an array of presentation and response formats, such as drag-and-drop using visuals and written responses. Feedback was communicated visually, including the use of videos, or via audio. In some of the apps, feedback involved specific guidance to learners during problem-solving, identifying specific errors and providing explanations, and the option for students to request hints. While the majority of feedback was corrective in nature, or provided an overview of the number of tasks correctly solved, there was evidence of more sophisticated and divergent forms of feedback.

Advances in technologies have resulted in the development of more complex game-based assessment systems, for example, in the form of simulations (e.g., Shute et al. 2017). Well-designed games have the capacity to collect a wide range of data about the user's performance as they progress through the game, such as response time and whether or not students request hints, and utilize this information to generate individualized formative feedback (Cayton-Hodges et al. 2015; Shute et al. 2017). Shute (2011) used the term "stealth assessment" to describe the seamless assessment and learning environment, whereby the individual is unaware of the assessment process during their engagement with a digital game. However, the analysis of complex performance data (that goes beyond the correctness of a response) and the subsequent translation to feedback that will be useful to learners is a challenging topic of ongoing research (Azevedo et al. 2010; Shute and Kim 2014). Shute and Emihovich examine the progress to date in ▶ Chap. 44, "Assessing Problem-Solving Skills in Game-Based Immersive Environments," in this section of this handbook.

Classroom Response Systems

Classroom response systems or "clickers" provide opportunities for nearly synchronous formative assessment in classroom settings and are most suitable in a convergent assessment context. Clickers consist of a handheld device used by students to transmit their responses to questions, which are then aggregated and displayed in a graph via a projection screen (Kay and LeSage 2009). Previous studies have identified a number of formative assessment applications for clickers, including identifying students' (mis)understandings of instructional materials, assessing students' capacity to transfer knowledge, student self-assessment, and ascertaining students' current knowledge base and capabilities (Caldwell 2007).

Classroom response systems enable teachers to obtain responses from all students, and use this information to modify course content or pacing to address student needs (DeSorbo et al. 2013; Feldman and Capobianco 2008; Vital 2011). Such systems are particularly valuable for students who are experiencing difficulties with content and may be reluctant to participate in class discussion. Many studies of clicker use in schools have utilized simple handheld devices that allow for multiple-choice type responses, consistent with a convergent assessment paradigm. These appear to result in improved levels of student engagement (DeSorbo et al. 2013; Vital 2011) and achievement (Mun et al. 2009), possibly associated with increased demands for participation and the availability of (generic) formative feedback. Reported challenges regarding the use of clickers include the malfunction of the hardware, time pressure, student maturity levels, limited response formats, the construction of appropriate questions, utilizing feedback formatively, and discomfort with the new technology that interfered with students' learning (Kay and Knaack 2009; Lee et al. 2012; Vital 2011). However, with the increasing accessibility of technology and use in all aspects of life, it is anticipated that these issues would have diminished over time.

More advanced classroom response systems enable a broader range of response formats such as open-ended responses, therefore addressing some of the limitations of earlier systems (Shirley and Irving 2015; Irving et al. 2016) and opening up possibilities for more divergent assessment. A case study of the use of classroom response systems in elementary mathematics classes with the addition of interactive whiteboards and notebooks enabled opportunities for high cognitive demand questioning (Polly et al. 2014). Students were given time to solve a complex task and write down their solution steps before selecting a response on their clicker. A camera allowed students to project their work on the whiteboard and to discuss their reasoning and approach to solving the task. This resulted in deeper levels of student learning, as well as better teacher understanding of students' knowledge and problem-solving processes, which enabled teachers to provide students with more detailed feedback. In summary, the system facilitated the opportunity to elicit whole class responses which informed both teacher and student decisions about next-step teaching and learning.

Web 2.0 Platforms for Mediating Feedback

Web 2.0 refers to web-based media that enables interactive authorship to generate content such as blogs, social media, e-portfolios, or wikis (Fendler 2011) in both synchronous and asynchronous communication. Teachers can gain information on student strengths and weaknesses, and levels of understanding and interest through student contributions to Web 2.0 platforms, thereby enabling formative assessment and adjustment of curriculum content as required (Ruday 2011). Web 2.0 supports cloud-based collaborative writing allowing for interaction between students and their peers and teachers to facilitate formative feedback and learning. It also provides a platform to provide open-ended assessment tasks and feedback that is more divergent in nature.

The capability of deep student engagement with assessment and multiple forms of feedback can be found in blogging software. For example, blogging software was used as a platform for a 'book club' for a third-grade class in the United States (Stover et al. 2016). Students utilized the blog to discuss the book, and to reflect on previous posts, reading-related skills, and habits. The teachers shared a rubric to facilitate student self-assessment of reading comprehension. The class discussed examples of blog posts and assessed their positioning on the rubric. Teachers interacted with students via the blog, providing comments to interrogate students' thinking and build comprehension. The blogs provided the teachers with more transparent information on student strengths and weaknesses in relation to reading comprehension and skills, which enabled them to differentiate instruction.

Another study, involving 40 Year 11 English students in China, used Facebook as the hub for peer and teacher feedback (Kio 2015). The teacher initiated and moderated a Facebook group for the class to provide peer support and feedback outside of school hours. To encourage participation, the teacher posted information about lessons, homework, assessment, and other activities. Students discussed class topics and provided peer feedback via the Facebook wall. While students reported that feedback from multiple peers was convenient and aided in motivation, it sometimes lacked the specificity and richness they required, and it remained a convergent form of feedback. A similar finding was found in a study that utilized a cloud-based platform for collaborative writing in four American schools Grade 6 to 8 English classes (Yim et al. 2014). The students used Google docs for simultaneous collaborative writing using the comment, highlight, and editing features. Students could choose who to share their work with, and request peer and teacher feedback over several rounds of revision. This resulted in focused dialogic feedback on the students' identified areas of need. However, while the platform overall supported the continual expansion and development of ideas through "the continuity of writing and revision" (p. 249), student feedback frequently focused on sentence-level features rather than broader-content-level issues. In addition, most students worked individually while providing, receiving, and using peer and teacher feedback rather than as a platform for collaborative writing. These studies demonstrate that the platform alone will not promote deep engagement – these skills need to be taught for the potential of the system to be realized.

The purposeful incorporation of an online platform with explicit instruction on self-regulatory skills was evident in a Scottish study involving 305 students aged 5–14 years (McLaren 2012). This study combined a multimedia "e-scape" portfolio and blog to assess and facilitate feedback on the skills of creativity, iterative design processes, and reflective thinking. Students were able to access a range of tools to record their thought processes including text, drawing, mind maps, photos, audio, and video. Examples of thought processes were captured using a rubric that required evidence of analysis skills, decision making, and justification. Students also recorded personal learning goals for the purpose of self-reflection and self-assessment. Each student was connected to the e-scape management system via classroom Wi-Fi, and teachers provided individual audio or textual feedback. Teachers indicated various approaches to feedback including probing for deeper thinking, encouraging self-reflection, or providing more information or instruction and directions for subsequent work.

Video Feedback

Video feedback has been utilized in classroom contexts for teacher feedback (Ostrow and Heffernan 2014) as well as supporting self-assessment (O'Loughlin et al. 2013), peer assessment (Lenters and Grant 2016), and reflecting on the feedback process itself (van der Kleij et al. 2017). Ostrow and Heffernan (2014) suggested that “the use of video forces the learner to slow down and internalize the concept that is being taught” (p. 299). O’Loughlin et al. (2013) reported enhanced levels of motivation, engagement, and learning for students when video recordings of performance were used for self-assessment in an Irish physical education class of 23 nine- to ten-year-old students. In this case, rubrics were used to guide students in self-assessing their video-recorded basketball skills, and the teacher provided supplementary feedback as needed.

Using video for recording peer feedback has also been found to have instructional merit. Lenters and Grant (2016) reported on a Canadian trial using iPads and iPods as recording devices for peer feedback in fifth-grade writing. The teacher and students were familiar with written and face-to-face peer feedback processes using structures such as “I noticed . . .” or “I wondered about . . .” (p. 190). The teacher and students reported two benefits of using video recordings for feedback. First, students were better able to communicate their feedback in the way they intended, which they indicated resulted in fewer misinterpretations. Second, students could consult the recorded feedback as often as needed. Although some students reported a certain level of discomfort recording their feedback, many reported feeling more comfortable recording their feedback than having to discuss this face-to-face with their peer, which resulted in more objective feedback.

The use of iPads for videoing one-to-one teacher–student feedback conversations for supporting self-reflection and self-regulation was trialled in Australia with six teacher–student pairs in Year 9 (van der Kleij et al. 2017). Individual video-stimulated recall sessions were held with participants in which they were asked to stop the video recording and comment on the instances they identified as relevant. The video technology enabled teachers to self-assess their feedback practices and the effect of these on the student. Besides reviewing the feedback, students justified their responses to the feedback and considered their contribution to the conversation. Through this reflective process opportunities for self-regulation of both teachers and students were realized.

These studies demonstrate the relative benefits of video feedback over written or face-to-face feedback for both teachers and students. Video recording offers both a personalized connection with the feedback, as well as, in the case of peer feedback, some distance to provide more objective comments. Being able to articulate the feedback and demonstrate through examples enables individualized feedback otherwise not possible in limited class time. The opportunity to revisit the feedback is another benefit of video recording.

Conclusion

Formative assessment and feedback have been shown to contribute to effective learning but, as has been shown, within the situated reality of classrooms there will be variable outcomes (Heitink et al. 2016). This chapter reviewed various ways in which IT has been used in formative assessment, focusing specifically on digital learning environments, game-based assessment, classroom response systems, Web 2.0, and video feedback. Using IT as a platform for feedback provides opportunity to individualize feedback, increase student engagement, collect learning evidence for all students, facilitate reflective processes, and support self-regulated learning. Reported potential challenges to the utilization of IT as a platform for divergent forms of feedback include time restrictions, limited response formats, technical difficulties, access to evidence of student learning for teachers (Faber et al. 2017), and teacher knowledge and skills, for example, in posing appropriate questions (Lee et al. 2012). However, most studies report on case studies in specific classes and more research on a larger scale is required to substantiate these findings.

One key finding is that although innovations in technology have evolved considerably, many promising possibilities are not yet being exploited for the purpose of formative assessment. Namely, digital assessment tasks frequently resemble paper-and-pencil tests, and feedback is often convergent, taking the form of ticks and crosses or written text of a corrective nature. Further, more research is warranted on the impact of regulation feedback and how this may enhance student learning (e.g., Kramarski and Gutman 2006). Moving forward, learning tasks could take place in, for example, 3D simulations, and feedback can be provided in the form of audio, video, and web links to online resources, on demand, or in dialogue with a virtual peer or teacher. It should be possible for students to ask for clarification or additional elaborations on feedback to enhance the usability of feedback. This would make feedback more accessible and engaging, and is likely to motivate students to engage with feedback.

Most importantly, research demonstrates that not the technologies themselves, but the ways in which they are used impact on their formative potential (e.g., Polly et al. 2014; Wang 2008). Skills in providing and accessing feedback need to be explicitly taught. As was highlighted in a recent review, teachers' knowledge and skills are vital to successful formative assessment practice (Heitink et al. 2016). For instance, if teachers do not have the skills to translate results into decisions for appropriate follow-up instruction and feedback (Lee et al. 2012), using IT will have limited formative potential. Another recurring issue is the quality of peer feedback (Kio 2015; Yim et al. 2014); if students do not possess skills in providing quality feedback, adding a digital tool for communicating such feedback is not going to enhance its effectiveness. Students need to be given guidance in the peer feedback process to make the process beneficial to both feedback providers and receivers (e.g., Lenters and Grant 2016).

Research to date suggests that formative assessment practices using IT are often convergent in nature, but possibilities exist for more divergent feedback practices. Once again, of importance here is how the technology is being used. For example, iPads can be used in very similar ways to paper-based materials, but also have the potential to be used by students to engage in formative assessment processes, through activities such as compiling digital portfolios to evidence their learning (Cumming and van der Kleij 2016), or by opening spaces for dialogue (van der Kleij et al. 2017). IT provides students with a platform for self- and peer assessment, and opportunities to develop a voice and exercise agency of their own learning journey. It can be designed to provide feedback with sufficient information to maintain achievable challenge, thus motivating students to continue. Developments in IT have produced promising results for providing timely, individualized, and challenging feedback that progresses student learning as well as scaffolding self-regulatory behaviors.

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Progress and Challenges for Automated Scoring and Feedback Systems for Large-Scale Assessments

43

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Contents

Abstract

Large-scale assessment refers to tests that are administered to large numbers of students and are used at local, state, and national levels to measure the progress of schools with respect to educational standards. In order to have accurate and fair measurements, large-scale assessment systems need to include all available students, which means a high volume of students, with large numbers of exams to be marked. The amount of marking that is required is extensive; thus marking

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exams at this scale requires a lot of work, which means a high volume of exam scripts need to be marked by tens of thousands of examiners appointed by the exam boards. The need for large-scale assessments and the high cost of manual marking and limited "turn around" time have led to developments, over some years, of automated assessment and marking. This chapter reviews the history and development of automated assessment systems. It includes findings from empirical research as well as highlights the theoretical considerations that emerge from such developments. In addition, the practical aspects of developing such assessments are explored with examples primarily from the UK and USA, including the systems and tools available, the current capabilities of natural language processing (NLP) approaches, and their limitations, ethical concerns, and future potential.

Keywords
Large-scale assessment · Automated assessment · Automated analysis of student scripts · Ethical issues in automated scoring

Introduction

Large-scale assessment refers to tests that are administered to large numbers of students and are used at local, state, and national levels to measure the progress of schools with respect to educational standards. For instance, the Organisation for Economic Co-operation and Development (OECD)'s Programme for International Student Assessment (PISA) is a triennial international large-scale assessment study that assesses the skills and knowledge of 15-year-old students in compulsory education since 2000 ("PISA" 2017). The aim of the PISA program is to compare education systems across the participating countries in Europe in order to provide evidence-based information on domestic educational policies.

In order to have accurate and fair measurements, large-scale assessment systems need to include all available students (Thurlow et al. 2001), which means high volume of students, with large numbers of exams to be marked, which in turn requires extensive effort. For example, the previous two-hour-long international PISA test was taken by over half a million students, representing 28 million 15-year-olds in 72 countries and economies. The need for large-scale assessments and the high cost of manual marking have led to developments, over some years, of automated assessment and marking.

This chapter reviews the history and development of automated assessment systems together with knowledge from empirical research as well as the theoretical considerations that emerge from such developments. In addition, the practical aspects of developing such assessments will be explored with examples primarily from the UK and USA, including the systems and tools available, the current capabilities of natural language processing (NLP) approaches, and their limitations, ethical concerns, and future potential.

Large-Scale Assessment: Issues and Potential Solutions

In Britain (except for Scotland), the General Certificate of Secondary Education (GCSE), Advanced Subsidiary (AS), and Advanced Level exams (A-level) are the main academic qualifications taken by all school students at the age of 16 and 18 years. To illustrate the scale of marking that is required, “in summer 2012, 1.27 million candidates took GCSEs in 48 subject areas,” and “over half a million candidates took A levels (or AS) in 36 subject areas” (Ofqual 2013, p. 4). Marking exams at this scale requires extensive work, which means a high volume of exam scripts need to be marked by tens of thousands of examiners appointed by the exam boards. The following table summarizes the breakdown of exams taken from each exam board (Table 1).

“The time pressures on exam boards to process this volume of scripts is great” (Ofqual 2013, p. 5). Thus the management of such a high-volume process is complex. Examiners are contracted (not on a full-time basis) and geographically distributed in the UK (some Pearson Edexcel examiners are also based in Australia), and they are marking scripts at their own convenience. In September 2009, Edexcel announced that they intended to employ artificial intelligence-based systems to automatically mark exam essays for English language tests. Their rationale was centered around the good correlation between human judges and artificial intelligence systems (Irvin 2009; Harris 2009). This announcement caused quite a storm, and some academics found the idea of machines judging the quality of extended writing as “ridiculous nonsense,” which also sparked another concern which was the wide-scale use of automatic marking of GCSEs and A-levels (Harris 2009). Although it was revealed that Edexcel planned to start trials of automatically marking essays in dummy GCSE-style questions in 2006 (Harris 2009), it was not adopted for anything other than multiple-choice tests (Irvin 2009). However a move was made for human markers to adopt an online marking approach rather than working with pen and paper.

It was only in 2013 that examiners started to adopt online marking. Although traditional pen and paper marking was replaced with “paperless” on-screen marking, it sparked a high volume of criticism not just from head teachers, teachers, and parents but even from some examiners themselves who reported that errors occurred in calculating the final mark, using this new system (Harrison 2013). The large

Table 1 Breakdown of exams taken from each exam board (Ofqual 2013)

Exam board	GCSE external exam scripts marked	A-level external exam scripts marked
AQA	4,259,000	1,683,000
CCEA	264,000	115,000[4]
OCR	2,871,000	1,026,000
Pearson Edexcel	2,638,000	1,143,000
WJEC	1,170,000	284,000
Total	11,022,000	4,154,000

amount of criticism about the digitalization of exam marking and the legal challenge over the previous year's GCSE English exam grades led Ofqual to publish a review of its quality of marking (Duffin 2013). This subsequent report published in 2013 argued that on-screen marking was a positive step forward with respect to quality assurance, as it facilitated flexible and frequent monitoring of examiners, therefore improving the reliability of the examining process. It also revealed that 1% of all the marking for GCSEs, A-levels, and other academic exams in England were marked automatically because multiple-choice exam papers, predominantly for science GCSEs (Ofqual 2013), were used.

There have been more recent advances with systems which automatically mark primary school mathematics problems. Kurvinen et al. (2015) developed the ViLLE tool and have shown that in Finland, pupils using this system received statistically significant higher grades than nonusers. Similarly in the UK, Adesina (2016) has shown that by using MuTAT, a semiautomatic computer-aided assessment system for primary mathematics, 26% savings in marking time were achieved compared to traditional paper and pencil marking. More importantly, the data from MuTAT allows teachers to see the arithmetic strategies employed by their students. This means they could provide more directed pedagogical assistance to individual pupils. The wide range of automated marking tools that are being developed and are now employed in primary schools suggest that these types of computer-assisted assessments can improve the quality of feedback and range of assessments for primary pupils while at the same time reducing staff workload.

Although there is controversy about automatic marking systems, Bektik (2017) has pointed out that there is also a problem with the reliability of human marking. "It is inevitable, with the best will in the world that two very experienced tutors can give a very different mark to the same assignment" (Bektik 2017, p. 194). Thus automated scoring systems can be helpful. "Human markers can disagree with each other and therefore they do not necessarily come to the same conclusion as their peers; which is a reliability concern. The automated output on the other hand is always the same, stays the same and is not subjective" (Bektik 2017, p. 253).

Moving toward the automatic marking of high-stakes examinations has been fraught with difficulties, but it is fair to say that the technology has advanced since 2009 when even on-screen marking triggered serious concerns and opposition. Almost a decade later, natural language processing systems have become more powerful in providing automated feedback. The next section discusses the development and improvement of automatic marking systems for essays and its potential for more wide-scale usage.

Early History: Automated Assessment and Scoring

Research in automated assessment and scoring began in the early 1960s. One of the first applications, and the idea of using computers to automatically score, came from a former high school English teacher, Page (1966, p. 238), whose aim was to "rescue the conscientious English teacher from his backbreaking burden." His article was greeted with high skepticism as the idea of "grading essays by computer" seemed nonsense and impossible for many people (Shermis and Burstein 2013). Page's admonition was that students, especially those with poor writing abilities, have to write more to be better writers. This was associated with the assumption that their academic tutors were spending too much time marking papers and were burdened with hours of grading written assignments. Page argued this is the biggest impediment to more writing as overburdened tutors would ask limited number of drafts from their students. Therefore, he worked on persuading educators that there is a need for computers to grade essays automatically and that this is feasible and promises to improve the quality of teaching (Page 1966). However, unlike skeptics, people who knew about disciplines such as linguistics and who understood about computers considered his approach as a "delightful toy" at that time (Page 1966, p. 238).

Page's aim was to develop a computer program that could evaluate student writing "as reliably as human readers," saving time and providing timely, speedy, reliable feedback to students (Page and Paulus 1968). However, access to computers was rare at that time apart from entering data via IBM's punch cards which was costly and not well-suited for the average person. What Page was suggesting sparked a controversial debate on the idea of "replacing human markers with machines," but there was no easily accessible hardware or software that was capable of doing half of what Page was suggesting.

Development of Automated Assessment Systems

When Page and Paulus (1968) published *The Analysis of Essays by Computer*, they visualized a promising future of automated programs that could evaluate both the aesthetic traits of essays and their content. However, it was not until the 1980s that such technology was accessible. As basic word processing systems became available in the 1980s, these systems made it possible to input text into automated essay assessment systems. By the early 1990s, the advances of the Internet and word processing systems made Page's idea of automatically evaluating student writing a reality. With important developments in the following decades, several studies have been conducted on automatic essay scoring (AES) and automated writing evaluation (AWE); see (Foltz et al. 1998; Landauer 2003; Shermis and Burstein 2003) for detailed descriptions of AES and AWE.

One of the widely known applications of AES is E-rater™. E-rater has been used by the Educational Testing Service (ETS®) for AES in the USA and became the first large-scale assessment tool to incorporate automated essay scoring (Attali and Burstein 2006). It is a web-based system that provides automated scoring and evaluation of student essays. ETS detects errors in grammar, usage, and mechanics, identifies discourse elements in an essay, and recognizes elements of undesirable style.

Page also worked on his innovative idea with Petersen in 1995, The Computer Moves into Essay Grading: Updating the Ancient Test, through ETS (Page and Petersen 1995). Page and Petersen's (1995) collaboration with ETS allowed them to show the possibility of Page's initial idea: "in a blind test a computer can simulate the judgement of a group of human judges on a brand-new set of essays" (p. 561). In recent days, this idea of computers simulating human judgment has been called artificial intelligence (AI)-based assessment. "AI can be defined as the ability of computer systems to behave in ways that we would think of as essentially human" (Luckin 2017, p. 1).

ETS is not the only testing service that makes use of automatic essay scoring systems. They have also been adopted as a second or check scorer in widely known American large-scale assessments, such as the Graduate Record Examination (GRE®), the Test of English as a Foreign Language (TOEFL®), and the Graduate Management Admissions Test (GMAT®). AES systems are also used as the primary essay scoring engine in various assessment and instructional products, including Accuplacer®, the Criterion® Online Writing Evaluation Service, IntelliMetric®, and the Pearson Test of English™, which are some examples of how AES has been developed following on from Page's original idea. It was Page who supplied the spark that ignited the controversial arguments around using computers to grade essays, which is discussed below in the "Ethical Concerns: Ongoing Controversy" section below.

Automated Marking in School Exams

Automated *exam* scoring is a more objective mode of classification, in which answers are analyzed for the presence of concrete facts or statements instead of using any continuous measure (Frost 2008). Automated marking of student assignments is usually around three types of assessment, (1) multiple-choice questions, (2) short-answer marking in free text, and (3) essay marking.

Automated assessment of multiple-choice questions has been relatively easy to implement, compared to the other two, as even generating multiple-choice questions automatically has become possible (Johnson et al. 2013). Also, the answers to multiple-choice questions are definitive and not open to any subjectivity which is why it is the most common type of assessment where complete automation is used. For instance, the latest PISA test in 2015, where multiple-choice questions were employed, was marked automatically. PISA moved from paper-based to computer-based testing in 2015. Response codes were applied to test items, "either by a more or less automated process of capturing the alternative chosen by the student for a multiple choice answer, or by a human judge (expert coder) selecting a code that best captures the kind of response given by a student to an item that requires a constructed response" (PISA 2013, p. 30).

New approaches and developments to automated scoring have made it possible to develop ways into automatic short-answer marking, which is pedagogically more powerful than multiple-choice questions to measure students' learning. For instance, research conducted by Sukkarieh et al. (2003) in Oxford University and in the Interactive Technologies in Assessment and Learning (ITAL) Unit of the University of Cambridge Local Examinations Syndicate (UCLES) showed that automatic short-answer marking (changing from a few words up to five lines) can also be possible and effective. The approach automatically marks short free text responses for factual science questions, to question types, which ask the student to *state*, *describe*, *suggest*, and *explain*. This technique has been successfully applied to the GCSE exam (Frost 2008). Sukkarieh et al. (2003) work reveals that for Biology GCSE, there was 88% agreement between the human marker and their system.

The third type of assessment, automated essay marking, which is the main focus of this chapter, is far more complex and open to even more controversy. The next section outlines the possibility of large-scale automated essay marking through the use of natural language processing systems.

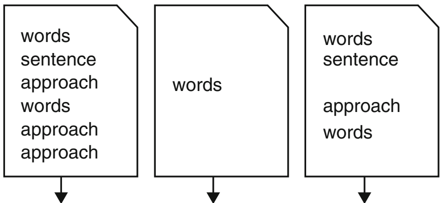
Capabilities and Challenges of Natural Language Processing Approaches

The main approaches in the field of computational linguistics relating to automated text analysis are "comparing text fragments as bags of words in vector space, using lexical resources and using Latent Semantic Analysis (LSA)" (Gabrilovich and Markovitch 2007). These techniques and their challenges are introduced below.

The Bag of Words Approach

Text documents can contain thousands of words which provide the starting point for approaches which treat a document as a metaphorical "bag of words." For example, when a user wants to use a query to search for similar documents, the following steps are applied to find out the proximity of a query, how close it is, to a document. As shown in Fig. 1, the query terms (*words*, *sentence*, and *approach*) are searched for in documents (A, B, and C).

The term frequency is the total number of matches between query terms and occurrences (*words* occur twice in document A). A TF analysis would show that



	Document A	Document B	Document C
words	2	1	2
sentence	1	0	1
approach	3	0	1

Fig. 1 The bag of words approach – term frequency. (Bektik 2017, p. 75)

documents A and C are most similar to each other, with document A being the best match to the user query. A strength of this approach is that it scales to millions of documents.

In terms of its logic, this approach accepts that a document with ten occurrences of a term is more relevant than a document with one occurrence of the term. This might be true; but even if it is, it may not be ten times more relevant. Relevance does not increase proportionally with term frequency. One approach to overcome this problem is by calculating the score as the sum of one plus the log of the term frequency for each term in a document. This technique has been shown to return superior results in information retrieval.

The bag of words approach does not incorporate a semantic structure (Frost 2008). "Thus if the answer requirement is a statement such as 'the cat chased the mouse', then an answer of 'the mouse chased the cat' would be accepted despite the clear semantic inequality, due to the identical set of words" (Frost 2008, p. 3).

Since good academic writing requires the appropriate use of relevant vocabulary from the domain of discourse (Hyland and Tse 2007; Ivanič 2004), the term frequency is only a partial solution. It is hard to imagine a high-quality essay, which does not cover much of the expected vocabulary, and a bag of words approach will assist in giving feedback on those grounds. However, the absence of any understanding of the role that different words play in language is an important limitation. Approaches that take into account word meanings add greater sophistication, and these are introduced next.

Lexical Resource-Based Approaches

It is possible to go beyond exact word matching by using lexical resources, databases containing machine-readable dictionaries which rapidly search lists of words, making them a very popular natural language processing (NLP) approach (Vossen 1998). They provide the opportunity to consider various linguistic phenomena such as synonymy, antonymy, and hyponymy. Synonymy is similarity of meaning; in terms of substitutability, it is having the same meaning as another word or phrase in the same language. "The antonym of a word x is sometimes not-x, but not always. For example, 'rich' and 'poor' are antonyms but to say that someone is not rich does not imply that they must be poor; many people consider themselves neither rich nor poor" (Miller et al. 1990, p. 7). "A hyponym inherits all the features of the more generic concept and adds at least one feature that distinguishes it from its superordinate" (Miller et al. 1990, p. 8). To illustrate hyponym, maple is a hyponym of tree, and tree is a hyponym of plant.

Throughout the years, different ranges of lexical resources have been created for automatic semantic processing of text documents. There are various resources/databases (e.g., PropBank, WordNet, SentiWordnet) that serve a range of purposes, and each has its own strengths and weaknesses. Although some lexical databases have the same purpose, such as providing synonymy information, their results can vary immensely. In order to overcome this limitation, a common strategy is to combine the benefits of multiple lexical resources, which is referred to as lexical substitution, e.g., Loper et al. (2007) and Sinha and Mihalcea (2009). This method was announced in the workshop on semantic evaluations (SemEval) in 2007. The idea is for the selected target (such as the word "bright") to return synonyms from several lexical resources. The appropriate ones can then be selected (Sinha and Mihalcea 2009). This approach is most appropriate for individual word comparison although some resources allow predicate-argument structure. Therefore, its adaptation for comparing longer texts, sentences, or paragraphs requires an extra level (Gabrilovich and Markovitch 2007).

Latent Semantic Analysis

The third approach, latent semantic analysis (LSA), is a fully automatic, mathematical, and statistical technique for automatic indexing and retrieval. It was designed to overcome the problems of other retrieval techniques that try to match words within user queries with the words of the document. As discussed in previous sections, a key deficiency of these kinds of information retrieval techniques is that individual words may not be reliable enough to retrieve the conceptual content. This is because there are various ways of expressing any given concept; "the literal terms in a user's query may not match those of a relevant document" (Landauer et al. 1998). LSA was designed to overcome this term-matching retrieval problem.

LSA assumes that there is some underlying latent semantic similarity between the user query and the documents. For instance, two documents might be semantically similar even if they do not contain the same words: "the words searchers use often are not the same as those by which the information they seek has been indexed" (Landauer et al. 1998). The fundamental deficiencies of most information retrieval techniques relate to three issues (Landauer et al. 1998):

- *Synonymy*: There are many ways to refer to the same object. Users in different contexts or with different needs, knowledge, and linguistic habits describe the same information by using different terms. For instance, there is only a 20% possibility that two people choose the same main keyword for a single well-known object.
- *Polysemy*: Most words have more than one distinct meaning. In different contexts or when used by different people, the same term can take on a different meaning.
- *Inadequate number of index terms*: The index terms identified for comparing two documents or the user query with documents are incomplete. They only contain a fraction of the terms under which users will try to look them up. The documents themselves do not contain all the terms that users will apply in their queries. For example, a writer might use the words "access" or "retrieval"; but a user might use the word "look-up" instead.

The LSA can be used for automating the marking. To do this, LSA needs to be trained in respect of domain-representative text (Foltz et al. 1999). It needs a "semantic space" which has been trained with the representative text, so, for example, if the system will be used to mark biology essays, then it will be trained with a relevant biology textbook. In the LSA, the essay to be graded is compared to all other essays and text within this semantic space, and the grades of similar essays are then used to predict what grade the expert would have given. One example of a system that uses LSA is the Intelligent Essay Assessor (IEA), a set of software tools for scoring the quality of essay content.

Current Applications

Large-scale assessment is the area where the use of IT for assessment is most highly developed, and it is focused on summative assessment and accreditation, e.g., the Graduate Record Examination and the Test of English as a Foreign Language. More recently the possibilities for automated systems that support formative assessment through constructive feedback have been explored, especially in higher education, although there are also many opportunities for such systems for school-level students. For instance, the Paperless School Marking Engine (PS-ME) is the free text marking engine founded by Mason and Grove-Stephensen (2002) at Birmingham University in the UK, for both summative and formative assessment with little or no human intervention in British schools. It can be integrated as part of a school's learning management systems (LMS) and relies on NLP approaches to cover Bloom's taxonomy (1971) specifically knowledge, understanding, and evaluation levels. PS-ME has been applied to low-stakes coursework, National Curriculum Grade, and GCSE examinations in the academic domain.

The automated essay scoring systems explained in the "Development of Automated Assessment Systems" section focus mainly on summative assessment, rather than providing formative feedback (Rivers et al. 2014). Automated essay evaluation technologies, however, can be used not just for speedy scoring but also for providing students with feedback which is specific to their needs in order to help them to improve their progress (Whitelock 2015). "Automated assessment provides the possibility of increasing the amount of feedback a student can receive during the learning process (possibly automatically generated) and so receive greater support for their learning" (Johnson et al. 2013, p. 17).

Nowadays, various technologies exist that provide automated feedback on students' writing. For instance:

- *OpenEssayist*, a web application system, has been designed to help students in higher education understand the strengths and weaknesses in their draft essays. The system was developed to offer automated feedback in a number of forms: highlighting elements of essay structure, key concepts, dispersion of keywords, and sentences throughout the essays and summarizing the essay content back to the student for their own reflection. There are two components to the system, the learning analytics engine, *EssayAnalyser*, which is a summarization engine, and the web application that provides feedback for students, *OpenEssayist*. *OpenEssayist* processes essays and offers feedback through key phrase extraction, by identifying which phrases are most suggestive of the content, and extractive summarization which identifies key sentences (Whitelock et al. 2015). Each essay is automatically preprocessed using modules from the Natural Language Processing Toolkit (Bird et al. 2009) that typically uses large bodies of linguistic data or corpora.

OpenEssayist invites students to engage with and reflect on their work, in any subject domain (Whitelock et al. 2015). It is for formative assessment purposes and not for giving the students marks but supports them to improve their work through their understanding of the requirements of academic essay writing (Whitelock et al. 2015).

The flow of activities in the system is as follows: (1) students prepare a draft essay offline and when they want to obtain feedback, (2) they log on to the OpenEssayist system and submit their essay for analysis, by copy and pasting their text; (3) OpenEssayist submits the raw text to the EssayAnalyser service; and (4) once finished, OpenEssayist retrieves and stores the summarization data. From that point on, the students can then explore the findings at their own pace. The system is simply offering repeated access to the summarization data and feedback, as a resource, until the students are prepared to submit and explore the summarization feedback on their second draft and on subsequent changes between drafts (Whitelock 2015).

The rationale for developing *OpenEssayist* was based upon the knowledge that university students find essay writing to be a challenging task. Therefore, a system that provides immediate feedback or "advice for action" (Feedback to students that they will take notice of and use in future learning, tasks, and assessments Whitelock 2011.) (Whitelock 2011) on students' draft essays could be one way of overcoming this challenge. Advice for action enables students to "move forward in their studies by using the information obtained from the analysis" (Whitelock et al. 2014).

- A *Coh-Metrix* is another automated natural language processing tool that looks for "cohesion" indicators, i.e., how well the written text "hangs together," including word characteristics, sentence characteristics, and the discourse relationships between ideas in the text (McNamara and Graesser 2012). "In *Coh-Metrix*, sentences, paragraphs, and texts are measured as weighted vectors and LSA values" (Crossley et al. 2008). The "cohesion" of a text refers to the presence or absence of cues in the text that help the reader to understand the relationship between the ideas presented, and "coherence" is perceived as what the reader takes from it. These cues include words and ideas repeated across sentences and sections, referential overlap, and connective words such as "because," "however," and "therefore" (McNamara et al. 2013).

McNamara et al. (2010) used *Coh-Metrix* to investigate the role of cohesive devices and linguistic sophistication in explaining human ratings of essay quality. The definition of writing quality has been based on human judgments, expert markers from academic communities, who have been trained to reliability using a standardized marking rubric.

Researchers explain that when the quality of writing improves, the number of cohesion features does not necessarily increase; there is no indication that higher scored essays were more cohesive. "Higher scored essays were more likely to contain linguistic features associated with text difficulty and sophisticated language" (McNamara et al. 2009, p. 73). More advanced readers and writers use cohesion connectives less (McNamara et al. 2014), and more skilled writers use more sophisticated language (McNamara et al. 2009).

Coh-Metrix has become the foundation in the Writing Pal intelligent system, which is explained next.

- *Writing Pal (W-Pal)* is an intelligent tutoring system designed to provide writing strategy instruction, game-based strategy practice, and personalized formative feedback for secondary-school and developing first-year undergraduate writers (McNamara et al. 2013). W-Pal provides students with training on the use of strategies to improve their writing quality and, more specifically, on how to write essays. With W-Pal, students are provided with lessons on strategies for the various phases of writing, such as generating and organizing ideas before writing; drafting an essay with strategies on building the structure of introduction, body, and conclusion; and revising the essay (McNamara et al. 2013). Each of these lessons includes practice in the form of mini-games.
- *LightSide Labs* is an educational technology company, dedicated to improving student writing skills. It has developed a framework which provides automated feedback on student writing in the K-12 classroom (Mayfield and Rosé 2013). The LightSide framework is open source allowing its users to develop new feature extraction and machine-learning technology features. LightSide is not an LSA application but instead a machine-learning application that uses samples of graded student writing as input into the algorithms to help the scoring engine learn and become more efficient through training with a large number of exemplar texts. Although it uses a machine-scoring algorithm, it also automatically generates specific and actionable feedback from student text during the writing process. The LightSide's Revision Assistant, an online program to help school teachers when assessing K-12 students' writing, provides automated writing support to students, on demand, as they draft, with each student's process tracked for teachers to review. The Revision Assistant system requires training, by learning how educators grade, evaluate students' work, and provide feedback. This information is then used to provide students with automated feedback throughout the writing process.

Ethical Concerns: Ongoing Controversy

Automatic feedback systems can start to produce meaningful dialogues between students and teachers (Ras et al. 2015). However, automated feedback systems, especially automated essay scoring applications, have been subject to significant controversy. On the one hand, there is significant support for AES as "automated essay scoring and evaluation becomes more widely accepted as an educational supplement for both assessment and classroom instruction" (preface in Shermis and Burstein 2003). There are several studies showing that AES systems work well, with studies reporting high agreement rates between AES systems and human markers (Bridgeman et al. 2012; Burstein and Chodorow 2010; Landauer et al. 2003).

On the other hand, there has been and still is significant opposition to AES, particularly to the idea, originated by Page, that "it might replace human scoring" (Ericsson and Haswell 2006; Herrington and Moran 2012). Harsh criticism comes particularly from the community of writing researchers. The Conference for College Composition which is a major organization for writing researchers has, during the last decade, actively opposed AES. Writing professionals claim that such systems prepare their students to write for machines, writers writing to computers (Herrington and Moran 2001), and therefore they say: "Because all writing is social, all writing should have human readers, regardless of the purpose of the writing . . . We oppose the use of machine-scored writing in the assessment of writing" (Deane 2013, p. 8). They have not revised their statement yet, although there has been a great deal of AES deployment over the last 15 years. Critics argued that the replacement of human markers by a machine would not just threaten the jobs of tutors but also change students' sense of what it means to write in school and at university (Herrington and Moran 2001).

Common criticisms of AES (based on Cheville 2004; Ericsson and Haswell 2006) focus on the capability of such systems to interpret meaning, evaluate factual correctness of the content, and quality of the argumentation. Machines cannot truly read, understand an essay, and interpret its meaning (Attali 2013). Therefore, there is a possibility that such systems can be gamed as AES systems can be insensitive to particular features in student writing that human markers might detect and penalize, such as repetition and lack of coherence (Deane 2013). There is little research regarding the impact of AES on writers' behavior or on the view of it as a barrier to be gamed and manipulated by tricks rather than communicating with a person (Deane 2013). The biggest opposition to AES focuses on when it is deployed as a replacement for a human scorer, when it becomes the sole scorer. However, such an extreme situation is rare as even the widely known large-scale assessment systems, like ETS, only use AES as a complement to the human marker.

It is true that current AES systems do not mimic human markers' ability to measure conceptual reasoning; thus AES measures a narrower range of skills than human markers (Deane 2013), though they could measure a lot that human markers ignore. Such systems are therefore criticized since they fail to measure higher-order writing skills such as high-quality and strong argumentation due to their limited nature (Attali 2013). For example, the E-rater measures efficiency in "knowledge-telling" writing and cannot score the "knowledge-transforming" writing to a currently accepted level. In his research, Bennett (2011) reports on the use of AES in the persuasive writing style. He concludes that although the overall correlation between human and machine scores is high, AES systems are better at scoring essays which are marked based on a text production rubric that values fluency, effective word choice, and accuracy of the text production than they are at scoring essays which are marked based on a critical-thinking rubric that values effective argumentation and attention to the audience.

When the focus of assessment is on students who need practice to improve their fluency, and control their text production processes with less cognitive load, the capacity of the AES is relatively strong (Kellogg and Raulerson 2007); but if the focus is on quality of argumentation, AES is relatively weak (Deane 2013).

Attali (2013) pointed out that there is a lack of understanding of what human markers do in their evaluation. He mentioned that the primary goal of AES is to ensure that human markers think similarly about what constitutes high- or low-quality student writing so that machine scores measure the same elements as human markers. However, there is evidence showing discrepancies between the ways human markers interpret the quality of the same essay (Attali et al. 2012).

If human markers are inconsistent and unreliable, then the machine cannot be trained effectively (Bridgeman 2013). Therefore, the aim of mimicking human markers is a difficult task to achieve. Bridgeman (2013) discusses how to assess the rater reliability so that machines can be trained better. However, in order to deploy an AES system by considering such limitations, this deployment must be sensitive to AES' own limitations as well. It does not understand the essay, and therefore it is limited to measuring a subset of the written context; therefore, AES should currently be considered as a "complement to human scoring" (Attali 2013, p. 194). A "division of labor" approach (Attali 2013, p. 194) between human markers and machines can be used to overcome such issues.

Concluding Remarks and the Future Potential

Authors of FuturICT, a visionary 10-year program which aims to revolutionize education, foresee that "automated assessment will have a huge impact on education in the future" (Johnson et al. 2013, p. 17). However, although authors foresee that within a decade understanding natural language will enable us to develop new generations of automated testing, skepticism and criticism have accompanied automated scoring and feedback systems over the years (Attali and Burstein 2006). "The past has been marked by argument rather than dialogue: one side is the researchers and developers of such systems and the other side is the critique of such systems from writing teachers and researchers" (Shermis and Burstein 2013, p. ix).

Since writing is an activity that is deeply human, its association with computational formulations is double-edged (Elliot and Williamson 2013). When algorithms are used by computers as the basis for assessing student writing beyond fluency or knowledge of grammar (Attali and Powers 2008), there is a suspicion that technology can corrupt the essence of a fundamental human activity (Ericsson and Haswell 2006; Herrington and Moran 2012; Elliot and Williamson 2013). Although, in general, AES systems mimic the human markers well enough, as evidenced by a number of high correlational studies that do not mean because the approach works well on average, there is no guarantee that it will work well in all population subgroups (Bridgeman 2013). Unlike the initial intention of Page, at the current time, AES should be used as a "complement to (instead of replacement for) human scoring, limited in its ability to measure a subset of the writing construct" (Attali 2013, p. 182).

It should be recognized that machines do not currently fully understand the language itself, the accuracy of the written material, the content, and the beauty and subtlety of sophisticated argumentation that would be credited by human markers because it flows beautifully (Bektik 2017). Machines have limited capacity to understand language and literacy; this capacity is mostly dependent on the rules that its developers have written to train them. On the other hand, human language has endless possibilities of creating and forming new sentences each time. Therefore, machines and human markers should complement each other, with the aim of providing better feedback to students.

Any feedback that is not fully understood or cannot be acted upon, however pertinent it may be, is likely to be ignored by the learner, thus will not facilitate learner improvement (Whitelock 2011). The detailed feedback process which is currently supplied by human markers should be supported by machines in order to provide timely, efficient, and reliable feedback. Similarly, developers of these machines should improve their tools so that they have a better understanding of what human markers really value and need. Therefore, the relationship between humans and machines should be mutually inclusive rather than exclusive in order to fully facilitate learner improvement (Bektik 2017).

More importantly these automatic marking systems that we argue can and should be used to provide the learner with formative feedback. This is because AES have the potential to change student learning from a more passive to a more knowledge building activity, where they start to be supported to criticize their own work and then to improve it.

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Assessing Problem-Solving Skills in Game-Based Immersive Environments

44

Valerie J. Shute and Benjamin Emihovich

Contents

Abstract

According to Pearson's Law: "That which is measured improves." But some important constructs, like problem-solving skill, are generally viewed as very difficult to measure for a variety of reasons (e.g., lack of a clear and agreed-upon definition, psychological and/or statistical multidimensionality of the construct, subjectivity of scoring, and so on). Adding to the challenge of validly measuring problem-solving skill is that formal education settings tend to focus only on well-structured problems – those that have correct and incorrect answers. However, these problems tend to have little transfer to the real world. In short, there is a gap in the kinds of problems being assessed and taught in schools and those desired in workplace environments. In this chapter, we focus on how game-based immersive environments, such as well-designed video games, can be used to both measure and promote the development of problem-solving skills in formal education settings. In this chapter, we discuss the theoretical foundations of problem-solving

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and provide a worked example of assessing it from gameplay using a well-designed video game. We conclude the chapter with a discussion on future implications for using game-based environments to measure and promote problem-solving skills in education.

Keywords

Assessment · Game-based learning · Problem-solving skill · Stealth assessment · Video games

Introduction to the Problem

Over the past couple of decades, developed and developing countries are increasingly relying on a knowledge economy to help solve complex problems arising from globalization such as issues related to global warming including the depletion of the ozone layer and the scarcity of natural resources in the environment. Solving complex problems requires one to think critically, creatively, and systemically when planning solutions, thus involves cognitive processes aimed at achieving a goal when the solution is hidden from the problem solver (Mayer and Wittrock 2006). Educators consider the assessment and support of problem-solving skills a primary goal of teaching and learning (e.g., Jonassen 1997; Shute and Wang 2016).

Problem-solving is also becoming increasingly desirable in twenty-first century workplace environments (Partnership for 21st Century Learning 2016). One of the challenges in teaching problem-solving skills in formal education settings stems from limitations with providing authentic problem-solving contexts. That is, in formal learning settings, students are typically required to solve well-structured problems that have limited transfer after instruction (Jonassen 2000). A well-structured problem is one that can be solved with a particular sequence of steps that leads to a correct answer. Most classroom textbook problems – particularly in STEM areas – feature well-structured problems that have correct answers. However, an ill-structured problem possesses a claim and a justifying argument without a specific correct answer. An example of an ill-structured problem would be to figure out a viable solution to a problem like what can be done when the population of a community is growing but the current water supply will not support many new people.

Instruction designed on specific principles of learning related to solving a variety of problems – from well-structured to ill-structured – in an authentic context is important for initial and long-term learning as well as promoting problem-solving transfer to novel contexts (Van Eck et al. 2017). But again, there is a gap in the kinds of problems being taught in schools with those being required in the workplace. Recent survey data indicates that only 24% of employers who hired recent college graduates stated that the graduates were able to analyze and solve complex problems in their workplace environments (Hart Research Associates 2015).

Facilitating learning by using immersive environments, such as well-designed video games in educational settings, is one promising way to bridge the aforementioned gap between school-based versus workplace or real-world problem-solving skills. Immersion in this context refers to the subjective impression one experiences when interacting with a realistic, digitally enhanced environment like a video game (Lessiter et al. 2001). This feeling of immersion enhances learning by allowing multiple perspectives, offering players a situated learning experience and promoting transfer (Dede 2009). In general, immersive environments support the following: distribution of knowledge across a community through situated learning, acquisition of fluency in multiple media, and interactions with different human or computer characters with different skills and abilities within authentic and novel problem-solving scenarios (Dede 2005).

Multiple perspectives in immersive environments allow for egocentric and exocentric frames of reference. Egocentric frames of reference engender motivation through embodied learning, whereas exocentric frames of reference promote abstract symbolic insights that are gained at a distance from the context of the environment (Dede 2009). In addition, immersive learning environments help learners practice as well as understand how to apply facts, principles, and concepts in context rather than abstractly. Learning abstractly via memorizing certain facts as well as abstract principles and concepts is how knowledge is typically taught in school (Barab and Dede 2007). But there is an alternative (and considerably more engaging) pedagogical approach to support learning. According to the recent report entitled “Essential Facts About The Computer and Video Game Industry” published by the Entertainment Software Association (ESA 2016), video games are played by 65% of US households and consumers spent over $23 billion dollars in the video game industry in 2015. Given the success of the video game industry, education researchers are exploring how well-designed video games can be used to support learning and assessment, referred to as game-based learning (GBL).

Over the past decade, researchers have been examining and testing various ways to deeply embed valid assessment for learning directly into video games with a technology called stealth assessment (see Shute and Ventura 2013). Establishing validity is key; herein referring to the psychometric quality of the assessment relative to its accuracy in measuring what is intended to be measured (also known as construct or convergent validity). Stealth assessment is grounded by an assessment design framework called evidence-centered design (ECD; Mislevy et al. 2003). In general, the main purpose of any assessment is to collect information that will allow the assessor to make valid inferences about what people know, can do, and to what degree (collectively referred to as “competencies” in this chapter). ECD defines a framework that consists of several conceptual and computational models that work in concert. The framework requires an assessor to: (a) define the claims to be made about learners’ competencies, (b) establish what constitutes valid evidence of a claim, and (c) determine the nature and form of tasks that will elicit that evidence.

In this chapter, we first review the literature on problem-solving skills. Next, we discuss current methods for assessing problem-solving skills and describe an approach to address some of the issues by presenting an example of stealth assessment in a research project. We then address the benefits and challenges of using video games in formal education settings. Finally, we conclude with ideas for next steps in this field of research.

Problem-Solving Skills

Early research on problem-solving included Thorndike's (1898) experiments on cats tasked with escaping a puzzle box. Thorndike determined that the cats were able to escape by mere associations and habits, or essentially by trial and error. The seminal work of Thorndike's research is regarded as significant in contributing to early behavioral learning theory in psychology, but many scholars regarded problem-solving as an unexplainable human behavior before Newell et al.'s (1958) theoretical work on the mechanisms of thinking and learning related to problem-solving (Simon and Newell 1971). The gap in research on problem-solving directed scholars to correct the antiquated narrative on the topic from unexplainable thinking to analyzing how human beings behave and what cognitive processes engage this critical aspect of thinking and learning.

In general, problem-solving can be defined as cognitive processing aimed at finding a solution to a goal when the solution is not known to the problem solver (Mayer 1992). According to Mayer and Wittrock's (2006) definition, problem-solving consists of four interrelated elements: (1) occurs within the problem solver's cognitive system; (2) requires the problem solver to theorize and manipulate information; (3) is goal oriented; and (4) relies upon the intellect and skills of the problem solver to establish the order in which each obstacle is handled before finding a solution.

While the elements of problem-solving seem straightforward, can problem-solving skills be fostered and improved? Polya (1945) argued that problem-solving is not an innate skill, but rather something that can, in fact, be developed, "Solving problems is a practical skill, let us say, like swimming... Trying to solve problems, you have to observe and imitate what other people do when solving problems; and, finally, you learn to solve problems by doing them." (p. 5). So students are not born with problem-solving skills. Instead, these skills are cultivated when students have opportunities to solve problems proportionate to their knowledge. Polya (1945) went on to identify a four-step problem-solving technique: understand the problem, devise a plan, carry out the plan, and review/extend. Later, Bransford and Stein (1984) integrated the collection of problem-solving research and proposed the IDEAL problem solver. Each letter of IDEAL stands for an important part of the problem-solving process: identify problems and opportunities; define alternative goals; explore possible strategies; anticipate outcomes and act on strategies; and then look back and learn. Two years later, Gick (1986) presented a simplified model of the problem-solving process including the construction of a representation, the search for a solution, the implementation of the solution, and monitoring the outcome of the solution. Around that time, the focus of research had been shifted toward a knowledge-based representation such as schemata.

How domain-general versus domain-specific are problem-solving skills? Unlike the aforementioned work on identifying general problem-solving models, the study of problem representation recognizes the importance of domain-specific knowledge in solving problems. The representation of problems refers to how a problem solver perceives and understands a phenomenon within the problem-solving environment. Jonassen concluded that "problem solving is not a uniform activity" (2000, p. 65). Instead, problems vary in terms of their structuredness, complexity, and the requirement for prior knowledge (Jonassen 2003). For example, the types of problems associated with driving a truck are quite different from those needed when negotiating a business deal. Thus, how well a person can solve a problem depends on the accuracy of the person's representation of the problem scenario.

Jonassen (1997) noted that people confront various types of problems that differ according to the problem scenario, the cognitive processes required to find a solution, and the problem structure. As mentioned earlier, the structuredness of a problem can range from very well-structured (i.e., facts, rules, and principles) to very ill-structured (i.e., poorly defined, inconclusive, or conflicting solution paths). Providing students with repeated practice on solving various ill-structured problems can be beneficial in formal education settings because students of all ages experience ill-structured problems that arise naturally from daily interactions with other people and the environment. Trying to solve these types of problems requires students to define (and sometimes redefine) the problem and develop a solution pathway based on the skills needed to reach the solution (Jonassen 2002).

Recent research indicates problem-solving skills involve two facets: rule identification and rule application (Schweizer et al. 2013). "Rules" in problem-solving refers to the principles that govern the procedures, the conduct, or the actions in a problem-solving context. Rule identification refers to the ability to acquire knowledge of the problem-solving environment, and rule application is the ability to control the environment by applying the knowledge acquired. Typically, it is difficult to directly collect data on students' rule identification ability. However, since rule application is the outward expression of one's rule identification, the measurement of rule application may be used to reflect students' ability to identify rules.

Complex problems usually combine a mix of basic rules with rules that require cognitive flexibility – the ability to adjust prior thoughts or beliefs and explore alternative strategies in response to changes in the environment (Miyake et al. 2000). Cognitive flexibility is the opposite of functional fixedness, which is the difficulty a person experiences when he or she is required to use objects (or strategies) in uncommon ways (Duncker 1945). Many researchers have targeted functional fixedness as the major obstacle to successful problem-solving (e.g., Anderson 1980). Moreover, problem-solving skills play an important role in everyday life and in many professions. Gagné (1980) believed that the central point of education is to teach people to become better problem solvers, and as noted earlier, problem-solving is recognized as one of the most important skills demanded in the job market (Partnership for 21st Century Skills 2016). Therefore, research on problem-solving skills and how to improve them are essential to prepare students for upcoming challenges in life and work. In the next two sections, we discuss challenges associated with assessing and supporting problem-solving skills in education followed by a concrete example of developing a stealth assessment for problem-solving skills embedded within a well-designed game.

Challenges with Assessing Problem-Solving Skills

Key measurement challenges for complex constructs like problem-solving skills include (a) lack of a clear and consensual definition and/or operationalization of the construct, (b) theoretical multidimensionality of the construct where certain dimensions may have internal as well as external sources, (c) difficulty disambiguating the generality of the construct (e.g., is there a single "problem-solving" variable or is it solely dependent on the context), and (d) reliance on outdated multiple-choice and self-report measures, the former narrowly focused and the latter flawed. Self-report measures in particular are problematic as they are subject to "social desirability effects" that can lead to false reports about behaviors, attitudes, and beliefs (see Paulhus 1991). In addition, test takers may interpret specific self-report items differently (e.g., what it means to enjoy solving "hard problems") leading to unreliability and lower validity (Lanyon and Goodstein 1997).

Innovative and valid performance-based assessments of problem-solving skills are needed that assess how students apply this skill in the solution of complex, real-world problems. One way to approach this problem is to use video games or similarly immersive environments, to simulate a variety of problems for performance-based assessment (DiCerbo and Behrens 2012; Gobert et al. 2013; Quellmalz et al. 2012).

Early approaches to performance-based assessment in GBL included using serious games as tools to improve skills as seen in *Marine DOOM*, a modified version of the game *DOOM*, designed to improve military thinking and decision-making skills (Krulak 1997). New developments in GBL include the use of virtual reality (VR) technologies to promote collaboration and deep learning across a range of educational areas and for a broad swath of students. And while some researchers have attempted to design specific games to promote problem-solving skill (e.g., Van Eck et al. 2009), there are various commercial video games on the market that may be used for this research, such as *Portal 2* (Shute et al. 2015a) and *Plants vs. Zombies 2* (Shute et al. 2016). Such game-based environments can provide meaningful assessment by supplying students with scenarios that require the application of different facets of problem-solving skill. Next we describe a way to measure problem-solving skills continually and unobtrusively.

Stealth Assessment of Problem-Solving Skills

Stealth assessment (Shute 2011) provides a way to embed valid assessments directly into immersive environments like video games, extending the evidence-centered assessment design framework by delineating specific gameplay behaviors (specified in the evidence model) and statistically linking them to competency model variables (Shute and Ventura 2013). Stealth assessment thus complements the use of well-designed games to measure and improve skills by eliciting and aggregating student data during gameplay that can be used to provide real-time inferences about knowledge and skill states that can inform policies relevant to a range of stakeholders (Cukier and Mayer-Schoenberger 2013).

The results of this analysis are data (e.g., scores) that are passed to the competency model, which statistically updates the claims about relevant competencies in the student model. The ECD approach combined with stealth assessment provides a framework for developing assessment tasks that are explicitly linked to claims about personal competencies via an evidentiary chain (i.e., valid arguments that serve to connect task performance to competency estimates) and are thus valid for their intended purposes. The estimates of competency levels can also be used diagnostically and formatively to provide adaptively selected levels, feedback, and other forms of learning support to students as they continue to engage in gameplay.

To illustrate, Shute et al. (2016) developed a stealth assessment of problem-solving skill and embedded it in a game called Use Your Brainz (a slightly modified version of Plants vs. Zombies 2). The game was then tested with a sample of middle-school students. The research team began by developing a problem-solving competency model based on a review of the relevant literature and also reviewed the Common Core State Standards (CCSS) related to problem-solving. They came up with a four-facet competency model, which included: (a) understanding givens and constraints, (b) planning a solution pathway, (c) using tools effectively/efficiently when implementing solutions, and (d) monitoring and evaluating progress. The first facet maps to "rule acquisition," and the remaining facets map to "rule application."

After playing the game repeatedly and watching expert solutions on YouTube, the researchers delineated 32 observable indicators that were associated with the four facets (i.e., listed the specific actions a person would do while engaged in gameplay that would provide evidence – positive and negative – towards one or more of the facets). For example, sunflowers produce sun power, which is the sole source of power that players may use to grow plants. At the beginning of a level, typically there are no sunflowers on the battlefield. To supply power to grow plants, players must plant sunflowers at the beginning of each level before zombies start to appear in waves. The scoring rule for this particular indicator was: "If a player plants more than three sunflowers before the second wave of zombies arrives, the student understands relevant time and resource constraints of the level." Table 1 displays a sample of indicators for each of the four problem-solving facets.

Table 1 Examples of indicators for each problem-solving facet. (From Shute et al. 2017)

Facet	Example indicators
Analyzing givens & constraints	Plants >3 Sunflowers before the second wave of zombies arrives Selects plants off the conveyor belt before it becomes full
Planning a solution pathway	Places sun producers in the back/left, offensive plants in the middle, and defensive plants up front/right Plants Twin Sunflowers or uses plant food on (Twin) Sunflowers in levels that require the production of X amount of sun
Using tools effectively and efficiently	Uses plant food when there are >5 zombies in the yard or zombies are getting close to the house (within 2 squares) Damages >3 zombies when firing a Coconut Cannon
Monitoring and evaluating progress	Shovels Sunflowers in the back and replaces them with offensive plants when the ratio of zombies to plants exceeds 2:1

Next, the researchers created a Q-matrix (Almond 2010) laying out all of the indicators in rows and the four facets in columns. A “1” was included in the crossed cell if the indicator was relevant to the facet and “0” if the facet did not apply to the indicator. They then went through each indicator and discussed how to classify it into discrete scoring categories such as “yes/no” or “very good/good/ok/poor.” The overall scoring rules were based on a tally of relevant instances of observables. Using the aforementioned sunflower indicator, if a player successfully planted more than three sunflowers before the second wave of zombies arrived on the scene, the log file would automatically record the action and categorize it as a “yes” status of the indicator.

Once all of the indicators were categorized into various states, statistical relationships were established between each indicator and the associated levels of the competency model variables. The researchers used Bayesian networks (BNs) to accumulate incoming data from gameplay and update beliefs in the competency model. A BN is a probabilistic graphical model that represents a set of random variables and their conditional dependencies via a directed acyclic graph. The relationship between each indicator and its associated competency model variable was thus expressed within conditional probability tables stored in each BN. There were a total of 43 BNs developed for this project, one for each level. Each of the 43 levels in the game had its own BN, reflecting the specific indicators of the level, as well as its particular difficulty and discrimination estimates. The statistical relationships carried in the BNs and the scoring rules described earlier formed the evidence model. For specific examples of scoring rules and BNs, see Shute et al. (2017).

To validate the stealth assessment, data were collected from middle school students who played the game-based assessment for 3 h (i.e., 1 h per day across 3 consecutive days) and then completed two external problem-solving measures (i.e., Raven’s Progressive Matrices and MicroDYN). Results indicated that the game-based stealth assessment estimates of problem-solving skill were significantly correlated with both Raven’s ($r = 0.40$, $p < 0.01$) and MicroDYN ($r = 0.41$; $p < 0.01$) which established the construct validity of the stealth assessment.

Next steps include running a larger validation study and developing tools to help educators interpret the results of the assessment, which will subsequently support the development of problem-solving skills. In the next section, we explore the benefits and challenges associated with using video games in a classroom environment.

Video Games in Formal Education Settings

Given the gap in problem-solving skills being taught in schools and those required in workplace environments, we suggested the integration of video games into formal learning curricula with the goal of improving problem-solving skills, and to prepare students with the skills necessary to succeed in a globally interconnected society. Similarly, Schrader et al. (2006) argued that gameplay experiences within video games can promote collaboration and problem-solving skills for students through immersive game environments. However, while many students and teachers clearly enjoy video gameplay, the majority do not fully understand how video games can be used to support learning outcomes (Selfe and Hawisher 2004).

Well-designed video games can support higher-level learning via offering players practice across multiple and varied problem-solving scenarios (Gee 2007, 2008; Van Eck 2006). Repeated practice with novel problems can improve problem-solving skills within a domain (Gagné et al. 2005). In K-12 settings, video games have been shown to improve creativity, recall of facts, and problem-solving skills when compared to computer-assisted instruction (Chuang and Chen 2009; Jackson et al. 2012). Overall, there seems to be consensus that video games can support changes in affect, behavior, knowledge, and skill acquisition for learners (Clark et al. 2016; Ifenthaler et al. 2012; Shute et al. 2015b; Sitzmann 2011; Wouters et al. 2013).

While well-designed video games can help improve cognitive competencies, there is also a need to bridge the gap between in-game knowledge and school knowledge (i.e., game-based learning and formal learning). One possibility involves the design of scaffolds that are both engaging and meaningful to instruction, such as presenting concepts that are directly tied to in-game performance and readily identifiable during gameplay (Barzilai and Blau 2014). As an example, avatars in *World of Warcraft* (i.e., the digital embodiment of a player in the game) communicate with each other to solve problems such as how to use given tools and resources to travel from one zone to another. Using tools and resources efficiently is a facet of problem-solving skill (Shute and Wang 2016). Introducing a problem-based scenario in *World of Warcraft* that requires students to learn how to reduce travel time from one zone to the next using resources (e.g., map and transportation hub) efficiently is one way to teach problem-solving skills in formal education settings.

In addition, reducing travel time is a relevant concept that can transfer from the game to the natural world. That is, designing scaffolding can challenge students to think critically during gameplay and provide them with meaningful connections between gameplay and educational concepts (Gee and Hayes 2011). Instruction that weaves gameplay concepts with educational content by using scaffolds can inform stakeholders and policy makers that video games are effective learning tools in formal education settings. Well-designed multiplayer video games like *World of Warcraft* also provide opportunities for collaborative learning and problem-solving that has relevant implications in workplace environments.

Certain well-designed video games that emphasize multiplayer interactivity during gameplay can also help players develop skills that are desirable in twenty-first century workplace environments. As an example, Symantec's former Chief Operating Officer (COO), Stephen Gillet, included *World of Warcraft* as one of his achievements on his résumé to highlight his experience in organizing large groups of individuals to solve difficult problems, demonstrate confidence in solving these problems through natural and immersive video game environments (i.e., analyzing different strategies and gameplay tactics with peers in-game and through social media platforms like Twitter), and distribute resources (i.e., gold, crafting components, weapons, and armor) to in-game friends (Pagliery 2014). These gameplay practices may lead to improvement in planning and executing strategies that can be applied to similar workforce-related collaborative projects in the natural world. We now conclude with our thoughts on future directions of game-based learning and assessment in academic research and practice.

Conclusions and Future Implications for Game-Based Assessment

The demand for skilled workers who can solve complex problems in twenty-first century workplace environments requires a shift in how to measure and support problem-solving skills in formal education settings. In this chapter, we defined problem-solving skills and explored the theoretical foundations for GBL to explain how interactions within immersive environments can promote the development of problem-solving skills. We outlined some of the challenges associated with assessing problem-solving skills in formal education settings (e.g., the prevalence of flawed assessment methods such as multiple-choice type of items and self-report surveys) and highlighted the importance of using performance-based assessments in education. This suggestion coincides with the growing labor demand for multi-skilled workers in a constantly changing global economic landscape.

In addition, we proposed a possible solution to reduce the gap between school-based and real-world problem-solving skills via integrating immersive environments like video games into formal education settings to help students improve their problem-solving skills by preparing them with repeated problem-solving scenarios through immersive gameplay. To illustrate, we included an example of a problem-solving stealth assessment (see Shute et al. 2016). Furthermore, recent research on the effects of immersive gameplay on cognitive and noncognitive skills demonstrates that learning does occur – for problem-solving skills, persistence, visual-spatial skills, and attention (e.g., Green and Bavelier 2012; Rowe et al. 2011; Shute et al. 2015a; Ventura et al. 2013). Some researchers, however, have reported null effects of immersive gameplay on cognitive skill acquisition (Ackerman et al. 2010; Baniqued et al. 2013; Boot et al. 2008) so clearly, more research is needed.

One future GBL research thread may aim to bridge the gap between the worlds of commercial versus educational video games. Towards that end, we need a systematic approach to designing game-based assessment that produces engaging video games and valid assessments. This will require an interdisciplinary team (e.g., experts in assessment, game design, content, instructional design, psychometrics, and learning sciences). Sound research methods are needed to explore how well-designed video games can be used as reliable and valid assessments of multiple and diverse competencies. From an assessment standpoint, research is needed to determine the value added of game-based assessment over traditional assessment relative to the quality of the assessment (i.e., validity, reliability, and generalizability) and the impact on learning, engagement, and transfer. This research should also include analyses on how game-based assessment data predict important external criteria (e.g., high school or college graduation, state test scores, and so on) relative to traditional assessments.

The ECD framework used in stealth assessment provides a systematic approach to assessment design and also provides a transparent way to reason about student performance. And while there are other ways to develop assessments, they often lack transparency as well as specification about the competencies and tend to focus on tasks that are too simple or inauthentic. This can result in creating assessments that measure unintended competencies and thus damage the reliability and validity of the assessment. In addition, using an ECD approach for the design of game-based assessments can provide a clear research and communication framework for assessment/learning experts and game designers who want to design and develop new educational and engaging game-based assessments that accurately measure important traditional and new competencies.

One final hurdle to surmount to weave such immersive video games into classrooms concerns the need for these games to provide easy-to-interpret reports to stakeholders – such as teachers, students, and parents. There are many ways an assessment can accumulate data (e.g., tallying frequency counts of events, automatically logging player information then mining the log file to make estimates of competency states via Bayesian networks). Regardless of the methodology for accumulating evidence, the ensuing estimates can be reported at various grain sizes (e.g., general problem-solving skill or specific facets) for diagnostic purposes (see Almond et al. 2009). And with regard to validity issues of game-based assessments, when embedded assessments are not only ongoing but also invisible, this can remove test anxiety, again leading to a more valid assessment.

In conclusion, we believe that conducting research with the goal of improving twenty-first century competencies like problem-solving skills for learners through immersive video gameplay environments is relevant and important to pursue given the emerging challenges of a globalized economy (i.e., renewable energy, pollution, climate change) and consequent problems to solve.

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Making Use of Data for Assessments: Harnessing Analytics and Data Science

45

Dirk Ifenthaler, Samuel Greiff, and David Gibson

Contents

Abstract

The increased availability of vast and highly varied amounts of data from learners, teachers, learning environments, and administrative systems within educational settings is overwhelming. The focus of this chapter is on how data with a large number of records, of widely differing datatypes, and arriving rapidly from multiple sources can be harnessed for meaningful assessments and supporting learners in a wide variety of learning situations. Distinct features of analytics-driven assessments may include self-assessments, peer assessments,

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and semantic rich and personalized feedback as well as adaptive prompts for reflection. The chapter concludes with future directions in the broad area of analytics-driven assessments for teachers and educational researchers.

Keywords
Assessment analytics · Learning analytics · Formative assessment · Large-Scale assessment · Data analytics

Introduction

During the past two decades, remarkable repertoires of computer-based applications and systems have been developed for supporting learning and teaching. The resulting changes in learning and teaching through the influence of emerging technologies require alternative perspectives for the design and development of learning environments (Spector 2009). Closely linked to the demand of alternative approaches for designing and developing learning environments is the necessity of enhancing the design and delivery of computer-based diagnostics and automated assessment systems (Almond et al. 2002). It is expected that advanced assessment systems accomplish specific requirements, such as (a) adaptability to different subject domains, (b) flexibility for experimental as well as learning and teaching settings, (c) management of huge amounts of data, (d) rapid analysis of complex and unstructured data, (e) immediate feedback for learners and educators, and (f) generation of automated reports of results (Ifenthaler et al. 2010).

In the meantime, the increased availability of vast and highly varied amounts of data from learners, teachers, learning environments, and administrative systems within educational settings is overwhelming. Addressing the challenges of processing such information are concepts of educational data mining (EDM), academic analytics (AA), and learning analytics (LA). Educational data mining, for instance, refers to the process of extracting useful information out of a large collection of complex educational data sets with mainly fuzzy relationships between different elements of the data set (Berland et al. 2014; Klosgen and Zytkow 2002). Academic analytics is the identification of meaningful patterns in educational data in order to inform academic matters (e.g., retention, success rates) and produce actionable strategies (e.g., budgeting, human resources) (Long and Siemens 2011). Learning analytics emphasizes insights and responses to real-time learning processes based on educational information from digital learning environments, administrative systems, and social platforms (Romero and Ventura 2015). Such dynamic educational information, sources, and analysis methods are used for real-time interpretation, modeling, prediction, and optimization of learning processes, learning environments, and educational decision-making (Ifenthaler 2015).

As noted by Ellis (2013), learning analytics fails to make use of educational data for assessment. Since then, despite recent advancements in learning analytics research, there are opportunities for applying dynamic findings to assessment challenges such as timeliness and relevance. Therefore, the focus of this chapter is on how data with a large number of records, of widely differing datatypes, and arriving rapidly from multiple sources can be harnessed for meaningful assessments and supporting learners in a wide variety of learning situations.

The Purposes of Educational Assessment

Tracing the history of educational assessment practice is challenging as there are a number of diverse concepts referring to the idea of assessment. Newton (2007), for instance, laments that the distinction between formative and summative assessment hindered the development of sound assessment practices on a broader level. Scriven (1967) is often referred to as the original source of this distinction. Bloom et al. (1971) were concerned with the long-lasting idea of assessment separating learners based on a summative perspective of knowledge and behavior – the assessment *of* learning. In addition, Bloom et al. (1971) supported the idea of developing the individual learner and supporting the learner and teacher toward mastery of a phenomenon – the assessment *for* learning. Following this discourse, Sadler (1989) developed a theory of formative assessment and effective feedback. Formative assessment helps students to understand their current state of learning and guides them in taking action to achieve the learning goals. A similar line of argumentation can be found in Black (1998) in which three main types of assessments are defined: (a) formative assessment to aid learning; (b) summative assessment for review, for transfer, and certification; and (c) summative assessment for accountability to the public. Pellegrino et al. (2001) extend these definitions with three main purposes of assessment: (a) assessment to assist learning (formative assessment), (b) assessment of individual student achievement (summative assessment), and (c) assessment to evaluate programs (evaluative assessment). Despite an intense debate over the past five decades, the distinction between formative and summative assessment has not resulted in a precise definition, and the distinction between the two remains blurry (Newton 2007). For widening the perspective, other terms have been introduced such as *learning-oriented assessment* (Carless 2007) emphasizing the development of learning elements of assessment or *sustainable assessment* (Boud 2000) proposing the support of student learning beyond the formal learning setting. A common thread among the many definitions points to the concept of feedback for a variety of purposes, audiences, and methods of assessment.

A feedback-rich learning environment driven by formative assessment enables learners to progress in their individual learning journey (Ifenthaler and Seel 2005). In a broader sense, feedback is considered to be any type of information provided to learners (Wagner and Wagner 1985). Feedback can take on many forms depending on the theoretical perspective, the role of feedback, and the methodological approaches (Ifenthaler 2009). Feedback can be provided through internal (individual cognitive monitoring processes) or external (various types of correction variables) sources of information. Internal feedback may validate the externally provided feedback, or it may lead to resistance against the externally provided feedback (Narciss 2008). Widely accepted forms of feedback include (a) knowledge of result, (b) knowledge of correct result, (c) knowledge of performance, (d) answer until correct, (e) knowledge of task constraints, (f) knowledge about concepts, (g) knowledge about mistakes, (h) knowledge about how to proceed, and (i) knowledge about metacognition (Ifenthaler 2009; Narciss 2008).

New opportunities arise from tools and technologies in classrooms which enable formative assessment practices to support twenty-first century learning (Spector et al. 2016). For example, automation as opposed to full- or part-manual approaches of formative assessment has created a new class of instructional and interactive technologies (Wiliam 2011). If the assessment can be carried out automatically and in real time, then its results can be used to inform (a) the learners during an ongoing learning process, (b) the teachers in order to create meaningful feedback and redesign learning events on the fly, and (c) the decision-makers to continuously optimize learning environments (Ifenthaler and Pirnay-Dummer 2014). Assessment results can then be aggregated, transformed, and thus utilized to create feedback panels or even personalized and adaptive feedback based on the current learner model. Such a formative assessment model with integrated real-time feedback requires access to rich data from various contexts of the educational arena (Baker and Siemens 2015; Ifenthaler 2015).

One example is the model-based assessment and feedback approach (Ifenthaler 2009), where a phenomenon in question is assessed in form of a written text or graphical representation. Model-based assessment and feedback aim at a restructuring of the underlying representations and a reconceptualization of the related concepts of the cognitive structure of the learner (Piaget 1950). New information provided through model-based feedback can be assimilated through the activation of an existing schema, adjustment by accretion, or tuning of existing schema. Otherwise, it is accommodated by means of a reorganization process which involves building mental models (Ifenthaler and Seel 2013). Hence, an analytics algorithm enables the generation of domain-specific feedback including different forms of model-based feedback. The automated language-oriented analysis can be applied domain independently for written texts or graphical representations against a single reference model or against multiple reference models (Coronges et al. 2007). Reference models can either be a person's prior understanding of a phenomenon in question, another person's understanding, a shared or aggregated understanding of the phenomenon of multiple persons, or an expert solution of the phenomenon in question. Automated model-based feedback models, generated on the fly, have been successfully tested for preflection and reflection in problem-solving scenarios (Ifenthaler 2012; Lehmann et al. 2014). Other studies using model-based assessment and feedback highlight the benefits of availability of informative feedback whenever the learner needs it, and its identical impact on problem-solving when compared with feedback models created by domain experts (Pirnay-Dummer and Ifenthaler 2011).

Harnessing Data and Analytics for Assessments

Interest in collecting and mining large sets of educational data on student background and performance has grown over the past years and is generally referred to as learning analytics (Baker and Siemens 2015). Learning analytics uses static and dynamic information about learners and learning environments – assessing, eliciting, and analyzing them – for real-time modeling, prediction, and optimization of learning processes, learning environments, and educational decision-making (Ifenthaler 2015, 2017). As the field of learning analytics is growing, several frameworks have been proposed, which focus on available data, instruments for data analysis, involved stakeholders, and its limitations (Buckingham Shum and Ferguson 2012; d'Aquin et al. 2014; Greller and Drachsler 2012; Ifenthaler and Widanapathirana 2014). For example, Greller and Drachsler (2012) introduce six critical dimensions of a learning analytics framework including stakeholders, objectives, data, instruments, and internal and external constraints. These dimensions are critical when designing and implementing learning analytics applications and therefore provide a valuable guideline. Still, elaborated and more importantly empirically validated learning analytics frameworks are scarce (Ifenthaler and Widanapathirana 2014). Another limitation of learning analytics frameworks is the missing link of learner characteristics (e.g., prior learning), learning behavior (e.g., access of materials), and curricular requirements (e.g., competences, sequencing of learning). Ifenthaler and Widanapathirana (2014) addressed most of these limitations by introducing a holistic learning analytics framework. This holistic learning analytics framework combines data sources directly linked to individual stakeholders and their interaction with the online learning environment, as well as curricular requirements. Additionally, data from outside of the educational system is integrated. The processing and analysis of the combined data are carried out in a multilayer data warehouse and returned to the stakeholders, e.g., institution, teacher, learner, in a meaningful way. Each of these stakeholders has unique needs for understanding and interpreting data that is most relevant for the decisions that need to be made (e.g., by a student for reworking, by a teacher for assisting in providing guidance and advice to the learner, by an institutional leader for aggregating results to make programmatic and curriculum decisions).

Figure 1 illustrates a holistic learning analytics framework for formal learning environments. The arrows document the data flow within the environment. For example, learning outcomes for a unit are defined in the curriculum which is directly linked to the learning environment. Students and teachers (with individual characteristics) interact with the learning environment to achieve the expected learning outcomes. Data from (a) student characteristics and teacher characteristics and (b) interaction traces from the learning environment are processed in the learning analytics engine with dynamic algorithms and further refined for personalized and adaptive interventions. These interventions (e.g., prompts, hints) are displayed in the learning environment in near real time. In addition, a reporting engine can produce insights for stakeholders on a summative level.

However, a yet to be solved limitation of learning analytics is the lack of a stronger focus on dynamic or real-time assessment for learning as well the improvement of learning environments. While the abovementioned holistic learning analytics framework includes allusions to assessment data (e.g., prior academic performance, self-tests) and accompanying feedback (e.g., metacognitive prompts, personalized scaffolds) (Ifenthaler and Widanapathirana 2014), distinct assessment

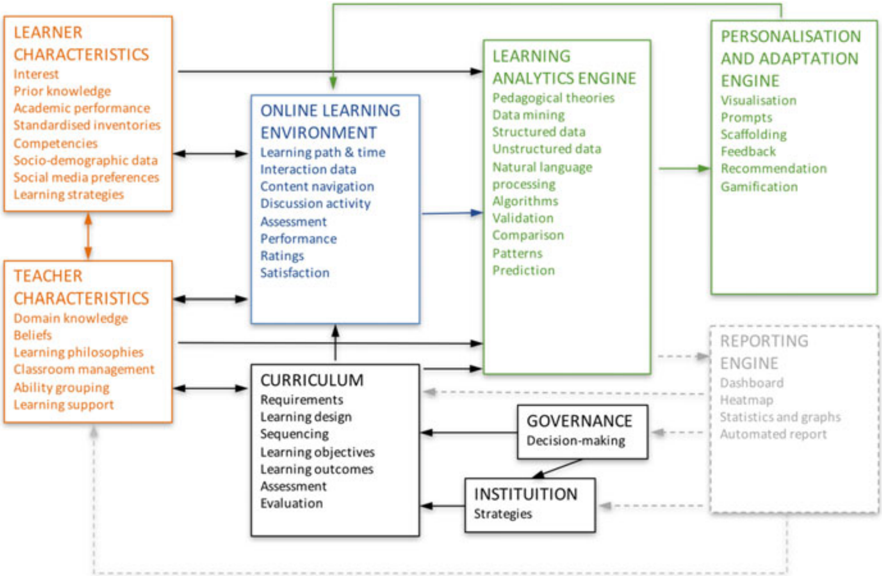

Fig. 1 Holistic learning analytics framework (Ifenthaler 2015)

analytics or analytics-driven formative and evaluative assessment features are not mentioned. Analytics-driven assessment harnesses formative data from learners and learning environments in order to facilitate learning processes in real time and help decision-makers to improve learning environments. Hence, analytics-driven assessment may provide multiple benefits for students, schools, and involved stakeholders. Distinct features of analytics-driven assessments may include (Ellis 2013; Ifenthaler and Widanapathirana 2014):

- Self-assessments linked to specific learning outcomes using multiple assessment formats (e.g., single- or multiple-choice, open text, etc.) and personalized real-time feedback (e.g., knowledge of result, knowledge about how to proceed)
- Peer assessments focusing on specific learning outcomes or general study skills (e.g., learning strategies, time management)
- Defining individual goals and desired achievements for subjects, modules, or classes and tracking learning-dependent progress toward them
- Semantic-rich feedback for written assignments in near real time using natural language processing
- Progress reports toward curricular required competences or learning outcomes including intraindividual and interindividual comparisons
- Reflective prompts highlighting persistence of strengths and weaknesses of specific learning events and assessment results (e.g., reoccurring errors, misconceptions, learning habits)

In order to implement analytics-driven assessment in classroom settings, advanced algorithms for assessment and personalization as well as systems for their continuous improvement have to be further developed. Only a few have been implemented in educational settings so far (Drachsler et al. 2008): (a) neighbor-based algorithms recommend similar learning materials, pathways, or tasks based on similar data generated by other learners; (b) demographics algorithms match learners with similar attributes and personalize the learning environment based on preferences of comparable learners; and (c) Bayesian classifier algorithms identify patterns of learners using training sets and predict the required learning materials and pathways. In addition, Ifenthaler and Widanapathirana (2014) report case studies that support the application of support vector machines (SVM) for learning analytics applications. SVM can efficiently perform a nonlinear classification using what is called the kernel trick, implicitly mapping their inputs into high-dimensional feature spaces (Cleophas and Zwinderman 2013). The flexibility for modeling nonlinear educational data, short training times for more robust models, and responsiveness to interactions and changing variables, as well as sensitivity to imperfect data sets are strong arguments for further implementation of SVM in analytics-driven assessments.

Given an analytics-driven assessment system outlined above, the learning environment can enable a personalized learning experience and adjust to the students' need in near real time. Making assessment data available to teachers may also help to change the culture of feedback in classrooms and to build positive perceptions toward analytics driven-assessment.

To sum up, making use of big data requires sophisticated learning analytics of formative assessment data, that is, analytics-driven assessment, collected from many different learners in a wide variety of learning situations and provided to relevant users at appropriate and meaningful levels of aggregation for analysis, insight, and decision-making. Analytics-driven assessments can thereby motivate individual students, help teachers adjust individual learning paths, and inform other stakeholders in schools of progress and achievements.

Computer-Generated Log Files in Large-Scale Assessments

One specific area of interest for learning analytics is the field of educational large-scale assessments (LSAs) because the wealth of data collected in LSAs allows for insights that are difficult to obtain in small-scale studies both in terms of the diversity of information covered and in terms of the population studied. Most of the LSAs have a political dimension to them as well and cover broad assessments of several learning outcomes (often referred to as competencies or proficiency levels) and background information in large and, of note, representative samples. This data is prone to be fully exploited by the emerging field of learning analytics, which directly relies on the use of computer-based assessment (CBA).

Over a decade ago, LSAs already employed CBA, but a widespread implementation of technology into the assessment process has only occurred recently. For instance, the largest educational LSA, the Programme for International Student Assessment (PISA) convened by the OECD on a triennial basis in over 70 countries (OECD 2013b), has comprehensively moved to CBA in its 2015 cycle and will even do more so in 2018. In fact, paper-pencil assessment materials are developed and maintained only for those participating countries that do not have the technological means of CBA. Given the unique combination of representative samples in LSAs, the carefully deployed background information in the form of self- and other-reported questionnaires, and the wealth of process information obtained within CBA, LSA data is an exemplary source for exploratory analysis and application in learning analytics.

However, the potential for LSA data has yet to be fully explored. In fact, LSAs have mainly focused only on comparisons between countries and have provided information on students' overall proficiency levels. One major criticism surrounding LSAs is that they only provide a rather distal summative assessment and that their results and implications are somewhat removed from actual applications and implications in the classroom. The wealth of data obtained within CBA in combination with the field of learning analytics has the as yet untapped potential of providing in-depth and fine-grained insights into learning processes and behavioral patterns on the basis of computer-generated log file analyses and extending the scope of LSAs into the realm of formative assessment. Despite the potential of applying learning analytics to assessment data obtained in LSAs, the currently available applications are scarce at best. For instance, only recently OECD has made (excerpts from) the computer-generated log file data available on a public repository for scientific analyses (www.oecd.org/pisa/data/). The actual use of insights obtained from such analyses in the reporting of studies such as PISA is something that has not been realized.

Educational data mining techniques are one way of exploring the relations between different variables, for instance, between behavioral patterns when working on the tasks and overall performance on the one hand and background variables on the other hand. This approach has yet to be fully utilized in the application of LSAs for mainly two reasons: (a) available software packages in the field of learning analytics are highly specialized and require substantial resources to be used, both financially and time-wise, and there is often a lack of both in LSAs; and (b) educational data mining is an excellent tool for initially discovering complex and fuzzy relations between variables. Thus, so far researchers have used more exploratory than confirmatory methods, but the latter in combination with a theoretical understanding will be required for fully understanding the educational implications of LSAs.

Recently, there have been some first attempts of investigating and incorporating analyses that were conceptually motivated and utilized information gained from computer-generated log file analyses into LSA. For instance, Goldhammer et al. (2014) used data from the Programme for the International Assessment of Adult Competencies (PIAAC; OECD 2013a) to show that time-on-task exhibited differential relations to different performance indicators. As theoretically expected, a shorter time-on-task was associated with better performance in reading (indicating quick and efficient automatic processing), whereas a longer time-on-task was associated with better performance in problem-solving (indicating thoughtful and controlled processing). In a similar vein, Greiff et al. (2016) investigated how several actions taken by students related to working on a complex problem-solving task (e.g., time-on-task, the strategy used, and the number of active interventions) related to overall problem-solving performance in a national large-scale study in Finland. They found that for some of the process indicators, there was a linear relation to performance, whereas for others the relation was of a reversed U-shape indicating, for instance, for time-on-task, an optimal level to be spent on a task with higher and lower values associated with lower performance.

Results on the basis of computer-generated log file analyses can thus be used to explain group differences in LSAs and other settings. For instance, Wüstenberg et al. (2014) compared performance differences in complex problem-solving, which was internationally assessed in the PISA 2012 cycle under the label "creative problem-solving" (OECD 2014), between a Hungarian and a German sample. They found that overall performance differences were closely mirrored by differences in exploration strategy, thus providing a fine-grained predecessor (and possibly explaining variable) for differences between the two groups. It is this kind of analysis that adds a formative aspect to the originally rather abstract nature of summative assessments in LSAs by relating abstract differences in overall performance to differences in underlying processes and actual behaviors. Consequently, there are first attempts of incorporating indicators from computer-generated log files into the reporting and scoring for LSA. For instance, for some of the problem-solving tasks administered in PISA 2012, students would receive partial credit even if they obtained the wrong solution to the problem, but log files indicated that their initial approach toward exploring the problem space was adequate. This concept is closely related to the idea of "stealth assessment" (Shute 2011) in which information that can be considered a by-product of the assessment process is integrated into the scoring and used as additional source of information. Readers may also be interested in the "Rule Space Method" which provides a foundation for cognitive diagnostics (Gierl 2007; Tatsuoka 2009).

Information concerning a student's task processes and behaviors during performance could also be used in providing very specific feedback to teachers about students' needs in an attempt to utilize the information from LSA for the classroom. For instance, Greiff et al. (submitted) used data obtained from log files to identify different types of students with different patterns of exploring complex problem-solving environments across a number of tasks in a sample of Hungarian students. Interestingly, several of the different types of explorers showed comparable levels of overall performance and would have been considered equal in terms of overall proficiency levels. However, when looking at actual task behaviors, some of these students might require different (e.g., more intensified) support and intervention than others because they displayed suboptimal task exploration. Thus, providing individualized information on task behavior – in addition to and beyond overall task performance – can yield valuable information to teachers in terms of a combination of formative and summative assessment data.

While such analyses have not been utilized on a large scale but are currently limited to single studies, this type of analysis could add substantial value to the current benefits of LSA. The conceptually motivated examples mentioned above could then be complemented by EDM techniques, which are best at discovering complex interactions between several actions but that are also more difficult to understand and to give meaning to. In the long run, additional information that is driven by assessment and learning analytics will help LSAs to gain legitimacy for student development and in the classroom.

Conclusions and Future Directions

The complexity of designing adaptive assessment and feedback systems has been discussed widely over the past few years (e.g., Sadler 2010; Shute 2008). The current challenge is to make use of data – from learners, teachers, and learning environments – for assessments. Several issues and future directions in the broad area of analytics-driven assessments arise for educational practice.

First, in relation to the challenges brought on by technology-enhanced assessments, the large amount of data now available for teachers is far too complex for conventional database software to store, manage, and process. In addition to the volume of available assessment data, the assessment data accumulates in real time. Finally, the source and nature of this enormous and quickly accumulating assessment data are highly diverse (Gibson and Webb 2015). Accordingly, technology-enhanced assessments underscore the need to develop assessment literacy in teachers and other stakeholders of assessment (Stiggins 1995). However, teachers seem not to be adequately prepared to assess students in classrooms in general (Mertler 2009) and, more importantly, when using technology-enhanced assessments. One historically well-documented reason for this inadequate preparation of teachers for assessments is the minimal preservice training in educational measurement and psychometrics experienced by most teachers (Plake 1993). Professional development in technology-enhanced assessment needs to focus on key issues of assessment (Stiggins 1995): (a) what to assess, (b) why to assess, (c) how to assess, (d) how to provide feedback, and (e) how to avoid assessment errors and biases. In addition, Mertler (2009) notes that workshops focusing on applied assessment decision-making can be beneficial for teacher's assessment literacy. Therefore, implementing new preservice and in-service programs for assessment literacy with a strong focus on technology-enhanced assessments seems to be of high priority. Along this line, empirical research is needed to investigate long-term impact on teachers' analytics-driven assessment practice. Such a new foundation of analytics-driven assessment methodology needs to provide teachers with practical hands-on experience on the fundamental platforms and analysis tools for linked big data, introduce several data storage methods and how to distribute and process them, introduce possible ways of handling analytics algorithms on different platforms, and highlight visualization techniques for big data analytics (Gibson and Ifenthaler 2017). Well-prepared teachers may demonstrate additional competencies such as understanding large-scale machine learning methods as foundations for human-computer interaction, artificial intelligence, and advanced network analysis.

Second, additional design research and development are needed in automation and semiautomation (e.g., humans and machines working together) in assessment systems. Automation and semiautomation of assessments to provide feedback, observations, classifications, and scoring are increasingly being used to serve both formative and summative purposes. For example, automated scoring systems have been used as a co-rater in large-scale standardized writing assessments since the late 1990s (e.g., e-rater by Educational Testing Service). Alternatively, the instructional applications of automated scoring systems are developed to facilitate the process of scoring and feedback in writing classrooms (Ifenthaler 2016). These systems mimic human scoring by using various methods of scoring, that is, statistics, machine learning, and natural language processing techniques. Implemented features of automated assessment systems vary widely, yet they all are trained with large sets of expert-rated sample open-ended assessment items to internalize features that are relevant to human scoring (Ifenthaler and Dikli 2015). Automated scoring systems compare the features in training sets to those in new test items to find similarities between high-/low-scoring training and high-/low-scoring new ones and then apply scoring information gained from training sets to new item responses. Shermis and Hamner (2013) demonstrated that automated assessments are capable of producing results similar to human assessment for extended-response writing items. Currently, automated and semiautomated assessment systems can be reliably applied in low-stakes assessment (e.g., evaluation of written essays). For example, students can submit their written essay (from home or from in the classroom) to a web-based platform and receive near real-time feedback regarding their (a) writing style, (b) scope of writing, or (c) structure and depth of arguments. Such improvement toward valid real-time feedback is expected as these systems are being developed further and might even be used for high-stakes assessment in the near future.

Third, Gibson et al. (2016) propose an open assessment resources approach that has the potential to increase trust in and use of open education resources (OER) in formal educational systems by adding clarity about assessment purposes and targets in the open resources world. Open assessment resources (OAR) with generalized formative feedback are aligned with a specific educative purpose expressed by some user of a specific OER toward the utility and expectations for using that OER to achieve an educational outcome. The generalization of feedback can follow anonymous crowd behavior (e.g., common misconceptions, common pathways of performance) in the OER rather than individualized behavior. Further, the OAR approach is focused on a few high-level assessable outcomes (e.g., collaboration, problem-solving, communication, creativity) and the feedback (e.g., recommendations for improved performance, prompts for further elaboration of ideas, suggestions for alternatives) that pertain to supporting and achieving these outcomes within a specific OER with fewer ethical challenges. An OAR system will support a wide range of assessment applications, from quizzes and tests to virtual performance assessments and game-based learning, focused on promoting deeper learning. The concept of *assessment activity* expresses the idea that authentic assessment is fundamental to learning,and the concept of *item bank* implies reusability, modularity, and automated assembly as well as presentation of assessment items (Gibson et al. 2016).

Fourth, utilizing data (i.e., in-game actions and behaviors that are digitally traced through numerical variables) from game-based learning environments may provide near real-time information about learners' performance and competency development. Still, the implementation of assessment into games adds an important but time-consuming step to the educational game design process. Ifenthaler et al. (2012) distinguish three types of game-based assessment: (a) game scoring, (b) external assessment, and (c) embedded assessment. Game scoring stems from traditional game design and focuses on targets achieved or obstacles overcome as well as time needed for reaching specific goals within a game. External assessment is realized outside of the game environment using traditional assessment approaches such as interviews, essays, knowledge maps, causal diagrams, or multiple-choice questions. A more effective form of assessment is the embedded or internal game-based assessment (Ge and Ifenthaler 2017). An unobtrusive version of embedded assessment is referred to as stealth assessment as mentioned before (for an application see Shute et al. 2016). Embedded assessment does not interrupt the game-play; however, it makes the purpose of assessment transparent to the learner. Embedded assessment is implemented in situ, that is, in action of the game-play. Hence, in situ assessment focuses on the learning-dependent progression and learning outcomes while playing a game. This opens up manifold opportunities in order to optimize learning processes and learning outcomes including personalized and adaptive feedback and scaffolds toward the intended learning outcomes of the game while at the same time coming along with several fairness-related challenges (Loh et al. 2015).

To conclude, analytics-driven assessments have yet to fully arrive in the everyday classroom but are rapidly emerging. In moving forward to embrace the opportunities that could be provided by analytics-driven assessment, the challenges that remain to be addressed must not be underestimated:

(a) Professional development of teachers is vital for advancing meaningful assessment practices in schools.
(b) Schools need to address ethics and privacy issues linked to data-driven assessments. They need to define who has access to which assessment data, where, and how long the assessment data will be stored and which procedures and algorithms to implement for further use of the available assessment data.
(c) The application of serious games analytics opens up opportunities for the assessment of engagement and other motivational (or even broader: non-cognitive) constructs within game-based learning environments. The availability of real-time information about the learners' actions and behaviors stemming from key decision points or game-specific events provides insights into the extent of the learners' engagement during game-play. The analysis of single action or behavior and the investigation of more complex series of actions and

behaviors can elicit patterns of engagement and therefore provide key insights into ongoing learning processes.

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A Futures Perspective on Information Technology and Assessment

46

Jason M. Lodge

Contents

Abstract

Assessment is perhaps the area, like no other, where the utility of information technology in education is tested. The possibilities for assessing using these technologies are expanding rapidly. In particular, new technologies afford possibilities for focusing assessment on learning as an ongoing developmental process, rather than on performance. Building on notions of assessment grounded in measurement theory, there are prospects for assessing students continuously while they learn in a developmental way through the use of data and analytics. The resulting picture of student development will then allow for a more holistic and systemic approach to assessment in the years ahead. While it is often problematic to make predictions about the future, in this chapter, I will attempt to draw on current developments to provide suggestions about where the

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intersections of assessment and information technologies are likely headed. That future is likely to entail more continuous, personalized forms of assessment that focus heavily on helping students to make better judgments about their own learning and development.

Keywords
Educational technology · Performance · Measurement · Continuous assessment

Introduction

Of the areas in which information technologies are poised to have an impact on education in the future, assessment is perhaps the most prominent. Across all levels of education, assessment influences student and teacher behavior, and the outcomes of assessment are key drivers of local, national, and international policy. With student learning increasingly occurring in ways that are mediated by information technologies, there is potential for fundamentally rethinking how assessment is conceptualized and implemented. There are simultaneously risks associated with not sufficiently catering to the changing information-rich world students increasingly find themselves in. There are also risks associated with expecting technologies to enhance assessment without necessary shifts in practice. While digitally mediated assessment practices were not long ago limited to computer-based testing, the possibilities for assessment with emerging information technologies have expanded rapidly. It is these fundamental shifts that will provide the basis for this chapter. However, the aim is not to focus on the technologies themselves but what these technologies mean for assessment practices. The resulting futures perspective will include possibilities for enhanced conceptualizations of assessment enabled through advanced information technologies. With the importance of assessment to policy and practice, the implications of evolving information technologies need to be considered carefully in the contexts in which they are to be applied.

Learning Versus Performance in Assessment

The notion of assessment *for* learning, as opposed to assessment *of* learning, has been discussed in the scholarly literature for some time (e.g., Black et al. 2003; Dann 2014; Wiliam 2011). In an attempt to capture the difference between these notions, Shute and Kim (2014) suggest that assessment of learning constitutes the summative aspects of assessment, while assessment for learning are the formative aspects (see also ▶ Chap. 41, "Assessment as, for, and of Twenty-First Century Learning Using Information Technology: An Overview" this volume). These definitions allude to assessment as a performative exercise. In other words, students perform a task, often leading to production of an artefact such as an essay or completed exam paper, which is then evaluated qualitatively and/or quantitatively. Teachers are able to use this information in meaningful ways to provide feedback to help student learning, thus highlighting that complex and nuanced practices occur around assessments of this kind. However, particularly in the case of standardized tests, “assessment of performance” does capture the essence of the mundane purpose and execution of assessment in educational settings broadly. In reality, the assessment process, whether formative or summative, in the majority of cases, assesses performance as an outcome rather than learning as a process.

Information technologies open avenues for rethinking the role that assessment plays in student development. The affordances of advanced information technologies now mean that assessment can be realistically viewed as an integrated, continuous feature of education in much the same way as learning itself can be seen as an integrated, continuous process. For example, Shute’s (2011) notion of “stealth assessment” and Webb et al.’s (2013) “quiet assessment” both allude to a more sophisticated approach to monitoring student progress as it occurs (see chapter 6.1 for further discussion). In other words, assessment can evolve to become seamlessly integrated into the learning process rather than being focused on performance and/or artifacts as the central point at which teachers make judgments about and provide feedback on student learning.

Information technologies have already begun to afford possibilities for assessing student learning progress (see Lodge et al. 2018, for an overview). One way of abstracting the shift in assessment approaches now possible through the development of information technologies is therefore through the affordances these technologies provide for assessing learning while it is occurring. Assessment of learning has traditionally been about measuring student performance periodically as they ostensibly progress in their understanding. Despite the possibilities available through the ongoing, iterative design of assessment items and tasks, there remains a fundamental problem with this approach as learning is not a series of loosely related performances but a continuous, developmental process. Assessment *for* learning similarly treats assessment as being distinct from the learning process, which suggests a necessary turn to notions of assessment *as* learning. In a similar vein, Black et al. (2006) argue that assessment should be focused on learning as a process and beyond to support learning how to learn. These ideas allude to an integrated means of incorporating assessment more seamlessly around learning. The aim is for assessment to more directly support and monitor the process of learning as well as support students to learn how best to learn themselves.

The difference between learning as performance and learning as developmental process has concurrently been receiving increased attention in the psychological science literature. For example, Soderstrom and Bjork (2015) argue that there has been an overemphasis on learning as performative rather than the process that it is more accurately conceptualized. The importance of being mindful of the difference between learning as performance and learning as process cannot be overstated. Perhaps the most compelling phenomenon pointing to the importance of assessment to the process of learning is the testing effect (Roediger and Karpicke 2006). The testing effect occurs because students learn by completing tests, a finding that has proven to be strongly robust and directly relevant to educational practice (Putnam et al. 2017). What this effect shows though is that it is not until the *process* of learning is considered that the real power of the testing effect becomes evident. While research on the testing effect has mostly been conducted in the laboratory, what it does provide a compelling example of assessment as learning when it is considered as a process and not just an outcome. Treating learning purely as an output or outcome also leads to neglect of the cognitive, affective, and other process-oriented elements of learning (see also De Houwer et al. 2013). This is perhaps again most evident in large-scale and standardized testing where there is a singular focus on assessing student learning as a snapshot of performance, and often only memory performance, at a single point in time.

Given that there appears to be a family resemblance between the movement in psychological and educational research toward reemphasizing that learning is an integrated developmental process and should be assessed accordingly, it is likely that this trend will flow across into educational practice. That is not to say that the translation of the research attempting to better understand these processes in the laboratory to the classroom will be seamless or easy (see Horvath and Lodge 2017). Despite the difficulties, educational technologies allow for new approaches that better capture learning as a process. For example, developments in information technologies allow for more fine-grained tracking and analysis of student learning as they progress through clickstream data and other real-time data collection methods (Lodge and Corrin 2017). The emergence and growth of the field of learning analytics affords new possibilities for collecting data continuously as students learn (Blikstein et al. 2014). This is a trend I will revisit later in the chapter. Suffice it to say that the evolution of information technologies will continue to support a necessary transition from assessment of performance to assessment as an integral part of the learning process (Lodge et al. 2018). A futures perspective in this context suggests that the distinction between formative and summative aspects of assessment might no longer be a useful dichotomy. Assessment as learning is a more integrated and continuous means of conceptualizing assessment that is enabled using information technologies. As part of the transition though, there is a need to review the role that assessment plays in measuring learning.

Assessment as Measurement

While there is a clear trend toward using assessment as a means of supporting learning, there remains an important role for assessment as a means of measuring. There will continue to be a requirement for ranking students and for ensuring that they meet particular standards throughout schooling. There will also be an ongoing need to compare performance within and between cohorts. While it is a laudable aim to attempt to use assessment as a formative support for student learning, there is no indication that the summative aspects of assessment can yet be abandoned altogether. There will be a need to compare students to other students and against set criteria for the foreseeable future. As is the case with assessment for learning though, there will also be fundamental implications of development in educational technologies on assessment as measurement. Among these will be an increased emphasis on measuring learning as opposed to measuring performance.

While psychometricians and others concerned with the use of assessment for measurement have moved toward refining and improving assessment instruments over time, these improvements have not necessarily resolved the problems associated with assessment being primarily *of* performance. Measurement theory has had a significant impact on testing and assessment in education for many decades (Allen and Yen 2001). The focus of much of this work has centered on the validity and reliability of assessment items. For example, item response theory (van der Linden and Hambleton 1997) and sophisticated modeling techniques (e.g., Jonsson and Svingby 2007) have been used extensively to determine the validity of various instruments for assessing student performance. The issue with the focus of this work is that it too has overemphasized the performance aspects of student learning over the developmental process, that is, learning. Ultimately, no matter the sophistication of the measure or the modeling, these instruments are only becoming better at predicting how a student will perform on a test, not necessarily how much they have learned.

When examining what information technologies might contribute to this problem, it is apparent that the use of data and analytics is the key development that might lead to true measurement of learning. Value-added measures of student achievement have for some time claimed to capture the developmental progress students make during their educational journey (Meyer 1997). What these measures have failed to capture is the trajectory by which students move from point A to point B. Rather, even with the most sophisticated instruments, the students' progress is measured at point A and at point B only. Information technologies now afford possibilities for continuous data collection, providing a means of better understanding how students progress from A to B. More recent movements in measurement theory are beginning to make use of this data to provide a more nuanced evaluation of student progress rather than to rely on high-level snapshots. For example, Milligan and Griffin (2016) analyzed the learning patterns evident in a massive open online course (MOOC) as participants progressed from novice to expert learners. The processes by which the participants engaged with the course were analyzed through measurement models to determine how effectively they were learning. The result of innovations such as this, combining new technologies and measurement theories, is the possibility of valid and reliable assessment of student learning in real time as it changes and as students adapt and develop. The potential of these advances is the possibility of a truer reflection of an individual student's educational journey rather than a crude comparison of performance snapshots. In the future, we can expect that measurement theory will shift in focus from performance to learning further enhancing the possibilities for continuous monitoring and assessment of student learning.

Assessment as Continuous

I now move from issues associated with measuring learning to delve further into the idea that learning is a continuous process and is therefore best assessed as such. If we are to accept the premise that learning is more than just about snapshots of performance over time and that measurement can occur continuously, this notion raises questions about what assessment of learning as a process would look like. This is an issue that has been addressed to an extent by research into continuous assessment. While the notion of continuous assessment has been around for some time (e.g., Nitko 1995), it has morphed into a more granular analysis of learning in relation to game-based (e.g., Kim et al. 2016), quiet assessment (Webb et al. 2013) and stealth assessment (Shute 2011). In the case of the latter, the progress students make is monitored unobtrusively and often in real time as they progress (Shute and Ventura 2013). These more recent advances move the idea of continuous assessment from being anything more regular than a final summative exam to a truly continuous evaluation process.

What the emergence of genuine continuous assessment suggests is that information technologies are providing insights into student learning that were not previously available. Data about student performance in real time has been used in sophisticated ways to both assess how the student is progressing and then to use this information to provide students with feedback. The examples of the technologies that demonstrate the full potential of these systems and underlying approaches tend to be in procedural domains. For example, flight simulators have long been used to assess the progress being made by trainee pilots (Hays et al. 1992). More recently advanced immersive simulations have also been used to assist with the education of surgeons (e.g., Piromchai et al. 2017) and dentists (e.g., Bakr et al. 2013). These technologies rely on sophisticated models of expert and novice behavior in the environment to model the performance of students relative to that of the expert. By constantly updating the weightings within the statistical models, predictions about how the student is progressing can be made in real time. This prediction is then used to trigger various forms of feedback within the system. This continuous monitoring and updating of predictive models provides continuous insight into student progress that has not been previously available.

One major hurdle for translating the research on simulated environments to the primary or secondary school environment is that it is not as straightforward to monitor and predict student progress in other domains beyond procedural tasks like flying an aircraft or performing surgery. Conceptual knowledge, in particular, is very difficult to capture through the behavior of students in a virtual environment. Conceptual knowledge is far more complex than procedural knowledge as it is more integrated, with multiple concepts overlapping and forming meta-constructs across multiple levels of organization in the mind (Caramazza and Mahon 2003). Perhaps the only example where systems have been developed to fully capture student progress through a conceptual lesson or environment are in intelligent tutoring systems (ITS; e.g., Woolf 2009). There are examples of these systems that have attempted to capture student progress as they develop conceptual understanding. For example, the AutoTutor system helps students develop conceptual knowledge through a dialogue-based interface, monitoring and responding in real time (Graesser et al. 2005).

What the work in both procedural and conceptual simulations suggests for the future is that these systems are poised to become more sophisticated and better attuned to individual differences in educational progress. The potential therefore is that information technologies will be better able to provide personalized learning experiences for students across knowledge domains. In other words, the potential latent in the notion of continuous assessment is poised to come to fruition. For example, students in the near future will be able to interact with increasingly sophisticated interactive digital environments that will respond in real time to their progress, both assessing said progress and providing feedback to keep them on track. While this potential has mostly only been realized to date with procedural tasks, the development in ITS suggests that there is a distinct possibility that systems will be developed in the near future that will effectively monitor and respond to students as the acquired conceptual understanding.

Assessment as Systemic

Considering assessment as a continuous process is a significant step toward a more holistic view of assessment relying on information technologies and the data they generate. Following on from these possibilities, it might then be feasible to consider assessment systemically. Traditional assessment practices have been criticized for only focusing on some aspects of students' development or knowledge. This is perhaps most evident in the widely adopted approach of using multiple choice questions (MCQs) in examinations. MCQs are criticized for allowing students to successfully complete the assessment task relying almost exclusively on recall or familiarity to respond to the questions (Roediger and Marsh 2005). The types of innovations alluded to in this chapter, however, provide means for not only continuously assessing students but also to consider assessing their progress more holistically and systemically.

In a recent paper, Jacobson et al. (2016) suggested that learning theory needs to be transformed into something more akin to a systemic epistemology. They highlight the ongoing debate between cognitive and embodied views of learning as necessitating a shift to more systemic ways of conceptualizing learning. The argument aligns with that of other authors and theorists (e.g., Mason 2008), who for some time have been claiming that educational practices occur in complex or super-complex environments. These environments therefore necessitate a complex, systems-based approach to research and practice (Jacobson et al. 2016), including in the design and execution of assessment. The implications of this argument for assessment practices are profound. A holistic, systemic approach to student assessment differs markedly from the approaches that have traditionally been used. For example, there are few, if any, assessment processes that directly evaluate student affect. This is despite the growing body of research demonstrating how fundamental emotion is in the learning process (Pekrun and Linnenbrink-Garcia 2014). Confusion, for example, appears to be an important part of the process of conceptual change (D'Mello et al. 2014). Future assessment design could therefore move beyond assessing cognitive elements of learning to also incorporate affective components.

Emotion provides one of many aspects of learning that could form part of a reimagined approach to assessment built on notions of systemic learning. There are many others including problem-solving, decision-making, capacity for self-regulation, and metacognition. In this way, assessment could be extended beyond performance and move toward the aim of supporting students to learning how to learn, as advocated by Black et al. (2006). Information technologies and particularly the possibilities provided by continuous assessment allow these factors to be considered seriously as part of the assessment process. One way of conceptualizing how this might occur is to consider what a systemic, continuous approach to assessing conceptual change might look like. The research literature on conceptual change is vast (e.g., see Amin and Levrini 2017 for recent overview), providing a solid foundation to speculate about what a rethinking of assessment in this domain might entail. Let's assume that a student has a fundamental misconception about a scientific phenomenon like gravity. Young people often misconceive the effect of gravity on falling objects of different mass (Clement 1982). A traditional approach to assessment might ask students to complete an exam with questions about how gravity really works. At best, this approach might help to develop some sense of their capacity to produce a response based on their understanding. If not designed well, however, the exam will merely gauge their capacity to remember what they were taught previously and produce a response at that moment in time. This approach might not give any indication that the student has effectively changed their mental representation of gravity as a concept.

A systemic, continuous approach to this problem would undoubtedly provide more insight into the progress the student makes in updating their mental representation. For example, the student might be asked to work through a conceptual simulation. The simulation could begin by asking the student to predict the rate at which two objects of different mass might fall to the ground. They then enter a simulated virtual space where they are able to experiment with different objects of different mass and observe as they fall. Their behavior in this simulation will provide clues as to how they interpret the concept. For example, students who rapidly cycle through the simulation may be overconfident suggesting that they will not adequately incorporate the new knowledge they are supposedly acquiring into the existing mental model they have (Lodge and Kennedy 2015). Another student might stop for an extended period while using the simulation, perhaps suggesting some level of confusion or disequilibrium that the student is actively trying to resolve (Arguel et al. 2017). What this example demonstrates is the power of a data-driven and systemic approach to continuous assessment. Aspects such as engagement, affect, confidence, and capacity for self-regulation can all be gleaned through the data collected. While the behavioral data might not directly measure these variables, the information provided to assessors is undoubtedly far richer and more complex than if the student merely completed an exam post-instruction.

Assessment as a Conversation

The discussion so far in this chapter has focused on the aspects of assessment related to measurement and continuous learning. In both these cases, I have suggested that data-driven approaches will contribute to a more holistic and systemic approach to assessment. One issue that arises from this suggestion is that the evaluation and feedback on student progress will become automated and require no human intervention. While this is true of some aspects of assessment, particularly the more procedural aspects, that is not to say I am predicting a purely automated approach to assessment in the foreseeable future. With advances in learning analytics, machine learning, and artificial intelligence, there will be increased use of automated systems for assessing student progress and providing feedback. Significant progress is already being made on systems to provide an evaluation and feedback to students. For example, advanced systems are increasingly becoming available that provide students with feedback on elements of their writing (Buckingham Shum et al. 2016). Automated assessment has also been experimented with in several contexts including massive open online courses (Pieterse 2013).

Despite the progress being made in these automated systems, there will continue to be a role for teachers and tutors into the foreseeable future. The main reasoning behind this is also due to the increased impact machine learning and artificial intelligence will have on society. The kinds of knowledge domains that can be easily encoded into a system such as declarative and procedural knowledge will become less important for humans. In other words, if machines can manage and make evaluative judgments about the development of knowledge in these domains, there will be less need for humans to acquire this knowledge. The jobs of the future will predominantly focus on the knowledge and processing that machines (as we currently conceptualize them at least) cannot do. Education will therefore increasingly need to help students to develop skills in high-level analysis, synthesis, and critical evaluation.

In order to model the kinds of thinking that machines are not good at, students need to observe these forms of thinking in action in another human. There will therefore continue to be a need for teachers and tutors to provide the kind of evaluative judgment and feedback to students that machines are not capable of. There will also be a continuing need for teachers to help students develop their capacity to make evaluative judgments about their own progress. Information technologies can also play a significant role in enhancing these processes. One way to think of this is to compare the traditional production of an artifact for evaluation and the process of providing feedback as a conversation. When students create an artifact, submit it, and wait for feedback, it can be a long and slow process; the conversation takes time. The use of information technologies allows both for this process to be sped up and for the conversation to be more nuanced and wide-ranging.

Building on the previous discussions of assessment as continuous and systemic, the use of information technologies also offers additional means of providing information to teachers about how students are progressing. The data generated as students interact with information technologies can be used to provide teachers with information about how students are doing through visualizations, dashboards, and alerts. What this then means is that teachers can not only evaluate what students produce but they also get more insight into how students are producing the artifact. Again, the process that people go through to make sense of and use knowledge will become increasingly important as machines impact on society. The information will allow teachers not only to assess the process of learning as well as the product or outcome, but it also allows more sophisticated means of intervention as there is more information upon which the teacher can intervene.

One way of considering the possibilities for this more sophisticated view of assessment as conversation is to look at the ways in which more sophisticated instruments are used in cognate areas. In clinical psychology, for example, highly precise psychometric instruments are not used as a means of measurement as much as they are to generate points for conversation between the client and psychologist. In a similar manner, dashboards and visualizations provide diagnostic information that can allow teachers to have a fuller discussion with students about how they are learning and not just what they are producing. For example, a science student might be unsystematic when attempting to understand a complex scientific concept, manipulating variables in a digital environment in a haphazard way. Systematic approaches are often more effective at attempting to understand complex phenomena (e.g., Dalgarno et al. 2014), so, if a teacher is provided with information that the student is using a less effective strategy, there is a possibility for the teacher to intervene and assist the student to adopt a more effective approach.

Information technologies therefore can provide teachers with a means of conducting cognitive diagnostic assessment (c.f. Leighton and Gierl 2007) in a more holistic way than is possible by assessing something that a student produces. By using information technologies to provide information to teachers about how students learn, they are better equipped to have a fuller conversation with students about how they are learning, thus helping to realize the promise of assessment and feedback cycles as an ongoing discussion between students and teachers. This, in turn, will give students more insight into the critical learning and thinking approaches that they can only learn from humans and that they will need to master in the twenty-first century.

Conclusion

Taken together, there are clear affordances being provided by advances in information technologies that are poised to have an impact on assessment in all educational settings. Whether or not these affordances are going to significantly advance student learning will depend on whether assessment practices also evolve as the technologies do. This evolution needs to be led by what is understood about the learning process and not by the tools themselves. Much has been written in the last decade about the risks associated with putting technology ahead of pedagogy (e.g., Selwyn 2014). Another foundational issue for developing effective practices for assessment using new technologies is that the evidence often lags behind the technical innovations

(Lodge and Horvath 2017). Solid, rigorous evidence about the ways in which new technologies can be best implemented in educational settings tends to take far longer than do the technologies to filter through to practice. New technologies often seem to educators and administrators to be a silver bullet for improving education or resolving a specific issue. The reality often does not meet the hype surrounding these new innovations. The timeline of new technologies and their use in relation to the evidence that they work is best captured in the Gartner hype cycle (Gartner Inc. 2015). Many innovations are initially overhyped, but then the initial hype dies down (into the trough of disillusionment) before reaching a point where the evidence about how best to use them catches up. There are risks in this cycle for the ways in which assessment is implemented and executed as information technologies continue their evolution.

While it is always difficult to make future predictions, my aim in this chapter was to examine some trends in relation to various aspects of assessment practice and project where those trends might take us in the future. These trends suggest a future where information technologies will afford more continuous, personalized ways of evaluating student progress and providing feedback to enhance their own capacity to learn and make evaluative judgments. The potential in these approaches is latent in the online, data-driven digital learning environments that are increasingly becoming available to educators and students. The risks associated with the growing use of these technologies are that assessment practices do not keep pace with the rate of change. I have attempted in this chapter to outline some of the key areas for attention from researchers and practitioners. These include considering the relationship between assessment and learning as a process and more holistic, systemic approaches to assessment allowing for more nuanced conversations between teachers and students. In doing so, the advantages of emerging technologies can be best deployed to support teachers and students rather than in a redundant attempt to replace teachers. Reconceptualizing assessment as a key part of the process of learning will go a long way to ensuring that the future of assessment mediated by information technologies will lead to better outcomes for students and teachers alike.

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Section VIII

Flexible, Distance, and Open Learning in the Twenty-First Century

Section Introduction: Flexible, Distance, and Open Learning in the Twenty-First Century

47

Roumen Nikolov and Kwok-Wing Lai

Abstract

This chapter provides an overview of the five chapters included in Section VIII of the Handbook – *Flexible, distance, and open learning in the twenty-first century.* These chapters focus on the pedagogies and designs of technology-enhanced environments developed to support flexible, distance, and open learning.

Keywords

Flexible learning · Distance learning · Open education resources · Massive open online courses · Virtual schools · Online communities · Personalised learning

With the proliferation of digital and mobile technologies and applications in the last decade, there has been significant growth in the delivery of distance and flexible education in the primary and secondary sectors globally; and the advent of MOOCs (Massive Open Online Courses) and OERs (Open Education Resources) has created new open learning opportunities. However, this growth has also led to new pedagogical and technical challenges at the classroom and policy levels, as there are issues of how best students can be supported in the new learning environments and how their learning needs and expectations can be met. In this section of the

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Handbook, the authors have reviewed and synthesized research on the theories and pedagogical practices of developing and facilitating online, flexible, and open learning environments and communities designed to support knowledge inquiry and collaboration.

The first chapter of this section, ▶ Chap. 48, "Distance and Flexible Learning in the Twenty-First Century" (Nikolov et al.) provides an overview of how new digital and mobile technologies can afford personalized and flexible learning; and in particular, how curriculum flexibility is supported by the use of these technologies. The concept curriculum flexibility, in terms of what, how, where, and when learning takes place, is used to frame the discussion. The elements and dimensions of a flexible curriculum designed to address learner diversities are also discussed. This overview chapter also provides a brief discussion of the issues and challenges facing flexible and distance teaching and learning in the twenty-first century.

In the second ▶ Chap. 49, "Virtual Schools: A Global Perspective," Davis and Ferdig begin by outlining the evolution of virtual schooling in the US and discussing the benefits and challenges of this mode of education. An organizational perspective on K-12 virtual schooling and online distance education is provided, with a detailed discussion of the roles and responsibilities of different players in this new learning environment. An illustration using an example from a US nonprofit virtual schooling, based on a framework developed by the first author, concludes the chapter.

In the third chapter, titled ▶ Chap. 50, "Open Education Resources, Massive Open Online Courses, and Online Platforms for Distance and Flexible Learning" Dron and Ardito discuss the constraints and resources needed to support current schooling, and argue that with the advent of ubiquitous networked technologies these constraints can be reduced and educational systems can become more open to students. The authors then review some main features of open learning and explore different kinds of openness that can support learning. How this openness can benefit primary and secondary students is also discussed in the chapter.

The fourth ▶ Chap. 51, "Online Learning Communities in K-12 Settings" (Tang and Lee), details how emergent technologies can afford social and interactive networking, and the authors review four established online learning communities, including the Knowledge Building communities, Quest Atlantis, Virtual Math Team, and Web-based Inquiry Science Environment as exemplary practices. In addition, two emergent online learning community platforms, Canvas K-12 and Brightspace are discussed. The concept and boundary of online learning communities, and issues in develpoping and implementing them; as well as major trends of research and key issues for future research are also reviewed in this chapter.

In the fifth and final chapter of this secion of the *Handbook,* ▶ Chap. 52, "Designing Blended, Flexible, and Personalized Learning" Pratt and Kovatcheva argue that an approach to implement flexible and personalized learning is to conceptualize them as blended learning, which can occur both online and offline. Models of blended learning are then reviewed. Design principles for blended learning are explored in detail, and the authors consider it critical that the design process be learner-centered, rather than driven by new technologies. Issues of future research are also outlined in this chapter.

Using digital technologies to afford learning at anytime and anywhere is not a novel concept. However, with the recent rapid advance in learning and social technologies, there has been increasing demand for learning to be more flexible and personalized, in order to support individual needs. In meeting these expectations, organizational structures as well as teaching and learning processes have undergone tremendous changes in the last decade. In reviewing these changes, the chapters in this section have highlighted the centrality of the learner in the learning process and how different approaches of technology-enhanced learning can support these changes.

Distance and Flexible Learning in the Twenty-First Century

48

Roumen Nikolov, Kwok-Wing Lai, Evgenia Sendova, and Herma Jonker

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Abstract

With the huge increase in Internet connectivity and mobility of learning devices, learning can now become much more flexible. In this chapter, we discuss how new technologies can afford personalized learning, and in particular, how curriculum flexibility is supported by the use of technologies. We frame curriculum flexibility in terms of what, how, where, and when learning takes place. Advances in curriculum flexibility are reviewed and the elements and dimensions of a flexible curriculum addressing learner diversities are discussed. Some of the issues and challenges of flexible and distance learning are also discussed in this chapter.

Keywords

Flexible learning · Distance learning · Curriculum flexibility · Personalized learning

Introduction

Since the publication of the first edition of the *International Handbook* (Voogt and Knezek 2008), an exponential increase in accessibility and connectivity of digital and mobile technologies has occurred. Reportedly in 2017, half of the world population are Internet users, with North America having the highest Internet penetration rate (88%) and even in Africa, being the region having the lowest Internet penetration rate, over a quarter (28%) of its population had Internet accessibility (Internet World Stats 2017). In fact, the growth of mobile devices has been very rapid in the developing regions in recent years, and it is estimated that by 2020, the smartphone adoption rate in the less economically advanced countries will reach 65% (GSMA 2015). This huge increase in connectivity has afforded new opportunities for learning in particular to support distance learning for children and young people globally.

This chapter frames information and communication technology (ICT) as a catalyst of a global educational reform that is based on designing and adopting new learning environments which do not have clear boundaries between the physical and virtual worlds. We consider that to successfully integrate these two worlds, appropriate instructional design strategies based on sound learning theories need to be employed. We begin this chapter by discussing how the new digital technologies support personalized learning and increase the flexibility of learning with regard to space and time, and thus afford learning at a distance. With the recent advances in research and practice in the flexibility of learning, we adopt *flexible learning* as a central concept. We will present a framework of flexible learning consisting four categories of flexibility (what, how, where, when), and these categories are discussed in subsequent sections, focusing on how technologies may benefit the learner. This chapter closes with a discussion on issues and challenges of flexible and distance learning.

Learner and Personalized Learning

Over the last decade, the prevalence and accessibility of digital and mobile technologies have changed drastically the way children and young people communicate, learn, and entertain (▶ Chap. 10, "The Learner and the Learning Process: Research and Practice in Technology-Enhanced Learning" by Lai, in Section III "The Learner and the Learning Process" of this *Handbook*). In formal education, teaching and learning increasingly rely on online electronic and multimedia resources rather than on printed materials. Learners thus have the opportunities to study on their own using aesthetically formatted and interactive multimedia learning materials. The increasing access to information also allows students to study individually according to their needs, skills, interests, and cognitive characteristics, and thus have greater control over their learning process. The recognition of the importance of learner agency for making learning more relevant to students is increasingly being recognized. Thus, there is a call for personalization, which is learner-centered, rather than individualization and differentiation, which are essentially teacher-centered (Bray and McClaskey 2015). A review conducted by Williams (2013) suggests that a personalized learning environment should be facilitated by (a) shifting the locus of control and ownership of learning to the students, with students becoming "co-authors' of learning" (Campbell et al. 2007, p. 138); (b) teachers knowing the capabilities of the students, their attainment as well as the progress of the students; (c) engaging students in authentic learning experiences; (d) developing a collaborative culture "where learners see themselves as both participants and contributors to the learning process" (p. 9); (e) the effective using of ICT; and (f) creating a student-centered environment where "learners feel supported to take ownership and risks with their learning" (p. 13). In using technologies to support personalalized learning, the recent advent of social media seems to be effective as young people use social media increasingly for communication and learning (▶ Chap. 14, "Bridging Formal and Informal Learning Through Technology in the Twenty-First Century: Issues and Challenges" by Lewin and Charania, in Section III "The Learner and the Learning Process" of this *Handbook*).

Advances in Flexible Learning

Nowadays, the term *flexible learning* is widely used, but the term is not universally defined (Tucker and Morris 2011). It is a misconception that flexibility is only connected to technologies, since it is also strongly connected to pedagogies. Flexible learning is not an alternative mode of education but an overall scheme for providing the learners greater opportunity for control over their learning process. Collis and Moonen (2001) maintain that the opportunity for the learner to make choices is one of the most important characteristics of flexible learning:

> Flexible learning is a movement away from a situation in which key decisions about learning dimensions are made in advance by the instructor or institution, towards a situation where the learner has a range of options from which to choose with respect to these key dimensions. (p. 10)

More recently, Cheong (2013) follows the same line of thought, arguing that "the nature of 'flexibility' revolves around learners: what choices are available and how they affect their learning" (p. 2). Several scholars have framed flexible learning into categories, or dimensions; for instance, Bergamin et al. (2012) provided a framework with 22 dimensions and seven categories: time, space, methods, learning styles, content, organization and infrastructure, and requirements; Tucker and Morris (2011) structure approaches to provide flexibility into five categories: time, content, access/entry requirements, pedagogy/instruction approach, and design and delivery. While categories and dimensions of flexibility proposed by scholars are slightly different, they primarily focused on the key elements of what curriculum flexibility is required in the twenty-first century education.

Curriculum flexibility (also called a *flexible curriculum*, *flexible learning*, *flexible education*) is regarded as a means for responding to learner diversity (Rao and Meo 2016). Central to a flexible curriculum are: (1) choices and options, and (2) the adaptation to/central position of individual student's needs. Within this body of research, it is found that curriculum flexibility in general supports student learning in diverse classrooms. This could be profitable for all learners (Rao and Meo 2016) as well as for specific groups of learners (e.g., for gifted learners, see de Jager 2013; for learners with special needs, see Lakkala et al. 2016).

The flexibility of learning can become visible in terms of what learning entails, and how, where, and when it occurs (Tucker and Morris 2011), thus involves all curriculum elements. In this regard, information and communication technologies (ICTs) are frequently mentioned in connection with curriculum flexibility. Offering the choices, options, alternatives, and variety via which a curriculum can be adapted to the learners' needs, can become realizable and manageable through the use of ICTs (Bingham et al. 2016; Collis and Moonen 2001; Granić et al. 2009; Heemskerk et al. 2011). More specifically, Rao and Meo (2016) state that "digital tools help to create flexible environments" because, for instance, "digital texts inherently include options that increase flexibility" (p. 10). Delivering content digitally makes it easier to adapt education to learners' pacing and learning paths, which ease the burden on individual teachers (Staker and Horn 2012). However, Bingham et al. (2016) found in their study that available digital content needed a lot of supplementations in order to match it to the individual learner's needs, therefore demanding extra efforts from the teachers.

Specific curriculum elements are explicitly connected to the aim of addressing learner diversity:

- Learners can work toward their own goals or levels of mastery (Mccarthy and Schauer 2017), or standardized goals from the starting point with flexible ways to reach these goals (Murphy and Rodriguez-Manzanares 2009; Rao and Meo 2016).
- Goals can be flexible and the way and form of assessments may vary, according to the individual preferences (Murphy and Rodriguez-Manzanares 2009; Rao and Meo 2016).

- Content can be offered through differentiated instruction, which "enables teachers to individualize so they can better respond to students' needs" (Tomlinson 2008, p. 29).
- A variety of learning activities is needed in order to support differences in perception, comprehension, processing, expression, and engagement amongst learners, thereby making sure each learner has the support to the degree to which it is needed (Rao and Meo 2016).
- Offering variety and choice is often mentioned as a means for matching materials/resources to different learners (Granić et al. 2009; Lakkala et al. 2016).
- Deliberately making use of grouping is another element that could address differences in learner's needs (Lakkala et al. 2016; Mccarthy and Schauer 2017). Varying grouping assumes flexible use of classrooms and learning spaces (Lakkala et al. 2016; Tomlinson et al. 2003).
- Time can be a flexible element in all lessons and in all lesson phases. Altemueller and Lindquist (2017), for instance, argue that using a flipped classroom design helps for the "modification of the traditional classroom [the amount of classroom time spent interacting and allows]. . .for more differentiation" (p. 343). Murphy and Rodriguez-Manzanares (2009) suggest offering asynchronous communication in order to support individual learner's pace and timeliness. However, de Jager (2013) concluded in her study that the majority of teachers never used time as a flexible element.
- Last but not least, the teacher role is important in a flexible learning environment. The teacher is the one who should offer the choices and adapt the lessons to the learners. Offering more flexibility to the learner puts higher demands on the teacher, and requires additional competencies and more time and effort from the teacher (Collis and Moonen 2001; Granić et al. 2009). Concerning the learner, it also requires higher level of self-initiative, self-motivation, and self-control. The active learner assumption is axiomatic (Nikolova 2001; Nikolova and Collis 1998).

Table 1 provides a summary of all elements and dimensions of a flexible curriculum. In the following sections, the main elements listed in Table 1, in particular, the environment, time, aims, and objectives, as well as learning and teaching strategies will be discussed.

Environment

When we talk about flexibility of learning, the learning environment refers to the place or space where learning takes place. Distance learning is now frequently undertaken within a virtual learning environment, and thus in some countries such as the USA, distance learning is often referred to as *online learning* or *e-learning*. An information space supported by the Internet and the Web provides a *learning space for complementing a physical environment*. Punie and Cabrera (2006) maintain that the contemporary learning space has to be a:

Table 1 Elements and dimensions of a flexible curriculum

Flexibility regarding	Curriculum elements	Dimensions
Aims and objectives **(*what*)**	Aims and objectives	• Levels: Multi or one for all • Uniform or personalized learning paths
	Content	• Topics: Choice, interests • Levels: Basics-repeated-enhanced (possibly beyond a given grade-level) • Instruction: Differentiated – Shorter/longer instruction, smaller/bigger steps, content broken down into different sized pieces, more/less structured • Form: Approach, ways in which the content is presented, various options for perception/ comprehension • Presence or lack of guiding questions, depth of guiding questions
	Assessment	• Grading: Personalized rubrics or same standards • Level of outcomes/products • Ways to demonstrate goal achievement: Choices in forms for the end product, alternative options to show what is learnt (Murphy and Rodriguez-Manzanares (2009)
Teaching and learning strategies **(*how*)**	Learning activities	• (More) open-ended or (more) close-ended • Levels of study skills • Learning styles • Amount of guidance • Assignments: Product and task options, homework • Ways to acquire knowledge, options for processing/ expression/engagement
	Materials/ resources	• Choices • Variety • High and low (or no!) tech • Texts at varied reading levels
	Grouping	• Grouping configurations: Individual/small groups/ whole-class • Collaboratively or individually • Seating arrangements and student groupings: Fixed or flexible
	Teacher role	• Make adaptations, create individual learning paths • Solo/co-teaching/engagement (external) others • Guide toward autonomous learning • Scaffold support
Environment **(*where*)**	Learning environment	• Inside/outside classroom/school • Use of building/rooms • Traditional/blended/digital
TIME **(*when*)**	Time	• Pace • Duration • Time span • Moment • Sequence • Synchronous/asynchronous communication • Deadlines: Fixed or loose

- *Connecting and social space*: Since learning is a social process, it needs to bring different actors together to share learning experiences. Learning spaces are both physical and virtual spaces that favor a learner-centered model but connected with the other actors involved in learning and with other social networks. As such, learning spaces should also link learning individuals with learning communities, organizations, and even learning cities and learning regions. Nikolov et al. (2016) argue that a new type of smart learning environments emerge based on the spatial intelligence of the cities: "Embedded networks of sensors and devices into the physical space of cities are expected advancing further the capabilities created by web 2.0 applications, social media and crowd sourcing. A real-time spatial intelligence is emerging having a direct impact on the services cities offer to their citizens. Collective intelligence and social media have been a major driver of spatial intelligence of cities" (p. 341).
- *Personal digital space*: Every learner should have a personal, digital learning space where all learning material is accessible anywhere, anytime, anyway (via multiple devices and media). Scott (2015) asserts that "personalized learning also enables the flexible use of space, which includes moving away from the classroom and into the community, and dividing up larger learning spaces into smaller ones" (p. 5).
- *Trusted space*: Learners should be able to trust and feel confident (e.g., on quality and reliability) about the digital learning spaces where learning content is co-produced and shared. Booth (2012) contends that "trust is a key facilitating factor for knowledge sharing in online communities" (p. 24) and the use of social network analysis as a methodological tool may be helpful to better understand the role of influential members in cultivating and sustaining knowledge sharing and trust.
- *Pleasant and emotional space:* ICT could make learning content more attractive (e.g., media-rich virtual environments and simulations) and support a space for communicating emotion (e.g., by connecting people with different personalities). As Psotka (2013) claims, such spaces can integrate a range of personalized strategies and "students who may have difficulty performing in class could potentially have time away from teachers and peers to engage in virtual problem-solving strategies synchronized to a learner's individual pace" (p. 78).
- *Creative/flexible space*: Learning spaces should support the development of creativity, rather than focussing exclusively on presenting and reproducing knowledge. Sriraman and Haavold (2016) report that "recent empirical studies have also found evidence that mathematical problem solving and problem posing can be used to develop creative abilities in mathematics for all students" (p. 15).
- *Open and reflexive space*: Future learning spaces would need to be open and module-based, enabling learners to re-enter the space whenever they wish.
- *Certified space*: Future learning can only be different from learning today if the current accreditation systems and learning assessment systems are adapted to the requirements of the knowledge-based society. The acquisition of ICT skills, digital competence, and other new skills, be it through formal education or nonformal or informal learning, should be demonstrated, evaluated, and also

certified. Yang (2015) claims that the new paradigm would include a shifts "from a centralised and state-controlled system to a decentralised, regulated, coordinated and partnership-based system; and, from a "diploma oriented system" to a system whose target is the professional inclusion of youth" (p. 19).

- *Knowledge management space*: The strength of most organizations lies in their people, hence the need to share experience and knowledge among colleagues, within the organization, and even across organizations to facilitate knowledge management. Cheng (2012) argues that the knowledge management at school "is a set of relatively new organisational activities that make use of knowledge as an important resource to improve organisational behaviours, decisions, student learning, teaching processes and collegial relationships that enable schools to improve their overall performance" (p. 590).

Kalay (2004) used *place* as a metaphor for a learning environment conceptualized (in the physical world) as the "setting that transforms mere spaces and activities into unique sociocultural events: the coming together of people to the same location, at the same time, for the purpose of participating in a common, authentic, one-of-a-kind, memorable activity" (p. 195). As maintained by Kalay (2004),

> place-making, rather than page-making, is a more appropriate metaphor for designing cyberspace: in addition to communication and information management, this metaphor affords a contextualized locus for situating the activities themselves, much like physical places do. Thus, the virtual places will include socio-cultural and perceptual qualities, enriching them to the point where they may approach - perhaps even surpass - comparable physical settings. (p.196)

Time

Flexibilty is also about when learning takes place. In terms of the time aspect, the changing nature of distance learning becomes clearly visible. While traditional distance learning is designed to facilitate self-study where all learning materials are provided to the student with no or minimum teaching needed, the advent of specialized video-conferencing technologies and more recently the Internet-based video-conferencing systems allow increased interactivity between the teacher and students and also among students (Lai 2017). Mobile technologies also increase the flexibility of distance learning, to be undertaken truly at any time and any place. There has also been a changing profile of distance learners in the last ten years. Universality of primary and secondary education in the economically more advanced countries made many urban school students take online distance courses to personalize their learning, since distance learning provides them a lot of flexibility without having the need for face-to-face contact. We have also seen an increase of open learning courses, popularized by the Massive Open Online Courses (MOOCs) being initially designed for higher education

(▶ Chap. 50, "Open Education Resources, Massive Open Online Courses, and Online Platforms for Distance and Flexible Learning" by Dron and Ardito, in Section VIII "Flexible, Distance, and Open Learning in the Twenty-First Century" of this *Handbook*) but subsequently also offered at the school level (Atkeson 2014). In the past, distance education has always been considered by policy makers as *education on the edge*, but increasingly with urban students now taking distance courses by choice, online distance education has fast become mainstreamed (Naidu 2016). However, it should be noted that online distance learning requires a higher level of self-directedness, and thus it may not be suitable for all learners. While there is a paucity of research of distance learning at the school levels, a large-scale review of 40,000 tertiary students in the US reports that some learners had problems in adapting to online courses, with gender, ethnicity, and age being factors affecting persistence and achievements (Xu and Jaggars 2013). We can expect that these demographic factors will also have an effect when primary and secondary students are involved in distance learning.

Aims and Objectives

This category refers to what has to be learnt: the aims and objectives, the content, and the way learning outcomes are assessed. For many online learners, distance learning is by choice rather than by need because online learning gives them a higher degree of control over their learning pathway. In some countries, policymakers thus encourage online distance learning as an alternative route to formal education. For example, there are now regulations in most of the states in the U.S. that high school students have to take at least one online distance course before they graduate. Various reports estimated that there are between two and six million distance students in the USA (Barbour et al. 2016). Similarly, there were more than 200,000 students enrolled in distance courses in over 300 virtual schools in the UK (UK Department of Education 2014).

Learning and Teaching Strategies

This category refers to how learning and teaching are conducted, underpinned by learning theories. It includes the learning activities, materials/resources, grouping, and the role of the teacher. The flexibility provided by Virtual Learning Environments (VLEs) makes it possible to adapt learning to the individual needs and preferred learning modes. However, it means that teachers have to step out of the traditional instructor's role and serve as a learning consultant, collaborator, and facilitator. Also, the majority of teachers do not, or hardly ever, adapt the curriculum to the learner's needs (de Jager 2013). At the best, teachers make minor adaptations in their lessons, but in order to respond adequately to diversity, it is important for teachers to "consistently, defensibly, and vigorously adjust curriculum and instruction in response to student readiness, interest, and learning profile" (Tomlinson et al. 2003, p. 131).

In flexible and distance learning, the learner is not considered just a consumer of the learning content but rather as a co-producer of such content. With the predominately Web 2.0 tools and applications being used in schools (▶ Chap. 10, "The Learner and the Learning Process: Research and Practice in Technology-Enhanced Learning" by Lai, in Section III "The Learner and the Learning Process" of this *Handbook*), Web-based virtual learning environments now provide opportunities for students, teachers, parents and other stakeholders to contribute useful educational resources (▶ Chap. 50, "Open Education Resources, Massive Open Online Courses, and Online Platforms for Distance and Flexible Learning" by Dron and Ardito, in Section VIII "Flexible, Distance, and Open Learning in the Twenty-First Century" of this *Handbook*). A lot of Web 2.0 School oriented portals provide access to web services and content for educational purposes in different school subjects, such as *Shambles: Education Project Asia* (http://www.shambles.net/).

An example of applying an innovative learner-centered strategy in a learning environment is the European project *WebLabs* (Kahn et al. 2011). The *WebLabs* learning model and the VLE supporting it, facilitated 10–13 years old students, together with their teachers and geographically dispersed researchers to involve in science and mathematics explorations by means of technology (a software environment for visual modeling). The students acted as partners in a research process and developed an understanding of mathematics as a science by posing questions, searching for information, formulating hypotheses, carrying out experiments, and solving open-ended problems. Based on their explorations by constructing infinite processes, they discussed within the Weblabs community such complex mathematical notions as *infinity, cardinality,* and *convergence.* They communicated and shared their experiences with peers, teachers, and researchers locally and globally through a Web-based collaborative system, in the form of so-called *Webreports*. During this communication, they acquired specific social experience and were stimulated to build valuable personal skills such as the ability to:

- Generate and verbalize ideas;
- Present their results according to specific standards;
- Share their experience by means of electronic communication;
- Work in a team and discuss their work, and
- Be (self-)critical to the work published in the virtual environment.

Another example to facilitate regular dissemination and sharing of know-how and best practices in using VLEs in science education is the Scientix project designed for the community of STEM educators across the European Union (EU) (Aguirre-Molina and Gras-Velázquez 2011). It has developed an online portal, which collects and disseminates teaching materials and research reports from European science education projects financed by EU under the 6th and 7th Framework Programmes for Research and Technological Development, the Lifelong Learning Programme and various national initiatives. It embraces a great number of science education projects (current and finished alike), thus assuring their further dissemination among a large spectrum of stakeholders – teachers, researchers, curriculum developers, policymakers, students, and parents. The portal is free-to-access and free-to-use, which makes the Scientix community open to anyone interested in science education in Europe. At present, there are more than 600 learning objects, findings of 200 STEM projects carried out over the past 10 years that can be accessed from the portal. The philosophy of the portal has been summarized by its creators in the following keywords: *search, find,* and *engage*, thus emphasizing the role of Scienitx as a knowledge building platform (Aguirre-Molina and Gras-Velázquez 2011). The fact that all the projects on the Scientix platform include elements of e-learning and various online technologies for education, communication, data collection, and dissemination could provide a valuable insight into what e-learning methods work best and what conditions make them more likely to succeed in supporting science education in Europe (Gras-Velázquez et al. 2013).

To support distance and online learning, a very popular and innovative didactic resource accessible at the Scientix portal are *online laboratories*. A good example of how to make use of them is the Go-lab project. It offers work with real (remote) laboratories that can be remotely operated by students to gather data from a real laboratory setup (e.g., Faulkes Telescope, offering not only a database of astronomic pictures but also the opportunity for the students to remotely operate the telescope and to take their own pictures of the Cosmos). The second type of online labs are the *virtual labs,* enabling students to simulate real equipment and experiments, e.g., LHC Game simulating the process in a particle accelerator such as the Large Hadron Collider used at CERN, or the Galaxy Crash simulating collisions of galaxies and letting the students check their hypotheses on how galaxies form and evolve in the Universe. The obvious advantage of online laboratories in e-learning is the opportunity for teachers and students to access high-tech scientific instruments and use them for research purposes, in harmony with the inquiry-based education. Furthermore, students can carry out experiments in the virtual labs to observe phenomena that cannot be seen in real situations. The main difficulty would be the incompatibilities to implement activities using the online laboratories while complying with national or school curriculum.

With younger students (primary/secondary levels), offering curriculum flexibility is often the task of the teachers. Only when students become older, the focus of curriculum flexibility shifts from the teacher to student. In higher and vocational education, the focus merely lies on student's choices and responsibility within the context of an educational program (Collis and Moonen 2001; Carlsen et al. 2016). This also applies to high school distance learning, as in the study of Murphy and Rodriguez-Manzanares (2009).

Issues and Challenges

Need for a Clear Focus on Pedagogies and Learning Theories

When designing distance and flexible learning, educators mostly refer to one of the three popular learning theories: behaviorism, cognitivism, and constructivism (▶ Chap. 11, "Information and Communication Technologies, and Learning

Theories: Putting Pedagogy into Practice" by Dennen et al., in Section III "The Learner and the Learning Process" of this *Handbook*), although the connectivist learning theory (Siemens 2014) has been gaining popularity, in particular in reference to the implementation of MOOCs in recent years.

The inquiry-based learning (IBL) approach provides a variety of good pedagogical practices. As Mikroyannidis et al. (2013) claim, when applying IBL,

> . . ...learners take the role of an explorer and scientist as they try to solve issues they came across and that made them wonder, thus tapping into their personal feelings of curiosity. IBL supports the meaningful contextualization of scientific concepts by relating them to personal experiences. It leads to structured knowledge about a domain and to more skills and competences about how to carry out efficient and communicable research. Thus, learners learn to investigate, collaborate, be creative, use their personal characteristics and identity to have influence in different environments and at different levels (e.g., me, neighbourhood, society, world). (p. 2094)

It should be noted that in designing flexible learning environments, attention should be focused first on the pedagogy used to support learning, before the affordances of the technologies to support such a pedagogy are considered.

Role of the Teacher

Closely related to the previous challenge is teachers' insufficient understanding of their role in a virtual learning environment. Teaching in a digital (perhaps online) and flexible learning environment is not a replication of face-to-face teaching (Lai 2014). There is a need for a change of epistemic beliefs, of how knowledge is created and developed, and how learner agency is facilitated. Professional development and learning has to be designed and implemented to support a change of pedagogical beliefs and practices. While teachers teach increasingly online, adequate teaching preparation in online teaching has not been recognized. It is thus not surprising to see many online courses which are based on behaviorist principles (Daniel 2012). Also, virtual schooling nowadays attracts many students who fail in the conventional systems or whose learning styles are not well accepted by traditional schools. How to support these students to be successful lifelong learners is a challenge for teachers and policymakers.

Problem of Information Overload

The enormous information overload of individuals and organizations is among the most important changes nowadays due to the low cost of multimedia information production and distribution and the diversity of distribution channels available. The information overload problem is being transformed to an information overkill problem as the filtering of the great volume of information cannot be easily made and only small amounts of information can be transformed into usable knowledge. Some new technologies that target this problem are under development, such as the semantic web, intelligent search agents, and learning analytics. The competitiveness of individuals and organizations highly depends on their ability to rapidly transform such information into applicable knowledge, which should be selectively distributed and used for just-in-time decision making and learning. The new generation of highly interactive multimedia and hypermedia learning environments foster learner-centered educational models and provide a different perspective for school education. To make use of the new opportunities offered by the ICT based online learning, in a world full of powerful instruments of producing and getting access to any kind of information at any time and any place, young learners need to acquire and develop the skill of not just accessing information but evaluating information critically to be transformed into useable knowledge. This is yet another challenge.

Conclusion

In this chapter, we have summarized some recent research trends in the fields of distance and flexible learning in primary and secondary education. We began by focusing on the learner and discussed the support provided by digital technologies to facilitate flexible and personalized learning. The technologies for distance and flexible learning and the virtual learning environments with fuzzy boundaries between the physical and virtual worlds provide a great variety of opportunities. It was identified that flexibility of what, how, where, and when to learn could adapt learning to the individual needs and preferences of the learners. Some important research issues and challenges have been identified in this chapter as well, including connecting pedagogies and learning theories with learner-centeredness and distance and flexible learning, the changing role of the teacher, the possible information overload, and the needs of new skills.

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Virtual Schools: A Global Perspective

49

Niki E. Davis and Richard E. Ferdig

Contents

Abstract

Each year, millions of K-12 students study one or more courses at a distance. Although the highest participation has been from learners in the USA, online flexible and distance K-12 schooling has become available to students from many countries around the globe. Its implementation and evolution is due, in part, to the varied ecosystems in which it appears. It began as a sharing economy; it now includes for-profit, nonprofit, and mixed business models that impact whole education systems and may continue to spread globally. Virtual schooling

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(VS) research overlaps in some ways with research in both traditional K-12 schooling and postsecondary online education. However, given its unique nature, research also specifically addresses virtual schooling's benefits, challenges, strategies, services, and varied impacts on educational systems. This chapter provides an organizational perspective on K-12 online distance education. It includes a synthesis of the research and a discussion of the misconceptions of roles and responsibilities. The chapter concludes with a detailed illustration of a nonprofit service, depicted within (Davis 2018, pp. 99–127) Global Arena Framework to clarify its complexity and potential.

Keywords
Virtual Schooling · K-12 distance learning · Organisational culture · Blended learning · Online learning · Distance education

Introduction

K-12 online and blended programs arguably gained their initial foothold in the USA in 1996 with the introduction *The Virtual School* and the *Florida Virtual School* (Ferdig and Kennedy 2014). Over the last 20 years, virtual and blended opportunities have exponentially grown for K-12 schools in the USA and in some parts of the world. For instance, it is estimated that millions of students each year participate in some form of K-12 online or blended instruction (Gemin et al. 2015). There is also a rich and growing body of research evidence supporting teaching and learning in such programs (Ferdig and Kennedy 2014, 2018; Davis 2018). What was once considered potentially a useful option solely for home-schooled, detained, or health-stricken students is now mandated in some locations. In sum, online flexible and distance learning has become one of the global modes of K-12 schooling.

The purpose of this chapter is to provide an organizational and brief historical perspective on K-12 virtual schooling in order to (a) set the stage for a deeper understanding of its multiple facets, (b) to provide illustration of the evolution of a nonprofit virtual school provider in the USA in order to paint a more comprehensive portrait of the benefits and challenges facing this mode of K-12 education, and (c) to introduce alternative and sometimes contentious contrasting points of view on virtual schooling.

Sketching the Landscape

Roblyer (2008) presented a history of virtual school establishment in the USA up to 2006 that began with the establishment of Utah's Electronic High School in 1994. At that time, virtual schooling largely focused on a few courses within secondary school programs where students would typically attend a face-to-face school in their home district (Roblyer 2008). They would enroll in an online program where they might take one or more classes in an online environment using a learning management system (LMS) and/or other online tools that complemented the LMS. The school or school district would still be responsible for providing some mentoring (typically a school counselor or administrator) and would report grades to the "face-to-face" school district, while the online service would provide the teacher and the content. These supplementary courses and programs were initially offered at the secondary levels. Given the rudimentary nature of early technologies available for online instruction and weak organizational structure, learners were expected to be relatively autonomous. Full-time programs were also offered by a few organizations, some of which had evolved from correspondence schools and colleges. However, this conception has changed, and virtual programs now commonly span primary and secondary offerings, and the terminology has moved away from virtual schooling to include terms such as blended and personalized online learning (Gemin et al. 2015). For a more recent historical view with a more critical perspective, see Barbour (2014, 2018).

Originally these online offerings emerged to serve the needs of students in districts that did not have enough mass to offer specialized courses (e.g., world languages and some sciences); today they have expanded into more mainstream curriculum courses to serve needs such as "credit recovery" and to overcome scheduling conflicts. Although these offerings appeared particularly inviting and promising for home-schooled students, students who had dropped out, teens who left school due to parenthood, students with health issues, or detained students, research suggests that many of these courses were heavily enrolled with gifted and advanced students looking for more curricular options and also students heavily enrolled in extracurricular activities who needed an augmented and flexible schedule (Ferdig and Cavanaugh 2011). Such schedules could also include online courses offered by universities to recruit and prepare the bright students that can be supported in the USA with public funding for dual enrolment in high school and in university.

While the growth of virtual schooling has been unusually strong in North America, particularly the United States, the emergence of virtual schooling remains patchy globally. The growth of virtual schooling naturally is related to the evolving needs of the population, the funding arrangements for public schooling, and the access to online infrastructure and practice (Davis 2018). In many countries, the role of correspondence distance education continues to serve these needs. For instance, in New Zealand, supplementary courses appeared around the same time as in the USA to address unmet needs (particularly in rural areas); the uptake has remained small and few regulatory changes had occurred (Powell and Barbour 2011) until recently. Arguably even those have had a relatively small impact compared to changes in the USA (Tolosa et al. 2017).

The growth of online and blended schooling has either necessitated or encouraged policy change. For instance, even in a supplementary role, virtual schools can face challenges from K-12 schools to local districts because they tend to compete for the same funding sources. In the USA, the National Educational Policy Center has raised awareness of this threat to the traditional goals of that nation system of public education, raising concerns about the "Macdonaldization" of public schooling and related disruption of enculturation into mainstream society (Miron and

Gulosino 2016). On the other hand, VS providers (e.g., Iowa Learning Online and the Virtual High School) work strategically to partner with rather than compete with the schools they serve (Davis 2018). Additionally, the growth of online learning in postsecondary education has stimulated changes in the regulation of education in some states within the USA to require students to participate in online learning experiences prior to graduation from high school (e.g., State of Michigan 2006). This has stimulated many additional states to develop a virtual schooling provider and/or cooperatives to support this mode of schooling and to inform policy development (Gemin et al. 2015). In contrast, Bacsich et al. (2013) noted that policy makers in countries that have few offerings have often been unaware of its potential and challenges. Their wiki with comprehensive worldwide coverage exhibited few cases in Europe or Asia where courses were taught by a distant teacher. Instead, online learning and teaching in Europe and Asia have largely added flexibility to provision by the same school campus or after school tuition services (see http://www.virtualschoolsandcolleges.eu).

Thus, research-based knowledge about virtual schooling is limited; even in the USA (see Archambault et al. 2016b) virtual schooling providers continue to evolve and emerge. The lack of experience and accurate information about this mode of K-12 schooling and the diversity of offerings has led to misleading preconceptions about virtual schooling that can fuel heated debates. An example from those in favor of VS is the Clayton Christensen Institute's so-called "proof points" (see http://www.christenseninstitute.org/publications/proof-points/). The points are essentially evaluative reports by academics connected with the Institute in the form of 12 case studies describing how traditional school districts have improved student learning outcomes after the implementation of blended learning. An example produced by those against VS is a series of reports published by the National Education Policy Center in Colorado (e.g., Miron and Gulosino 2016) who describe VS as threat to a somewhat twentieth century vision for K-12 public schooling.

Given these conflicting and often naïve or limited perspectives on the very diverse landscapes of VS, it is important for practitioners, leaders, policy makers, and researchers to become more aware of the enormous variety with virtual school providers and the ways in which they are evolving locally, nationally, and globally. It is also critical for such audiences to be aware of the highly variable quality of information that is published about them, which may be overly biased and/or influenced by strongly held beliefs.

Models of Virtual Schooling

Regardless of the supplementary or full nature of the online program, the landscape has become increasingly chaotic with the proliferation of online providers with a diverse range of practices and business models. The early VS providers adopted a "shared economy" business model that aimed to partner with K-12 school districts and schools rather than to compete. Examples include VHS, which emerged as part of a nationally funded research project and traded seats in science courses for the online teaching by science teachers nationwide (Zucker and Kozma 2003), Iowa Learning Online (illustrated later in this chapter), and New Zealand's Virtual Learning Network community of services that continues to use this model (Tolosa et al. 2017). Other business models with layers of online services have emerged; by 2015, there were many services and products marketed by nonprofit VS providers as well as by for-profit companies such as K12 Inc. and Pearson Education.

It has become increasingly difficult to estimate the number of K-12 students who participate in VS each year, as the annual report of K-12 virtual schooling has documented. For example, Gemin et al. (2015) estimated that millions of K-12 students took online classes that year; they also estimated that US$ 380 million was spent on learning management systems and platforms in the USA where for-profit companies such as K12 Inc. were listed in the Stock Exchange. Estimating the numbers of enrolled online *and blended* students up to postsecondary levels is too complex to aggregate figures accurately. This is due to the broad notions and multiple definitions of blended learning. In addition, many virtual schools that offer completely online courses and programs also offer services that support face-to-face blended courses, thus making enrolment estimation difficult or impossible. Finally, the for-profit companies that provide many of the services are understandably reluctant to disclose their business model and outcomes. In summary, online and blended programs are now embedded as a mode of learning in pre- as well as postsecondary education in many forms that continue to evolve and coevolve together with knock-on impacts whole systems K-12 schools including bureaucracy and politics nationwide and possibly globally.

Does Research with Adults Learning at a Distance Online Transfer to K-12?

Prior to synthesizing the existing research related to the major components of virtual schooling, it is useful to question why research differs between virtual schooling and traditional face-to-face education. In other words, there is a need to clarify why an educator might be cautious of directly applying educational research in more traditional settings to inform expectations of virtual schooling experiences. Ferdig et al. (2009) identified this in relation to the 80/20 rule that is well published in other disciplines. In evaluating virtual schools in 22 of the 50 states in the USA, they found strong evidence that 80% of virtual school practices, opportunities, and challenges were shared regardless of state border, while 20% of such processes and problems were unique to the educational context of the virtual school. The unique finding was that many virtual schools and programs were completely unaware that 80% of their problems and opportunities were similar to those of other virtual schools. Many of these schools were under the impression that what they were practicing or, in some cases, attempting to practice, were unique to their situation.

This same 80/20 principle was then applied by the same researchers to the existing research in the field of virtual schooling. DiPietro et al. (2008) studied teacher processes and practices in online programs to explore and compare (a) K-12 online vs. K-12 face-to-face and (b) K-12 online vs. postsecondary online. Researchers found that there were indeed research, practice, and policy outcomes that were equivalent between K-12 teachers in virtual schools and K-12 face-to-face programs as well as in between K-12 online teachers and postsecondary online teachers, such as similarities in classroom management, instructional strategies, and assessment techniques. The researchers also found unique circumstances within K-12 online instruction that did not appear in K-12 face-to-face education or postsecondary online education that included communication, community issues/ concerns, and support strategies. In sum, when further examining research related to the components within virtual schools, it is necessary to examine but also go beyond traditional K-12 face-to-face and postsecondary online research findings because of the unique nature of K-12 virtual schooling. In some cases, the research is emerging, while in others researchers have discovered significant outcomes.

Identifying the Players and Their Roles

In research into face-to-face K-12 classrooms, three traditional components are commonly recognized: the teacher, the learner, and the curriculum content. This is not to downplay the role of the others. Parents, administrators, and others including support staff such as school counselors obviously support and engage students in their learning (to varying degrees). However, these roles become significantly enhanced and/or modified in virtual schooling due to the nature of engagement in online settings; some would use the term "decoupled" to indicate that a role has become spread across multiple people. Such decoupling with the deployment of computers is common in other sectors such as banking where organizational structures have become flatter (Davis 2018). In most VS contexts, the roles of the traditional players (student, teacher, content) are commonly modified by their new settings and particular contexts, and, where this does not occur, the quality of education can be reduced.

The changes in roles have been easiest to research in supplementary schooling because this involves collaboration between organizations, which naturally leads to the decoupling of roles, reporting lines, and changes in the evolving business models. Davis and Niederhauser (2005) contrasted the case studies of supplementary course models: (1) an Australian VS service that developed and offered online courses into traditional public schools with (2) schools in the USA that cooperated so that a teacher in one school designed and offered his course across multiple schools that deploy some sort of bartering arrangement. The second model is more challenging because the teacher leading the course is innovating as an online teacher in addition to remaining embedded in the traditional culture. As a result, such a distant teacher is rarely supported by a traditional school as much as a teacher employed to teach distant students by a virtual schooling provider. The latter is often embedded alongside people who are committed to supporting K-12 online learning and the related evolution of practices. The difference between campus based and online cultures of K-12 schooling are discussed in more detail including a

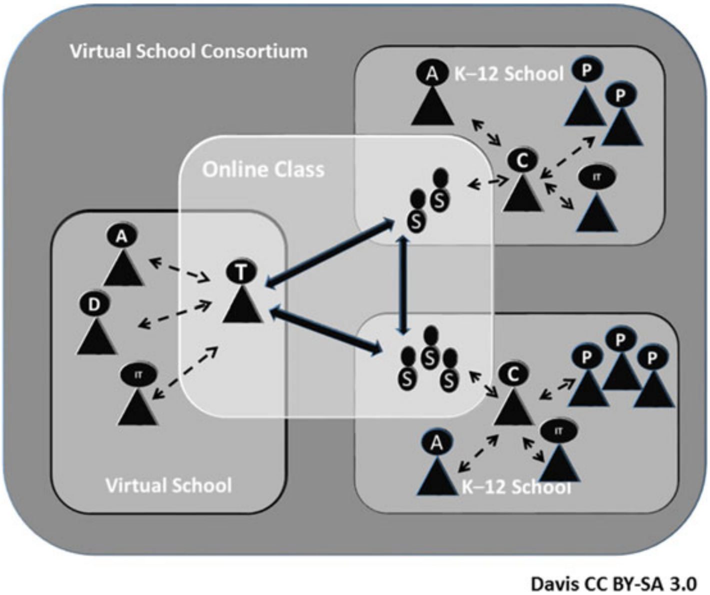

Fig. 1 The roles and responsibilities for an online class offered by a virtual school as a supplementary course for students in other K-12 schools. (First published in Davis et al. (2018) under CC by SA. Key: *A* administrator, *C* coach, *D* instructional designer, *IT* technician, *P* parent or guardian, *S* student, *T* teacher. The dotted line indicates sporadic communication, whereas the unbroken lines between the teacher and students indicate that communication is ongoing)

contrast with the emerging practices of co-teaching in innovative learning environments enriched with Cloud-based tools by Davis et al. (2018).

Figure 1 illustrates an approach where a virtual schooling service provides a supplementary course into two schools. Readers are encouraged to imagine the increasing complexity with the more common situation of a class of students spread across five or more schools and may wish to note that such complexity is not likely to be encountered in cooperating schools because it becomes impractical. A diagram is useful to appreciate changes in the roles and responsibilities of those involved in K-12 education because multiple organizations are involved and the three traditional roles introduced earlier become decoupled and spread across a number of people. The adoption of online learning also brings in new players such as instructional designers who collaborate in the construction of LMS course shells filled with relevant content and activities for a particular curriculum.

As illustrated in Fig. 1, the VS class has an online environment that is spread across at least three organizations: an online teacher (T) who is an expert in the content area leads a course offering from within the virtual school for students (S), who are located in at least two different K-12 schools. The course shell in the LMS is the main virtual environment, and it is loaded with relevant content and activity structures that may be deployed multiple times by different teachers. The work to design and load such an LMS course tends to include an instructional designer (D) as well as one or more teachers who are expert in the content area and/or the pedagogy of the virtual school. As a result, the teacher (T) leading a particular course offering may be restricted by the administration policy of the virtual school from adapting the materials or pedagogy. Virtual schools may also purchase such course shells and adapt them; for example, Gemin et al. (2015) note that a service for Christian schools had purchased course shells and adapted them to reflect Christian values before incorporating them within their menu of course offerings. Additional technologies are usually blended with the LMS to reduce the perceived distance between the participants and to increase student engagement. For example, desktop videoconferencing is relatively common between the teacher and students in the class. The critical role of these digital tools leads to the inclusion of an IT support role (IT) in all locations because technical issues can block access. However, the biggest decoupling has led to the recognition of the importance of the role of a facilitator (F) who is located on the same campus of each site with students and who, in addition to advocating for and coaching the students, is responsible for liaison with their parents (P). For home-schooled students, this facilitator is likely to include a parent complemented by another adult to provide independent quality assurance of summative assessment.

A virtual schooling service commonly sets a style for its approach and pedagogy and provides an induction for its teachers and the other participants. So while practice varies between VS organizations, it is likely to be standardized within the organization, e.g., the early VHS pedagogy was documented by Zucker and Kozma (2003). This is similar to the ways in which traditional schools evolve to fit within their stakeholders including local, regional, and national regulation and cultural expectations. VS services have evolved to address challenges including strategies for accurate and timely assessment and the secure administration of credits that are part of the process required for students to progress through an educational system. There is therefore a role for an administrator (A) on each site and knock-on impacts for administrators at the state and national level; this is illustrated later for Iowa Learning Online.

Some of the current literature in the field is described below as it relates to the learner, teacher, administrator, parent, and facilitator; more research is needed to enhance knowledge of these and other roles, their variations with cultural differences, and evolution over time.

The Learner

The central participant in VS schooling is the learner. Early work in this area examined characteristics of learners who are more or less successful in online and blended learning environments (e.g., Roblyer and Davis 2008; Roblyer and Marshall 2002) in the hope that this could be applied to improve selection and advice to students and their parents. A reliable instrument did not emerge due in part to the continuing evolution of VS, including increased induction and ongoing support for students who were less autonomous. More recent investigations have examined the challenges and opportunities for particular types of students such as those recognized to be "at-risk" of underachieving (e.g., Repetto and Spitler 2014; Ferdig 2010b), students with disabilities (Greer et al. 2014), and students facing health and medical issues (Fernandez et al. 2016; Thompson et al. 2012). More traditionally marginalized populations enroll in online courses at higher rates than other student populations (Thompson et al. 2012), such as students with disabilities, and this increases the challenges for course design and facilitation. This research indicates that virtual schooling can lead to successful outcomes, particularly for more autonomous, motivated learners who have IT skills. However, not all learners are successful in these environments, and only some may become successful when necessary supports are put in place (an example of such is a biology course adapted by Iowa Learning Online for credit recovery is described later). It is also important to note that students benefit from relevant counseling, plus induction to online learning environments that include development of both technical and study skills (Roblyer and Davis 2008).

The Teacher

The second central participant is the teacher. Teacher here refers to the actual instructional leader of a particular offering of an online or blended course (the facilitator at each school where student reside is a separate role described later). Research in this area has described the types of preparation required for successful online and blended practice during which the teacher often gains experience in learning online and may construct a course shell to use subsequently (e.g., Dawley et al. 2010). Researchers have also examined teacher standards (Kennedy and Archambault 2012b), preservice teacher field experiences (Archambault et al. 2016b; Compton and Davis 2010), online best practices (DiPietro et al. 2008), and teacher mentoring and continued professional development (Dawson and Dana 2014a, b). This research provides evidence that teaching K-12 online and in blended environments has some similarities to teaching K-12 face-to-face and some similarities to teaching postsecondary online. There are also some important differences; for instance, postsecondary education andragogy (rather than pedagogy) does not have the duty of care that is necessary when teaching minors. In sum, there are nuances in teaching in these K-12 virtual environments that require continuing teacher professional development (Ferdig 2010a), and such professional development varies with the content area, curriculum, cultural contexts, and time.

The Administrator

There are at least two types of administrators identified in online and blended K-12 instruction. The first is the administrator of the virtual or blended school; the second is the administrator of the face-to-face school where the online student typically resides. Unfortunately, although a large body of literature exists on traditional educational administration, there is little research on best practices of each of these types of administrators in online or blended environments (McLeod and Richardson 2014; LaFrance and Beck 2014; Richardson et al. 2015; Archambault et al. 2016a). What research does exist reinforces the important role of the administrator in providing opportunities for online and blended instruction as well as in providing professional development for staff including teachers and facilitators (Ferdig et al. 2016). In an exploratory study, Beck and Maranto (2014) asked teachers in two virtual charter schools in the USA to compare their experience in virtual charter schools with their prior experience of traditional public schools and found that they tended "to rate the virtual charters more positively on empowering and respecting teachers, and on developing a student-centered school culture, and there was potential for more innovative personal practices" (p. 68), but little evidence of social constructivist practices was found.

The Parent

Parents (and/or other guardians) obviously play a critical role in the education of a child (e.g., Barton et al. 2004). In online and blended environments, parents are often asked to play a larger role given the fact that students are not colocated with their teacher and may study more at home. These roles vary between management (e.g., timekeeping) and basic instruction (providing scaffolding) as well as counseling in the choice of courses (Beck et al. 2014b). As in other areas, although the research in this area is sparse, there is evidence that role of the parent is influential (e.g., Black 2009), that levels of parent involvement vary, and that they require guidance including less formal professional development that includes strategies for supporting children who are learning online (Hasler-Waters et al. 2014).

The Facilitator

Online and distance programs introduced a new (or at least changed) role that we call the facilitator, although many other terms are used including mentor, student coach, and eDean. The facilitator is someone on each school campus who acts as the contact person for the students taking online courses from provider(s) of VS services. The facilitator is critical because the mental and physical distance between teacher of a course and his or her students can lead to high rates of student attrition. Facilitators advocate for VS students on their school campus and help them navigate instructional issues, communication with instructors, limited content scaffolding, and technological problems. They may also have a role as a proctor for the quality assurance of summative assessment. They are also likely to brief parents, administrators, and school counselors on the students' progress. More research is required, but evidence indicates that facilitators have a positive impact on student success and reduce attrition (Borup and Drysdale 2014; Pullar and Brennan 2008). Descriptions of the contexts and roles of mentors in Michigan have been useful to illustrate the evolution of their practice and the importance of school leadership support (e.g., Bruno 2017). In one outstanding case study, the school principal had selected a teacher who had counseling qualifications and supported him to establish innovative practices. The students who needed most support studied in a closely supervised classroom on the school campus, whereas less formal arrangements that were negotiated with more autonomous students included studying from home when that suited those students' needs.

The way in which these and other roles work together varies with the organization of VS, so an illustration of these and other key roles is now illustrated by describing a course offered by the Iowa Learning Online. The evolution of the service over time is also mapped using Davis' (2018) Arena of Change with digital technologies in education to clarify the complex interactions impacting the evolution of VS practices.

A Case Study of Virtual Schooling in the USA

As stated above, practice in VS varies enormously and continues to evolve with changes in educational systems locally and globally. The decoupling of roles and the collaboration between educational organizations and services are complex and difficult to comprehend and communicate. Therefore this section focuses on one particular instance of a statewide virtual schooling service. It aims to set this particular instance of VS in a global context in order to illustrate the importance of multiple partnerships between schools and services that collaborate as well as the decoupling of traditional roles of participants in supplementary courses provided by Iowa Learning Online (ILO).

This case study of a VS service called Iowa Learning Online is drawn from collaborative research led by the first author that began as this service emerged in 2004 (a more detailed account appears in Davis 2018). A decade after it was established, Gemin et al. (2015) reported that, in terms of size, ILO was one of the smallest of the 24 state providers within the USA. The associated state Department of Education tweeted in 2015: "Iowa Learning Online proudly partnership with ~150 schools to serve 1500+ [course] enrolments." Having coevolved with online learning to serve K-12 schools and administrators of its state (as described in detail in Davis 2018), ILO has retained four clear equitable objectives that it has published on its web site. Iowa Learning Online (ILO):

1. Is a supplemental program that partners with local school districts and cannot replace them. Local districts continue to award their students the credits earned upon successful completion of ILO courses.
2. Serves a variety of educational needs and a broad range of learners. It is open to meeting the needs of all high school students.
3. Collaborates to provide quality learning opportunities for students anywhere in the state.

4. Values continuous improvement toward innovative, quality learner opportunities utilizing emerging technologies (see http://www.iowalearningonline.org).

The survival and steady growth of ILO provides evidence that its strategy remains fit for purpose in this largely rural state. In 2016, changes in legislation recognized the need for the ILO to network nationally with a national/international association for K-12 online learning (iNACOL) in order to better inform the state's politicians and administrators. In contrast with some other states, Iowa has kept its investment low beginning with an unfunded mandate in 2004 that required the founders Gail Wortmann (the master teacher who identified the need for ILO) and Pam Pfitzenmaier (the first administrative leader within the state Department of Education) to work within existing resources. Their vision and funding regime may have supported ILO to retain its tight focus on the needs of its state, in contrast with nationwide initiatives such as VHS that have spread overseas and for-profit services such as K12 Inc. (Zucker and Kozma 2003; Davis 2018).

Case studies of courses within ILO include the first course (high school anatomy) that was created and taught by founder Gail Wortmann, with support from instructional designers in Iowa Public TV (Davis et al. 2007). The structure of this first ILO course acted as a guide for subsequent courses, particularly those of high school physics and chemistry, not least because Gail's role as ILO master teacher started with the recruitment and mentoring of ILO teachers and her role grew to include many forms of professional development leadership and quality assurance, including ongoing appraisal of the ILO teachers to retain their licenses to teach within the stage of Iowa. The research of these and other courses led the production of Fig. 1 to clarify the changes and variations in the roles and responsibilities of VS participants, particularly the facilitator. It is interesting to note that an ILO course in basic biology that was designed to increase the range of students served by addressing the needs of those unable to graduate from high school due to their lack of science credits enhanced the role of the facilitator for these students. In this case additional support provided by teacher aids for students with exceptional needs provided the additional facilitating resource required.

Harms et al. (2010) applied communication theory to interpret Gail Wortmann's atypical strategy for videoconference (Wortmann retained it largely for "office hours" so that students could drop into her virtual office); at that time other teachers commonly used videoconference to present content. Where the message (topic or practice) to be communicated is less clear, a high bandwidth improves the chance of effective communication. Given that the bandwidth can be increased for only limited periods in distance education, the narrow communication bandwidth of a LMS or web site is more appropriate for the content and messages of the teacher because she knows what she wants to communicate and so there is less uncertainty. In contrast, the teacher is much less certain what her students' responses are likely to be and often needs to check those messages and understanding. Thus the high bandwidth enabled by multiple media and the two-way communication of videoconference is prioritized for student-to-teacher conversations that can correct misunderstanding and misconceptions, and these sessions are also likely to include aspects of formative and occasionally summative assessment.

During the first virtual field experiences developed in collaboration with Gail Wortmann for preservice student teachers, this videoconferencing pedagogy was observed, analyzed, and reflected upon. For the field experience, Gail added online chat as back channel for communication with the preservice teachers during this observation, which was followed by debriefing conversation over videoconference after the high school students had disconnected from her virtual classroom. The preservice teachers were also guided to undertake observation activities within the LMS course shell (Compton and Davis 2010).

The landscape of VS is complex and continues to evolve under many influences local, regional, and global. Although Iowa Learning Online only serves students in the state of Iowa, it continues to be impacted by global as well as local changes as shown in Fig. 2. A global perspective of the ILO physics course offered by ILO in 2004 is depicted in Fig. 2 using the Arena Framework developed by the first author (Davis 2018), which applies human ecology theory to the coevolution of both digital technologies and education. The ecosystem of teacher and his class was embedded within many layers of ecosystem communities within the global ecosphere. The physics teacher (T) who was leading this offering of a collaboratively designed ILO

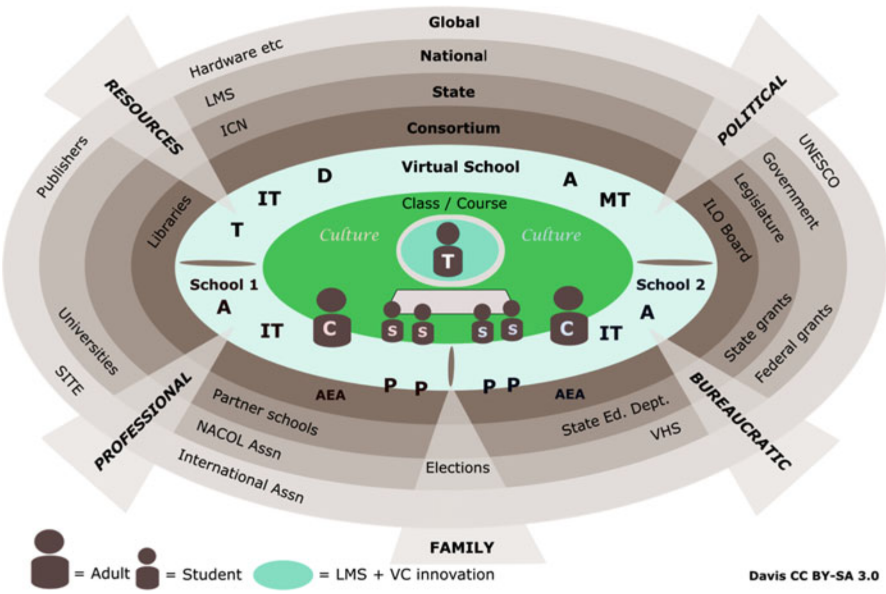

Fig. 2 Iowa Learning Online's first online physics course offering in 2004. The physics teacher is at the center set within the global ecosphere. (Derived from Davis et al. (2013), under a CC by SA license. Key: *A* administrator, *AEA* area education agency, *C* ILO student coach also known as facilitator, *D* instructional designer, *ICN* Iowa Communications Network, *IPTV* Iowa Public TV, *IT* technician, *LMS* learning management system, *MT* master teacher, *NACOL* North American Council of Online Learning, *S* student, *T* teacher, *VHS* the Virtual High School)

course is pictured at the center of the global ecosphere through the screen of a computer. High school students in at least two high schools were in his virtual classroom, and the word culture is repeated to indicate that many cultural influences that influence behavior in this class ecosystem have been brought into the course ecosystem by the teacher, the students, and the multiple schools within which they worked. In each school the ILO required that an ILO coach (C) adopts the role of facilitator who, in addition to coaching ILO students, advocated for them and worked in other ways with parents (P), ILO staff, and his or her own school staff including administrators (A), technicians (IT), plus staff in the area education agency (AEA) responsible for that public school. The ILO teacher had similar collaborators in the ILO, plus Gail Wortmann the master teacher (MT) and an instructional designer (D) who supported the development of the LMS course site and other resources. The agencies noted in the outer layers of the ecosphere also influenced this and many other VS courses. These influences have been grouped into five sectors; for example, in the resource sector the Iowa Communications Network videoconference (ICN VC) service was provided by the state into all high schools, the LMS was a provided by a nationwide for-profit company, and the textbooks were purchased from international publishers.

Figure 2 shows a map of all of these influences, and this landscape would have close similarity to that of another ILO course offering. However, a course offered by a different VS organization, such as the Virtual High School, evolved different practices because those ecosystems would have evolved under different conditions. Mapping in the Arena Framework clarifies that the central physics teacher’s practice is interlinked with the practice of many other participants. Participants who are closer to the class have more influence on behavior within the class, but it is notable that the influence extends globally not least through resources that have become part of the virtual schooling environment. For example, videoconferencing has become accessible over the internet on personal devices and so by 2015 that was used in preference to the Iowa Communications Network (ICN) classroom in each high school. Administrative practices have also evolved since 2004, but most obvious is the increase in the guidance material available for all participants, including parents plus many other roles that were listed in the 2017 ILO online guidance.

Conclusion

In our synthesis of the research, we have found that it is important to interpret research findings and position papers about VS with caution due to heated debates, polarized views, and widespread misconceptions. Authors who have been involved in virtual schooling are likely to be more positive (e.g., iNACOL), while those with strong beliefs about the traditional purpose of schooling in their country may be biased in the opposite direction (e.g., Miron and Gulosino 2016). Finally there are those who are new to this phenomenon who may overgeneralize from their personal experience of online learning or lack of it.

While the positive or negative impact of VS is debated, it has evolved in many contexts to serve particular needs of a range of K-12 students and communities. What began as a sharing economy with open resources now also includes for-profit, nonprofit, and mixed business models. Virtual schooling decouples the roles and responsibilities of educators and learners, spreading the traditional role of a school teacher across more people and places. In the USA, at least, it has increased the presence of for-profit companies in education. This may expand globally where there is a cultural and economic fit. While concerns about the "Macdonaldization" of K-12 schooling are being met with changes in bureaucracy in many states of the USA and nations with foresight, it is likely that some policy makers will remain ignorant of the challenges and potential range of VS. It is likely that the overlap with "smart" innovative learning environments that increase opportunities for Cloud-based personalized learning and cooperative teaching will continue to converge and confuse the landscape of virtual schooling within flexible and distance education for K-12 students. What is not contentious is that more research is needed and that such research would do well to adopt holistic perspectives that allows for systemic analyses. The application of Davis' Arena Framework to one VS service in this chapter shows that VS can be interpreted from a coevolutionary perspective in a way that can unmask of the many interacting layers of VS that influence the practice, potential, and challenges of K-12 virtual schools and services locally and globally. This sets the stage for a more nuanced and accurate view of K-12 VS in the future, including mapping further growth and challenges.

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Open Education Resources, Massive Open Online Courses, and Online Platforms for Distance and Flexible Learning

50

Jon Dron and Gerald Ardito

Contents

Abstract

Our educational systems as we know them today evolved in a physical context defined by scarcity. The constraints of the physical realities of schools of various types – agora, one-room schoolhouses, and more modern schools of all types – and the need for all students and teachers to gather in one place at one time set limits on the availability of teaching, space, time, and resources. The advent of ubiquitous networked devices that cheaply connect us with one another, and with the reified interactions and the content we create, has greatly diminished such

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constraints, as have new pedagogies more suited to these open and connected learning environments. We are only beginning to adapt our educational systems to fit this new, less rivalrous, less bounded, more open reality. This chapter describes some of the main features of this more open universe, explores the different kinds of openness that are enabled, and describes some of their consequences for primary and secondary educators and learners.

Keywords
Openness · Online Learning · Connectivism · OER · Control

Introduction

Our educational systems as we know them today evolved in a physical context defined by scarcity. The constraints of the physical realities of schools of various types – agora, one-room schoolhouses, and more modern schools of all types – and the need for all students and teachers to gather in one place at one time set limits on the availability of teaching, space, time, and resources. The advent of ubiquitous networked devices that cheaply connect us with one another, and with the reified interactions and the content we create, has greatly diminished such constraints, as have new pedagogies more suited to these open and connected learning environments. We are only beginning to adapt our educational systems to fit this new, less rivalrous, less bounded, more open reality. This chapter describes some of the main features of this more open universe, explores the different kinds of openness that are enabled, and describes some of their consequences for primary and secondary educators and learners.

Openness and Constraint

Openness is, fundamentally, about freedom from constraint. Constraints – of space, time, economics, legislation, path dependency, capability, and so on – conspire to reduce choice, creating limits on what we can and cannot do: they close avenues and doors that we might otherwise step through. This is not necessarily a bad thing. As Stravinsky put it, "The more constraints one imposes, the more one frees one's self" (quoted in Simpson 1988). We need structure, and we need something to kick against, if we are to do or create anything. As Boden (1995) explains, "constraints, far from being opposed to creativity, make creativity possible. To throw away all constraints would be to destroy the capacity for creative thinking. Random processes alone can produce only first-time curiosities, not radical surprises" (p. 123). Limitless choice is almost as bad as no choice at all, reducing our ability to control our lives. As Schwartz (2004) puts it, "Having the opportunity to choose is no blessing if we feel we do not have the wherewithal to choose wisely" (p. 104). For all that, having no choice at all, when we wish to choose, is unequivocally a bad thing. When something is closed, it prevents us from being able to choose. When something is open, it presents an avenue of opportunity, but doors and windows only have any value when they are surrounded by walls. This relationship between constraint and freedom is also relevant in traditional closed educational settings and pedagogies as well in more open contexts (Drexler 2010; Dron 2007).

The focus of this chapter is on systems and structures of all types that, when assembled, result in and from an increase in openness: open online tools, systems, and content, open educational resources, open pedagogies, open-source software, and open learning experiences. By this, we imply that they exist in a context of closed systems and structures and, importantly, that they represent a continuum and a spectrum of openness. These have been infrequently discussed in primary and secondary educational contexts. Part of our focus here will be to discuss the practices of open education in all of its forms in higher education, then to use that work to explore openness in primary and secondary settings.

Openness and Educational Contexts

There are many shades of meaning of the word “open” as it is applied in an educational context. Until the late twentieth century, discussion of “open education” was largely limited to higher education and was focused primarily on enabling open *access*. This was in contrast to the typical (and still common) competitive admission requirements of much of higher education that deliberately excludes those with insufficient qualifications. For most primary and secondary schools, in most nations, some level of ubiquitous access was achieved many decades or centuries previously. Indeed, in most countries, children are required to go through at least primary schooling. However, there is a world of difference between *allowing* anyone to have access to education and *mandating* that they must. The very thing that open universities fought to achieve for adults – access to education – is not a right but an obligation for children in many countries, and, for most people, the opportunities to diverge from the defaults provided are limited. In many countries, legislation and/or economic constraints limit the capacity of people to choose, for themselves or their children, the form, content, location, timing, pacing, or outcomes of education. Parents may be able to pick between schools, or even to homeschool their children, but schooling (of a defined character) is not optional. Thus, openness in primary and secondary schooling is to some extent the opposite of openness in higher education: *it is concerned with means to escape or bypass mandatory schooling and/or the constraints it imposes, rather than to gain access to it*. To some extent this difference is unsurprising: for many years, “open” education was closely bound to the concept of “independent learning,” so, as children are often described as “dependent” and assumed to lack the maturity to manage their own learning, allowing them autonomy is not an option. But there is much more to openness than just access.

Generations of Distance Learning Pedagogies

The first open universities, schools, and colleges to bear the name sought to reduce other barriers apart from access, mainly through correspondence or broadcast models of distance teaching, which allowed learners freedoms in time, place, and, to some extent, pace of learning. There were sporadic innovative approaches to reaching geographically dispersed school children by two-way radio, such as through the Australian School of the Air (Connor 1970), albeit that these were more often used as a supplement to traditional classroom teaching than as fully distance technologies. However, whether through correspondence or broadcast technologies, up until the final decades of the twentieth century, distance education focused heavily on content delivery and skills acquisition, not by choice but by necessity. Limited opportunities for dialogue meant that the first generation of distance education pedagogies inevitably employed largely behaviorist/cognitivist approach to teaching, with an instructivist ethos and a focus on individuals as independent learners able to follow guidance by themselves (Anderson and Dron 2011). These courses were highly scalable, often enrolling hundreds or even thousands of simultaneous learners, all of whom independently worked their way through study packs of materials, rarely if ever meeting another student or their tutor. Such courses were typically developed by teams, with specialties in a variety of areas such as subject matter, instructional design, editing, and video production. Though this scalability was seen as a strength by many (Peters 1994), such pedagogies lent themselves best to an indoctrination model, in which the wise imparted knowledge to the less wise. In this chapter, we are using the term pedagogies in the broadest sense to refer to the wide range of practices, strategies, and interactions employed in learning settings. They were objective-driven and, of necessity, teacher-controlled. In pedagogical terms, they were anything but open, limiting learner choice considerably, notwithstanding the fact that how these content producers believed that what they were teaching was seldom if ever exactly how learners were learning (Haughey and Muirhead 2005).

As richly functional and widely available Internet technologies emerged, two-way communication became cheap, effective, and reliable. This opened up opportunities for a second generation of distance education pedagogies, anchored in the social constructivist tradition that was already well-developed in traditional teaching and educational settings, following thinking from the likes of Vygotsky (1978) and Dewey (1897), taking advantage of the freedoms offered by online tools (Jonassen 1994). Typically, such courses relied upon discussion forums of one form or another, from early bulletin boards (Mason 1994) to later quite ubiquitous uses of learning management systems, through both synchronous and asynchronous communication tools. While such courses might sometimes make use of open (freely available and modifiable) content and, at least in open universities, were typically open in terms of access, their small-group-oriented pedagogies scaled very poorly, and they were limited to relatively small cohorts of synchronously taught students (Annand 1999). The need to synchronize the activities of a group of learners reduced the openness of pace enjoyed by their first-generation counterparts and tended to greatly increase the cost of delivery compared with their instructivist forebears, which therefore continued (and continue) to thrive. Indeed, the first-generation instructivist model of distance teaching remains perhaps the most common form of distance education, including in most recent MOOCs (massive open online courses).

In recent years, as both openly available content and openly shared networks and communities became widespread and ubiquitous, a third generation of distance education pedagogy has emerged, which Anderson and Dron (2011) describe as the connectivist generation. This centers around a set of theoretical models, exemplified in the eponymous connectivism itself (Siemens 2005), that attempt to explain and predict knowledge creation in the world of plenty enabled by the Internet. Connectivist-generation theories:

- Incorporate concepts of distributed cognition (Pea 1993; Clark 2008), in which knowledge is distributed across a network of human and nonhuman actors.
- Make use of complexity theory, in which patterns and structures in both minds and social engagements are emergent more than designed (Doll 2008; Doolittle 2000; Hase and Kenyon 2007).
- Assume ubiquitous access to a vast network of people and resources, meaning that traversal of that network and sensemaking in a context of plenty are both critical tools and central objects of learning.
- Stipulate that sharing of knowledge within a network is a sine qua non of learning. Everyone teaches everyone.

Connectivist models are scalable, social, and inherently open, but they fit uneasily within a context of formal education: with a focus on networked individuals and emergence, rather than planned curricula, they are difficult to adapt to an educational machine that is grounded in measurable, uniform outcomes. Since these characteristics essentially define primary and secondary educational settings, these connectivist models have rarely been applied in their study and practice. The advent of connectivist approaches has thus done little or nothing to diminish the ubiquity and value of first- and second-generation models, which remain as popular as ever. This is a theme we will also see in the development – or lack therefore – of open education in primary and secondary settings.

Kinds of Openness

The word "open" is meaningless unless seen as one end of a continuum with "closed." Fundamentally, openness is about freedom. Early distance universities provided freedom for learners to engage in forms of learning that were otherwise closed to them. These freedoms extend not only to access but to the ways that learning happens once access has been granted. Morten Paulsen has classified six cooperative freedoms that might be provided in an online distance context: time, place, pace, medium, access, and content (Paulsen 1993). Paulsen's model was designed for a specific formal learning context and was developed when Web and mobile technologies were still in their infancy. Using Paulsen's cooperative freedoms as a basis, Dron and Anderson (2014) have built on his model to extend it to cover social learning in contexts beyond the classroom and to cater for the affordances of modern tools and systems. Dron and Anderson reject "access" as a freedom, seeing it more as a precondition for learning than a controllable aspect of it. Their ten freedoms are:

1. Content – what is learned
2. Place – where it is learned
3. Disclosure – what is revealed of ourselves to others and to whom
4. Delegation – the extent to which we delegate control of our learning trajectory to others
5. Time – when it is learned
6. Medium – the format (e.g., text, video, animation, audio, etc.)
7. Technology – the physical and virtual tools we use
8. Relationship – whether and how we relate to others
9. Method – the pedagogies and other processes used to support learning
10. Pace – the rate at which learning happens

This formulation of cooperative freedoms coupled with the more modern pedagogies such as connectivism begins to point to models of educational settings of all types with increased levels of freedom. Access to high-quality materials – open content – for this type of learning is also essential.

Open Content

Libraries, museums, galleries, and broadcast media (from open lectures through to television) historically gave some measure of open access to rivalrous content, allowing knowledge to be shared at relatively low cost to knowledge seekers. It was, though, not until the growth of the Internet and, especially, the World Wide Web that non-rivalrous learning content became viable at a large scale. Indeed, in the early days of the Internet, especially following the invention of the World Wide Web, open access was the default. However, the growth of learning management systems and digital rights management in the mid-late 1990s decimated the availability and usefulness of the open educational content and systems that had flourished in the early days of the web. In reaction to this, MIT's OpenCourseWare and related initiatives emerged in the early 2000s to become a significant movement, with participating institutions freely sharing content such as lecture notes, assignments, lesson plans, and even textbooks. This movement continues to grow, through initiatives like the OERs (a not-for-profit network of institutions offering free online courses) and Lumen Learning.

There are, however, many different ways to understand openness of content in this context. David Wiley (Wiley et al. 2014, p. 783) has defined the five potential freedoms of OERs, including the rights to:

1. Retain – the right to make, own, and control copies of the content (e.g., download, duplicate, store, and manage)
2. Reuse – the right to use the content in a wide range of ways (e.g., in a class, in a study group, on a website, in a video)
3. Revise – the right to adapt, adjust, modify, or alter the content itself (e.g., translate the content into another language)

4. Remix – the right to combine the original or revised content with other material to create something new (e.g., incorporate the content into a mash-up)
5. Redistribute – the right to share copies of the original content, your revisions, or your remixes with others (e.g., give a copy of the content to a friend)

These rights are reflected in a set of widely used open copyright licenses for content, developed in the early 2000s, Creative Commons (CC). CC took inspiration from earlier open software licenses such as GPL (General Public Licence), Apache, and Berkeley (which involve complexities not found in most content, such as patent law, source code requirements, and functional roles in machinery), applying the general principles that they embody to a broad range of cultural works. CC licenses range from completely open (CC0) that explicitly mirrors the total abnegation of rights provided by public domain resources, to uses that allow all the five Rs but that add constraints such as the requirement to attribute the original source (CC-BY), or to release derivative works under the same license (CC-SA), to almost completely closed variants that are not far removed from the traditional closed "all rights reserved" licenses of commercial copyrighted materials (e.g., CC-BY-ND-NC, which allows no commercial use and no revisions or remixes). These types of open materials have made their way into primary and secondary educational settings. This has been more constrained in places where instruction and curriculum development has been seen as more of a closed system due to national, regional, and local standards and norms, which are intensely prevalent.

The spectrum of openness of content and process in any given context can be rich and complex. For example, one of the mostly widely used resources in primary and secondary schooling, the Khan Academy, makes much of its content (videos and tutorials) available freely but does not allow commercial use, demands attribution, and that all derivatives apply the same license. However, this is not true of everything on the site. The Khan Academy strongly defends its rights over not just the rest of its own content but also to any comments, help, or tutorials given by visitors to the site. Moreover, to gain more than skin-deep access to the site itself, it is necessary to give up some privacy, whether through sharing via social media or signing up to the site itself.

Reuse, revision, remixing, and redistribution are typically of greatest value to those that provide an educational service (teachers) rather than those that use the service (learners). Learners are, of course, the ultimate beneficiaries, both in terms of receiving higher-quality tuition and in avoiding the costs of textbooks and other resources, but the audience for many OERs is teachers or learning designers that orchestrate the learning transactions. Open content is concerned with learning resources, rather than learning processes. This has been criticized for its reinforcement of an institutional model that is, in many ways, closed. As Fiedler (2014) puts it, "OER initiatives tend to remain within the boundaries of the established activity systems of 'schooling' that are formed around the seemingly incontrovertible claim that all serious learning activity has to be closely-coupled to a corresponding teaching activity (executed by either a human actor or technical system) and its instrumentation" (p. 2). This focus is, at least on the face of it, somewhat at odds with the openness of connectivist-generation pedagogies.

OERs do, though, have great value in such contexts, not just in reducing costs for all concerned but in enabling the evolution of better resources, spreading good practice, and increasing the range of content available to learners. Thanks to the low costs and widespread availability of OERs, students as well as teachers may have greater freedom in choosing appropriate methods of learning. Perhaps most significantly, the content of first-generation instructivist distance education courses, that in the past cost around $100,000 to develop, can now be shared, remixed, customized, and reused for a fraction of the price. This has led, since the early 2010s, to the obvious next step – the MOOC.

These online asynchronous connectivist educational settings have become more and more common for adult learning of various types, but have not yet demonstrated much presence in primary and secondary settings, and so will not be further discussed at this point. It is worth noting that the second author has done some work to introduce these concepts into a secondary setting and that this work holds promise for wider adoption. This work is discussed in more detail below.

Open Pedagogies

The technological origins of most formal educational systems in the world today lie mainly in a need to efficiently spread doctrinal knowledge, be it of a religious, professional, political, or military nature, within a technology- and resource-constrained context. Educational systems were a response to the fact that there was a body of knowledge held by a few that needed to be passed on to many: they were a solution to scarcity. Prior to the advent of printing and later technologies of mass distribution, the most effective means of passing on such knowledge was for an individual to stand in front of a crowd of people and to lecture and/or demonstrate. Often this involved reading from a (scarce and expensive) book. Indeed, a "lecturer," a term still widely in use today, is, literally, one who reads. For this to be effective, learners had to gather with the lecturer in one place at one time: timetables and gathering places were needed. There would be no sense in delivering lectures when everyone was away or on holiday, so there would be periods when no lectures were given, and "terms" over which they ran. For convenience and comfort, it made sense for buildings to be constructed to house these people – classrooms, schools, etc. Rules, both explicit and implicit, were needed to maintain order in classrooms and to ensure people attended. From that emerged a wide range of further constraints that limited the range of possible pedagogies that could be used. Dron (2016) refers to these physical contingencies in learning environments as p-learning. He uses the term to refer both to the physical components, like classrooms and textbooks, but also to the associated pedagogical methods, organization procedures, and rules that form conventional, non-digital educational technologies.

This model of p-learning is still the one most prevalent in the vast majority of primary and secondary educational settings.

As with almost all technologies of any significance, with pragmatic solutions to the constraints of physical and temporal boundaries came side effects. One of these was a loss of learner control. Structurally, disempowerment of students was made highly probable through a combination of factors such as:

- The power structures that naturally evolve when one person needs to maintain order among many
- The architectural features that reinforce that authority
- The constraints of having to manage the time of many people and teach them largely the same things at the same time
- The simple fact that a teacher has to fill the time with some kind of directed activity and thus is in control, even when they choose to delegate that control to students
- The rules and norms of behavior needed for classrooms to work effectively
- The demands of assessment

When everyone is taught the same thing in the same way at the same time, there will always be some who find it too boring and others that find it too confusing. Additionally, there will be some who learn faster or slower than others. Forcing everyone to learn the same things in the same way and on the same schedule is guaranteed to lead to at least some unwilling or unmotivated learners. With luck and a good deal of teaching skill, perhaps a good number of students will be challenged and curious about the subject matter, but the chances of all individuals in a class having their curiosity, need to attain competence, and need for challenge fulfilled at any one time are slim. The necessary combination of teachers being in control and the need to overcome boredom and confusion – along with a process model that, for organizational convenience, makes every course some multiple of a particular length, largely determined by mediaeval holiday patterns, fitting into timetables designed for efficient resource allocation rather than learning, with classrooms designed for lectures, split into disciplinary areas that exclude one another – has formed the context and the environment in which the bulk of pedagogical theory and practice has developed.

This model is the one most commonly employed in primary and secondary settings, although the set of justifications differ slightly. In those settings, authorities and the common wisdom have insisted that a lack of freedom and openness is necessitated by developmental and conceptual immaturity of young people. For a variety of reasons, this mind-set has not been much changed by powerful work with young people described by Dewey, Papert, Resnick, and others. This will be discussed further below.

Effects of p-Learning on Motivation

Intrinsic motivation cannot arise without support for autonomy, competence, and relatedness (Deci et al. 1999; Frey and Jegen 2000; Hartnett et al. 2011; Reeve et al. 2008; Deci and Ryan 2008). Although educational institutions typically provide good support for social relatedness, it is seldom close enough to compensate for failings in autonomy and competence support. Because the educational system impedes (if not saps) intrinsic motivation by default, one typical response of schools and teachers is consequently to apply extrinsic motivation, primarily in the form of rewards and punishments, as well as in enforced rules of behavior and conduct. Grades are a particularly ubiquitous form of extrinsic motivation and are particularly harmful because they invariably encourage a strong focus on the goal of passing the tests, rather than on love of learning for its own sake. The power relationships that are entailed also teach some bad meta-lessons, such as that it is OK for one person to deliberately manipulate and coerce another to do their bidding. However, if the ends were worthwhile, it might be justifiable. Unfortunately, extrinsic motivation, at least in its externally regulated reward/punishment form, kills intrinsic motivation (Lee et al. 2016; Legault 2016). Formerly intrinsically motivated learners who are offered rewards or punishments not only lose their initial intrinsic motivation, but the effects persist when the rewards or punishments are taken away. In effect, rewards and punishments replace intrinsic motivation, for a long time after they are applied and, often, permanently. When extrinsic motivation is taken away, there is nothing left or, worse, an actual antipathy to the subject. Schools and universities are thus structurally inclined to kill the love of learning in their students.

Online and Open Education in Primary and Secondary Settings

Over the past few years, primary and secondary schools started to embrace online learning. This adoption of some aspects of online education has two forms. The first is in the form of platforms that provide online supplements to the traditional face-to-face experiences, such as Edmodo or Moodle or Google Classroom. The second is in the more expansive form of virtual middle and high schools. While it is certainly possible that teachers and schools using these platforms may also be making use of open education resources, the platforms themselves are typically proprietary – and controlled by publishers like Pearson – and have frequently raised concerns about student data privacy. At the same time, these platforms even when they appear to have social networking build in (like Edmodo) tend to reinforce an instructivist model, with the same types of limits to student freedoms and openness. This is unsurprising, because their underlying p-learning patterns are not just inherited from their physics-bound forebears but must integrate and interoperate with them.

There are some pedagogies commonly used in primary and secondary settings that work to maximize the students' cooperative freedoms and classroom openness. In project-based learning, students typically work in groups to apply and deepen what they are learning by engaging with a project. When well designed, these types of projects have been demonstrated to enhance student learning and self-regulatory skills, such as collaboration (Ardito et al. 2014; Egberink et al. 2015; Liu et al. 2009). Problem-based learning, another student inquiry-focused pedagogy, has students work toward mastery of various contents and skills by working individually or collaboratively to solve authentic problems. When the problems are authentic and seem to have no obvious or singular solution, students exhibit deep engagement and learning (de Jesus et al. 2005; Savery and Duffy 1995). While these and other inquiry learning-based pedagogies promote student choice and pedagogical openness, they have met with some resistance in the face of educational reform efforts favoring standardized curricula and testing.

There are, however, some models of student-centered and technology-enhanced learning environments in primary and secondary settings that support student freedoms and the employment of newer open pedagogies. Some of these models stretch back over three decades.

As discussed above, new pedagogies like connectivism have been developed to support student-centered, technology-enhanced learning in settings such as connectivist massive open online courses (cMOOCs). Per Siemens (2012), cMOOCs are distinguished by four characteristics: autonomy of the learner; diversity of tools, learners, and knowledge; interactivity; and openness of access, content, and assessments. While they occur more sparsely at the primary and secondary levels, there have been some notable examples of learning environments which have been very open in all the ways we have been discussing. Perhaps not unsurprisingly, these have featured extensive use of technology.

Seymour Papert, a mathematician and former colleague of Jean Piaget, came to believe that in contrast to Piaget, all thinking was ultimately concrete (Papert and Harel 1991). From this insight came a learning theory, constructionism, which posited that learning takes place through the process of building things. Then Papert started playing with the earliest personal computers and came to understand that a computer could be the ultimate learning machine since it could be programmed to be anything that the child is interested in exploring (Papert 1993). This flexibility would allow the child to learn in response to his/her intrinsic interests. From this work came LOGO, a software that allowed children to learn computer programming through controlling a turtle affectionately known as Seymour.

Papert organized and designed some of the earliest learning settings that make extensive use of computers. He designed software – LOGO – which boldly sought to teach the formerly esoteric and rarefied skills of computer programming to young people, even those in primary grades, to positive effect (Clements 1985). For several years, both the tools – like LOGO – and the pedagogies, like constructionism, gained some footing in primary and secondary educational settings. Their focus on student creativity and multiple means of expression and representation achieved powerful results in a variety of settings – in primitive online settings featuring collaborative construction (Evard 1996), children building robots (Martin 1994), and with adjudicated youth (Cavallo et al. 2004). Many of these ideas and programs came to fruition in the One Laptop Per Child (OLPC) project, which developed both an open learning device, the XO laptop, and an open software platform (Sugar), both of which could be modified by users (Urrea and Bender 2012). Despite being powerful open primary and secondary educational experiences, this type of student-centered, open-ended learning was soon overcome by the fallout of *A Nation at Risk* in the United States and other reports suggesting that more control was needed of curricula and assessment if students were to truly learn (Gardner 1983).

Currently, backlash from these types of stringent, instructivist educational reforms is showing some promise in terms of providing opportunities for educators to experiment with learning environments that are designed with real openness in mind. More and more primary and secondary classrooms are supporting a 1:1 laptop model and/or Bring Your Own Devices (BYOD) programs. Rather than powerful tools like cell phones and tablets being excluded from the classroom, they are being actively embraced by more teachers and schools. This allows students to access the Web and its wide selection of open educational resources like Wikipedia, YouTube, Khan Academy, and TED Talks in formally sanctioned ways.

Some recent work in a secondary educational setting has demonstrated a potential new model for open education through the use of the same tools that have empowered open learning in higher education settings, such as cMOOCs. The second author is a former secondary science teacher (and current teacher educator). Following up earlier work on the use of technology tools to foster, support, and promote student ownership and motivation (Clayton and Ardito 2009), he completely redesigned his biology class as a set of fully self-directed units in order to maximize student autonomy, relatedness, and competence. In this redesign, students were free to navigate through the units of the course in whatever order they wished, working with others or not as they chose. This learning environment was supported by some technological tools to allow ease and freedom of access. Moodle was employed as a learning management system, and Edmodo (a social network designed for school settings) was used as a communication tool. The students, as evidenced by the development of powerful self-regulatory behaviors, their academic achievement, and their own self-reports, thrived in this unique learning environment. Student work demonstrated more creativity and depth than in the more teacher-centered iteration of the course. The needs of individual students were better met. Students with learning challenges reported feeling for the first time in their school lives not being “yanked along” to catch up, while higher-achieving students described “feel free to go as fast as they wanted.” Both groups of students had been freed from the arbitrary constraint of teacher-imposed pacing (Ardito 2015).

Other types of open educational settings are being piloted, particularly in technology-rich areas as STEM (science, technology, engineering, and mathematics) and makerspaces (Martinez and Stager 2014) and efforts to bring computing programming into schools (Resnick et al. 2009), but much more work is needed to alter the expectations and norms of school administrators, teachers, parents, and students. As discussed above, education is a complex system, and its design must be altered for lasting change in the area of openness, particularly in primary and secondary settings.

An initiative that has probably had greater publicity than most is Sugata Mitra’s Hole in the Wall project (Mitra 2012). Recognizing the cost of effective teaching in India, Mitra hypothesized that children, given a network-connected computer, would be able to teach themselves. He reported that children apparently learned together how to use machines and attained learning not too far removed from that of children educated in schools. Though lacking theoretical foundation, his methods were to a large extent a physical manifestation of connectivist thinking. The children were not teacherless – they had millions of teachers and, especially in their physical social groups, taught one another exactly as connectivism recommends, determining their own goals, forming physical social networks, and inventing open pedagogies. Unfortunately, Mitra's excitement was a little premature, and the holes in the wall are now exactly that, victims of vandalism and neglect. Without focus, without role models, without protection from bullies and overdominant children, and above all without the enthusiastic observation of excited researchers, the system proved not to be self-sustaining. Mitra himself has moved on to run the SOLE (Self-Organized Learning Environment) project, which has led to mentors and guides in traditional schools, along with far more restricted access to machines, rather than the self-organization he originally sought, but that retains a similar learner-driven focus. As with our other examples, a hybrid of a high level of openness combined with a little structure enables open pedagogies to be used in otherwise traditional environments.

Barriers to Adoption

One of the most surprising barriers to adoption of open educational resources is resistance from teachers, with widespread perceptions that, despite all evidence to the contrary, OERs are of lower quality than closed content. It is certainly true that many OERs do not go through the same kinds of quality control processes of published content, nor are there many organizations dedicated to collecting and curating them. Good-quality resources can therefore be hard to find in a swamp of lower-quality materials. It is easy to see how teachers' perceptions might be colored by this. Among the services publishers provide are that they market their goods well and do all that they can to provide teachers with relevant, targeted resources that have been through editorial processes. There is a need for a greater number of similar services for OERs, but, also, there is a need for a shift in culture. When teachers understand the value of being able to modify, remix, and adapt content and when that becomes a norm, OERs can offer a vastly improved experience for learners. When teachers share the improvements they have made with other teachers, the resulting OERs evolve to be ever-higher quality. This virtuous circle needs to be kick-started with intentional initiatives, at government and institutional levels. However, a much bigger barrier remains.

Mitra's Hole in the Wall project and the OLPC initiative highlight one of the biggest barriers to openness of all: open, online learning is only possible at all with networked devices and access to services they provide. Online access is virtually ubiquitous in only a very few regions, and there are still billions of those that would most benefit from open education who have little or no access at all. While growth of Internet access continues unabated, with around half of the world's population online (http://www.internetworldstats.com/stats.htm accessed 10th February, 2017), and prices of connections and devices fall daily, the digital divide remains a huge and pressing concern. Most benefits of open, online learning can only be achieved if everyone has access to their own device, which is anything but the case in even advanced economies like the United States, Canada, or Europe. It is frustrating that many initiatives that might reduce that divide are cynical, commercially driven ventures. For example, Facebook's internet.org project – an attempt to bring wider access through free data services in developing countries – has been extensively and rightly criticized for being a closed service that primarily benefits Facebook, denies access to many open resources, and is aimed at locking in future customers. E-book readers might potentially offer access to vast libraries of millions of free books, papers, courses, and other content, paying for themselves in hardly any time at all, but are deliberately locked in and crippled by digital rights management and ever more publisher-friendly copyright laws.

Conclusion

Online learning (e-learning) has far fuzzier and less fixed boundaries than collocated learning (p-learning), even in its most classroom-like forms such as webinars. For most variations, including almost all MOOCs and all open educational resources, learners control the time, the place, and the pace (at least to some extent) of their learning. Even in synchronous online classes, learners always inhabit more than one space, each with its own distractions. Other online environments and communities are at most a click of a mouse away and may inhabit the screen simultaneously, and the distractions of the physical environment are ever-present. In truly open educational settings, learners may choose how they dress, how they behave, and how they react, without fear of censure. They may chat with others and, indeed, are often encouraged to do so. Cell phones are hardly ever banned in online classrooms. Content is more fluid, whether intentionally hyperlinked or not: features such as right-clicks for word definitions, copy and pasting to search Wikipedia or Google, and searchable (though not always easily browsable) content are the norm. The learner has, inherently, more agency than their p-learning counterparts. Given such advantages, it is not surprising that e-learning is a phenomenally successful form of intentional learning. From Wikipedia to Google Search to MOOCs to the Khan Academy to Lynda, not to mention vast amounts of learning shared on social networks, YouTube, SlideShare, Stack Exchange, Slashdot, and countless other social sites, e-learning is the dominant starting point and often the central motif for intentional learning among Internet-connected people on this planet. The affordances and shifted boundaries of e-learning are what gave rise to the theory of connectivism. It is precisely this combination of a surfeit of people and resources, easy connection, open availability, controllable engagement, distributed cognition, and fluid boundaries that the theory attempts to address, making it one of the first net-native pedagogical theories.

For all its strengths, e-learning (as already noted, especially in a connectivist tradition) does not fit well with patterns of teaching and learning designs that are made to work in a physical setting. In particular, extrinsic motivation loses much of its power when there is limited perceived social pressure, no requirement of attendance, no surrounding social safety net, and a limited sense of being part of a crowd. Simply transferring open pedagogies into a traditional educational setting is unlikely to be universally welcomed and unlikely to fit neatly into a system that has evolved for over a 1000 years to prevent such anarchy. There are existing primary and secondary schooling models that would make more fertile ground, such as those found in schools based on the Summerhill model (Neill and Lamb 1995) or perhaps in Montessori or Steiner (Waldorf) schools. Such methods also have a significant growing role in homeschooling, where the benefits of a learning network beyond the home are particularly strong and the value of accessible, open educational resources and communities is unusually high. Movements such as unschooling, edupunk, and hacking education (Stephens 2013) are making waves of increasing importance, built on open access, open content, and open pedagogies, combined with open networks of learners and teachers that share a passion for learning and a willingness to break out of the closed cloisters of academic institutions.

There are some rich history and some current efforts to bring this type of open education (and its many benefits) into primary and secondary settings. Much of this work is promising, and it remains to be seen whether it can help change the norms and expectations of administrators, teachers, parents, and students. This work also suggests that new models and opportunities for learning and education can be explored within these types of open settings. We certainly hope that they can and will be used to that effect.

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Online Learning Communities in K-12 Settings

51

Seng Chee Tan and Alwyn Vwen Yen Lee

Contents

Abstract

This review is a major update of the chapter on online learning communities in K-12 settings in the first edition of this handbook. This chapter clarifies the concept and boundary of online learning communities, identifies major trends

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of research, and suggests pertinent issues for future research. Four established online learning communities, which have sustained for more than a decade and are supported by research, are reviewed on their changes and evolutions over the last decade. They include Knowledge Building Communities, Quest Atlantis, Virtual Math Team, and Web-Based Inquiry Science Environment. The success of the intended design principles and characteristics of these learning environments are evaluated along the cognitive, social, and technological dimensions. Two emergent online learning community platforms, Canvas K-12 and Brightspace, are also reviewed. These platforms make use of emerging technologies such as social and interactive networking, which are new trends that online learning communities are gravitating toward. Potential issues surrounding K-12 online learning communities are discussed. These issues include infrastructure, culture and practices of school teaching and learning, development and assessment process of authentic knowledge, usage and ethics of learning analytics, and possibilities and impact on education due to advances in technologies.

Keywords

Online learning communities · K-12 · Cognitive dimension · Social dimension · Technological dimension

Introduction

The pervasiveness of technological innovation and usage in this digital age has provided affordances for online learning communities to take on multiple structures and forms. The turn of the century has also seen previously emerging technologies becoming mature and stable, and these technologies are gradually integrated into larger and scaled-up learning systems. Historically, online learning communities started with the introduction of the World Wide Web (WWW) by Tim Berners-Lee in 1989, which provided an information space for hosting resources that are accessible through the Internet. Consequently, communicative and physical barriers between communities are constantly being broken down, and the way in which people connect is changing dramatically. Networking technologies have also brought communities, especially online communities closer together, and it has significant impact on K-12 students' learning. It is a timely development for twenty-first-century learning where students are required to develop knowledge-creation competency and integrate knowledge innovation with digital literacy, which are critical skills for individual's growth and contribution to new economies (Anderson 2008). There is a need to look at the presence of cultural will to "live for work" (Cooke 2002, p. 1), which entails capabilities of learning and innovation as key economic instruments that are at the heart of the *knowledge society.*

With the advancement of technology, K-12 learning communities are continuously embedding different forms of technologies and tools within the learning environment to nurture desirable attributes within students. Online learning communities have gradually shifted away from the mindset of using digital technologies and platforms just to transfer and distribute learning resources; teachers, with their modus operandi of teaching, have realized how the affordances of technologies can provide alternative methods of achieving learning objectives with greater efficiency and effectiveness. As an emerging field of study that has garnered more attention over the last decade, this review aims to highlight the changes and improvements to four established online learning communities and seeks to examine the emergence of newer online learning communities in the context of innovative technological advancements, changing perspectives, and cultural practices.

This review is organized around the following questions:

1. What technologies have been introduced over the last decade that could be used to establish and sustain online learning communities?
2. Are the established online learning communities – Knowledge Building Communities, Quest Atlantis, Virtual Math Team, and Web-Based Inquiry Science Environment – successful in their intended goals? Are there changes in their themes of research or have the direction of communal learning been modified?
3. What are the emerging online learning community platforms and how are they different from the four established communities?
4. What are the potential research and practical implementation issues that might surface and need to be explored?

Disruptive Technologies in the Past Decade

Educational technologies have advanced beyond the initial prototyping stages of development and matured into stable products, platforms, and media that provide students with endless opportunities for learning and sharing of knowledge (Dede 2004). Newer disruptive technologies have since been developed, after the introduction of the World Wide Web (WWW) in 1989 and the Internet in the mid-1990s. The semantic web was developed to allow common data formats to be shared and exchanged across the Internet, with the semantic web markup becoming a mainstay in millions of web domains (Guha 2013). Search engines (e.g., Google, Yahoo) are game changers that provide users with accessible and efficient methods in searching for information. While the first generation of websites, or Web 1.0 sites, are useful for providing access to data on the web throughout the community, they constrain most users to passive viewing of content. Web 2.0 websites, on the other hand, encourage interoperability and user-generated content, thus allow users to interact and collaborate with one another and create opportunities for easier formation of online communities.

Disruptive and influential technologies are subsequently built on top of the abovementioned elements. Internet-based encyclopedias such as Wikipedia, which was introduced in 2001, provide knowledge sources that culminate from users' contributors and moderation. Social media platforms such as Facebook (founded 2003) and Twitter (founded 2006) have also changed the landscape of how information can be propagated through the Internet and how information can be virally shared through social networks. These technologies provide mechanisms and means for inter-user interactions within and outside of users' communities, while the technology providers play the sole purpose of hosting user-generated information. Social technologies, in the form of blogs, wikis, and social networks, are breaking down traditional organizational walls and allowing the establishment of newer communities that encourage user's contribution of content. The method of presenting and archiving of knowledge has also been enhanced, as exemplified by the way media is presented and distributed through blogs (e.g., Blogger) that is archived in cloud storage. Together with massively scaled-up media distribution platforms such as YouTube (founded in 2005), cutting-edge technology is constantly pushing the envelope in which online learning is occurring in K-12 settings.

The communities that are forged online through social technologies are self-sufficient in generating, sharing, and building of knowledge within their communities, as the participants take on the agency to share and distribute knowledge that is of both individual and communal interests. However, new mindsets and epistemologies (Lim et al. 2010) are needed to leverage these social technologies for participatory learning rather than the acquisition of knowledge (Sfard 1998). Hence, time is required to overcome cultural resistance and early failures. The trend of facilitating social interactions among learners and encouraging learner's agency can also be felt in more traditional technological platforms. By making use of robust and mature technology in developing online platforms and creating new social networks, learning management systems (LMSs) have seen prevalent usage in schools and institutions. LMSs that were once used mainly for the management of learning have been enhanced to enable social collaborative learning.

Another novel online creation is the massive open online courses (MOOCs) that aim to provide open access to courses and content to online learners via the Internet. Stand-alone online courses provided through individual delivery platforms started gathering a critically large number of users, and the major service providers such as edX, Coursera, and Udacity began associating themselves with institutions to host MOOCs across the world and deliver content to large numbers of interested learners in their respective physical locations.

With the emergence of LMSs and MOOCs, it is not surprising that companies create products and learning platforms that appeal to the broad masses of learners by populating their platform with a wide range of topics that learners will be interested in. Also, the increasing prevalence of mobile learning technology means that learners could now learn at different locations and contexts, while learning designers focus on the learner and learning process (Sharples 2006). Learning on demand and consuming knowledge in bite-sized lessons could, therefore, shape the future of learning for students (Armstrong and Sadler-Smith 2008).

These technological advancements have ramifications for K-12 education through platforms that could potentially support deep learning among learners and afford efficient teaching and management on the teacher's part. For example, harnessing the power of learning analytics, teachers could track students' learning progress and class performance through indicators in LMS or MOOCs and decide on relevant actions, such as paying more attention to specific students who might require assistance or providing formative feedback promptly to rectify misconceptions. Also, students are able to follow their interests and choose to participate in the online communities that they are comfortable with.

Defining Online Learning Communities

Since inception, online learning communities have been labeled by researchers as Virtual Learning Communities (Henri and Pudelko 2003) or Cyberspace Classrooms (Palloff and Pratt 2001). Online learning communities are tangible entities that are used to express desired characteristics of learning communities, formed through the mutual shaping of the community and the identities of its members, as the community progresses toward shared learning goals (Khoo and Forret 2015). The concept of an online learning community can be explicated by examining each of the three terms: *community*, *learning*, and *online*.

As a *community*, an online learning community is a cohesive social entity where members are connected in mind (McMillan and Chavis 1986); this *sense of community* has four sociological dimensions, namely, membership, influence, integration and fulfillment of needs, and shared emotional connection. A community is and must be inclusive, requiring commitment and consensus among members (Peck 2010). Interaction among community members helps develop mutual influence and trust upon each other while fostering a sense of communal identity and belonging that helps define the boundaries and criteria for membership to the community. Being able to identify oneself within the community allows individuals to contribute to the community and, conversely, to be influenced by the community. Cultures and norms within the community provide the fulfillment of needs for individuals and simultaneously reward and reinforce their practices. A community is, therefore, both a system and a process where diverse human needs such as survival, socialization, and sense of identity can be fulfilled.

As a *learning* community, an online learning community is a Community of Learners (CoLs) that aims to instill and foster deep disciplinary understanding of both subject matter and ways in which the disciplinary community works with knowledge within a certain domain (Bielaczyc et al. 2013). Four characteristics of a learning community were identified (Bielaczyc and Collins 1999), namely, shared objective of advancing collective knowledge, diversity of expertise among members, emphasis on learning how to learn, and the mechanism for sharing what is learned. A learning community has a “culture of learning such that everyone is involved in a collective effort of understanding” (Bielaczyc and Collins 1999, p. 271). The common goal of learning entails sharing “a set of knowing, a set of practices, and the shared value of the knowledge that these procedures generate” (Riel and Fulton 2001, p. 519). The participating members of the community are valued for the knowledge they possess as an individual with their desire to learn within the community to achieve the common goal of learning. By collectively working together to engage in inquiries or conduct investigations, both learners and the community as a whole develop social capabilities in learning how to learn, and knowledge can be constructed through involvement in the community’s shared values, beliefs, languages, and ways of doing things. In short, members in a CoL are “socialized into the world of knowledge” (Bereiter 2002, p. 220). For CoL to be successful, community members have to be organized around a structural dependence principle. “Frequently, the students do not have a clear picture of where and how they fit into the school experience” (McCaleb 2013, p. 49), which often results in school failure and dropouts. In forming the CoL within K-12 settings, “the community should be organized such that students are dependent on other students’ contributions in some way. It is important to have a valid reason for students to work together that makes sense to the students, such as common task that requires joint effort” (Bielaczyc and Collins 1999, p. 288).

Within an *online learning community*, technologies are used to support the service of learning, with the distinct characteristic of embedded pedagogical support in the software. Examples of such technologies include Knowledge Forum (Scardamalia and Bereiter 2003), Collaborative and Multimedia Interactive Learning Environment (CaMILE), Scaffolded Multi-user Integrated Learning Environment (SMILE) (Guzdial et al. 1997), and Future Learning Environments 3 or FLE3 (Muukkonen et al. 1999). These are called computer-supported collaborative learning (CSCL) technologies. With the affordances generated by cutting-edge networking technology integrated with educational practices and pedagogies, platforms that were previously only used for hosting and informational viewing have been transformed into user-friendly and interactive interfaces. Users can draw on and contribute diverse opinions and views, as part of the process of forming an inclusive and interactive online learning community. Accessibility to online courses has been enhanced due to newer technologies that support massive open online courses (MOOCs) in tertiary institutions and universities (e.g., Khoo and Forret 2015), which are also increasingly being offered to K-12 schools and classrooms (e.g., Manlove et al. 2006). Novel technologies are also developed in conjunction with the integration of modern hardware and software, such as the Zydeco application, a context-aware platform, that allows mobile devices to integrate and share multimedia resources for students and their peers to review. Zydeco can be used for supporting knowledge claims (Cober et al. 2015) or supporting student inquiry during collaboration (Kuhn et al. 2010).

Review of Established Online Learning Communities in K-12 Settings

This section summarizes studies on four established online learning communities, namely, Knowledge Building Communities (KBC), Quest Atlantis (QA), Virtual Math Team (VMT), and Web-Based Inquiry Science Environment (WISE). These communities are chosen based on the following criteria: learning in K-12 settings, usage of the computer network as a mediation tool, and evidence of a design effort toward fostering a sense of community. Both formal and informal learning, as well as online and blended environments, are considered, but studies based on ad hoc groups displaying no evidence of effort toward fostering a sense of community are excluded. These online learning communities are evaluated with respect to their intended goals, research themes being pursued, the direction of communal learning, and circumstances that lead to changes.

Knowledge Building Community

A Knowledge Building Community (KBC) consists of learners with shared common goal in advancing knowledge of the group, and learning is intentional and collaborative. Pioneered by Scardamalia and Bereiter (2003), knowledge building involves "the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts" (p. 1370). In contrary to traditional teacher-led instruction, teachers in a knowledge building community play the role of cocreating knowledge together with students, instead of being the sole authoritarian source of information within the classroom. Over the years, KBC has grown, with the development of Knowledge Building International (KBI) (http://www.ikit.org/kbi) that is dedicated to research and practice of knowledge building and the launch of a multination design research project called Building Cultural Capacity for Innovation (BCCI) (http://www.ikit.org/bcci). The project is dedicated to the twenty-first-century principle of knowledge for public good and seeks to provide a place for everyone in the knowledge society. As part of the online learning community, knowledge building channels students' efforts toward solving authentic societal problems to serve the community.

1. *Cognitive dimension*. The central principle of knowledge building is idea-centric learning that starts with students putting their ideas in a shared space (e.g., discussion boards, online forums). Students' ideas become shared objects of inquiry to be discussed, revised, built upon, and superseded. Cognitively, students are engaged in knowledge building discourse aims at co-construction of knowledge backed by evidence, while taking collective responsibility in idea improvement. It entails deep learning and higher-order thinking such as metacognition. Recent developments have provided students with avenues for indicating their perspectives of opinions and highlighting portions of discourse that are deemed promising, so that more promising ideas can be further discussed and developed. Recent studies have reported success in improving student learning within K-12 settings (e.g., Zhang and Sun 2011).
2. *Social dimension*. KBC encourages users to use Knowledge Forum (http://www.knowledgeforum.com/) as a platform for learners' views and opinions to be shared and viewed by the community members so that learners' ideas can be built on and developed further. The increased online visibility invokes more interactions between learners, and the success of the KBC highly depends on the establishment of socio-cognitive norms and values that members of the community are aware of and strive to work toward. Within KBC, the renegotiation of institutional power (Tan and Tan 2006) is needed to foster greater student responsibilities for their learning. Recent studies have shown that students in KBCs have taken initiatives as leaders within their communities to lead the group

at different points in time of discourse (Ma et al. 2015). Rotating leadership seems to be an emergent phenomenon of knowledge building, with the potential to be an indicator of collective cognitive responsibility.

3. *Technological support and infrastructure*. The general interface of Knowledge Forum has been largely the same with the stable version of 4.8, but more recent updates (versions 5 and 6) have integrated newer analytical tools with a more vibrant look and feel that appeal to students. Templates with customizable scaffolds are provided to facilitate knowledge building discourse. The introduction of the *Promising Ideas* tool allows peers to highlight part of a discourse and append reasons that the highlighted ideas should be pursued further. These added features of the technological platform encourage idea improvement by allowing time-efficient reviewing of notes and encouraging users to efficiently synthesize and summarize ideas at a higher level of understanding. With a wide range of Web 2.0 tools and emphasis on learning analytics, researchers have also provided additional analytical tools to understand further forum discourse. Examples include the temporal analysis of discourse using social network analysis with KBDeX (Oshima et al. 2012) and the identification and analysis of ideas within discourse using keywords (Lee et al. 2016).

Atlantis Remixed (Rebranded from Quest Atlantis)

Atlantis Remixed (ARX) project (http://atlantisremixed.org/), previously known as Quest Atlantis, is now supported by Arizona State University. ARX is a three-dimensional multiuser virtual world that incorporates strategies of online gaming and narration, targeting learners aged 9–16. The design of ARX combines academic concepts and meaningful play with disciplinary practices to help students develop the triadic foundation of *education*, *entertainment*, and a set of *social commitments*. With the rebranding of QA to ARX, QA storyline has also changed. Participants, called *remixers*, are provided with the opportunity to direct their learning and to conduct meaningful work in a playful environment, through socialization efforts with other participants from around the world and through engagement in ideas using in-game structures. ARX's user base has expanded to over 100,000 children in 18 countries.

1. *Cognitive dimension*. ARX is designed based on a participatory framework that emphasizes action and reflection as central components of learning. Three elements are prominent within the game: *quests*, *missions*, and *units*. These elements help connect students to academic standards, social commitments, interrelated tasks of multiple learning opportunities, and are designed to provide authentic, engaging, and meaningful learning experiences. Students travel through worlds and villages in Atlantis to solve real-world, inquiry-based challenges; such experiential game-based learning encourages students' self-directed learning. Recent studies have shown a positive impact on students regarding gains in literacy, persuasive writing, and engagement (Arici and Barab 2013). Game tools and scaffolds are added in the revamped environment so that students

can act “a head above” with their current literacy capabilities, and teachers provide in-game formative feedback as the *editor*.

2. *Social dimension*. ARX maintains the goal of fostering social commitment and providing students with a safe and protected environment for learning. ARX remains committed to empowering individual students and communities to foster social commitment via seven principles, namely, personal agency, diversity affirmation, healthy communities, social responsibility, environmental awareness, creative expression, and compassionate wisdom (Barab et al. 2004). As an environment that hosts the online learning community, ARX has extended its support in classrooms by offering help to students on ways to navigate the virtual world and ways to interact with peers and teachers within the context of the learning through the game (Thome 2014).
3. *Technological support and infrastructure*. The virtual world of Atlantis in ARX can be accessed using a client web browser to display content and connects users via the Internet. A remote host server stores the resources and connects the participants. The virtual world consistently underwent multiple versions of content and visualization changes, but the core element of massively multiplayer online games (MMOG) ensures that it is capable of supporting a large number of learners simultaneously. Students are continuously rewarded for good play, and the advancement system ensures there is a progressive acquisition of knowledge and sustained participation in ARX.

Virtual Math Team (VMT) Project

The VMT project (http://vmt.mathforum.org/VMTLobby/) started in 2002 and is still active in 2017. It provides an online synchronous environment where students around the world can gather in teams to engage in deep conceptual mathematical reasoning (Stahl 2009). VMT is an extension to the regular suite of interactive math education services (e.g., The Problem of the Week, Ask Dr. Math) offered in The Math Forum, and it is also an expansive resource for the improvement of mathematics learning, teaching, and communication (Virtual Math Team n.d.). The Math Forum is a center for mathematics and mathematics education on the Internet (http://mathforum.org/about.forum.html) that started in 1992 at Swarthmore College. Funded by the National Science Foundation, it started as the Geometry Forum, and later evolved into The Math Forum in 1996.

1. *Cognitive dimension*. The VMT project has three primary goals: to develop and provide stimulating online mathematics learning for student teams around the world, to play the role of educational technology designers that foster mathematical discourse and collaborative knowledge building, and to understand the nature of team interaction during discourse within the online learning environment (Stahl 2009). The online learning environment consists of different discussion chat rooms to meet the demands of various situations and requirements, and such flexibility encourages learners to be active members of a math-discourse virtual

community, that in turn helps to grow the community. To determine cognitive effects of using assistive tools within VMT, the system included a Replayer tool that can trace a student's learning session. This allows researchers to review the student's interactions with the tools and observe what was displayed to the student when solving mathematical problems (Weusijana et al. 2010). By making mathematical thinking visible and analyzable within a session, it is possible to analyze how students construct solutions and reason in the joint problem space (Sarmiento and Stahl 2008).

2. *Social dimension*. To encourage ownership among students, VMT allows the students to establish social practices that structure the behavior of participants, but it also attempts to define expectations about how the informal learning space could be used (Virtual Math Team n.d.). Over the years, VMT strives to supplement small group's experiences of VMT chat and incorporate adaptable and personalizable interactions (Virtual Math Team n.d.). Collaborative knowledge building is fostered through math discourse among the users, and the online learning environment set up within VMT provided ample affordances for social interaction among the participants. The need to monitor and observe students is necessary for effective mentorship, and the process was enhanced by the addition of whiteboards that allow mentors to provide feedback synchronously.
3. *Technological support and infrastructure*. From the initiation of VMT, some tools that support learning and communication – such as textbox, whiteboard function, chat log, and referencing tools – were made available. Previously, only the textbox is synchronous. The team at VMT has been making major updates to their toolkit in recent years to implement a multiuser synchronous dynamic mathematics whiteboard to improve inquiry of mathematical disciplinary content (Weusijana et al. 2010). In addition to the original whiteboard's history and chat referencing feature, the newer whiteboard function uses the open source GeoGebra system (https://www.geogebra.org) to provide a dynamic shared space for drawing mathematical objects and graphical representation of the problem, as well as the added functionality of importing and exporting worksheets. Users can make use of saved worksheets to build on their peer's work; newcomers can also pick up from where other students have left off in the previous sessions of the problem-solving process.

The Web-Based Inquiry Science Environment (WISE)

The latest version of WISE Virtual Learning Environment (https://wise.berkeley.edu/) is a web-browser-based environment that affords (1) free customizable curriculum projects on topics central to science standards and (2) guidance for teachers on how Internet-based projects can assist improvements in teaching and learning within Grade 6–12 science classrooms (Slotta and Linn 2009). Through WISE, students have access to real-world evidence from the Internet and will be able to engage in exploration of authentic scientific controversies (Raes et al. 2012). A large user base of over 15,000 teachers and over 100,000 K-12 students have participated in WISE projects, and findings over the years on curriculum and assessment have culminated in effective models of professional development that enable effective implementation and practices of science inquiry within classrooms.

1. *Cognitive dimension*. Premise on socio-constructivist approach of learning (Vygotsky 1978), WISE provides prompts as scaffolds to support students in self-regulated learning; this important feature in WISE has seen increasing usage (Bannert 2009). As Internet resources are fundamental to WISE projects, students learn to use online resources critically and productively to elicit ideas and to deepen their understanding of a topic (Linn et al. 2003). By making science visible and accessible with technological enhancement and a better user interface, students can learn from one another and develop skills in conducting scientific inquiry and learn to be active contributors to the scientific enterprise.
2. *Social dimension*. Apart from tools such as asynchronous discussions and anonymous contributions that encourage students to interact, critique, and learn from one another, tools such as *Idea Basket* provide persistent space for students to collate and sort multimedia information. Students can use the *Explanation Builder* to formulate arguments using evidence from the *Idea Basket*. The provision of animation tools *WISE Draw* and the *Flipbook Animator* allows students to represent their arguments by creating drawings, diagrams, or animation; students can playback their flipbook-style animations to illustrate concepts or processes that are better explained in animation. Arguments can be translated into various representational formats so that students, who have different explanatory theories and perspectives within the discussion groups, can engage in scientific arguments and work toward achieving a consensus.
3. *Technological support and infrastructure*. Versions 4 and 5 of WISE were introduced in recent years with significant technological updates. For example, the real-time functionalities in WISE afford new kinds of student interactions such as adaptive navigation and provide support for displaying content on mobile devices. Real-time communication has been integrated across tools such as the *Classroom Manager* and student project interfaces so that automated assessment and feedback tools can generate real-time alerts and scaffolds. Student learning process is further improved through timely feedback with greater communication efficiency between teachers and students, while greater accessibility of content is achieved through porting of content onto mobile devices, which allows greater visibility of content and feedback.

Emerging Studies of Online Learning Communities in K-12 Settings

In recent years, a new trend emerged in the use of learning management system (LMS) technologies for online learning communities in K-12 settings. These online communities exhibit the following characteristics: (1) use of technological platforms with adaptive tools that are accessible, user-friendly, and simple to adopt by teachers and students; (2) shift away from traditional teacher-led instruction to become student-focused, while preserving the goal of learning; (3) ability to host both student-initiated and teacher-provided content and assist teachers in designing and delivering instruction using customizable interfaces for various learning needs; and (4) provide built-in analytics and indicators that monitor student learning progress and provide real-time functionalities for discussion and feedback. For illustrative purposes, two emerging online learning communities that possess the features mentioned above are reviewed, while we acknowledge the presence of other systems such as Blackboard Learn (Bradford et al. 2007).

Canvas K-12

Canvas (https://www.canvaslms.com/k-12/) is a cloud-based LMS set up by Instructure (https://www.instructure.com/) that is based in Utah; the company also developed a MOOC platform named Canvas Network. Canvas K-12, designed especially for elementary and secondary schools, was launched in 2012. It is well known for its ease of use and adoption by communities, mobile-friendliness, and alignment to the pedagogical principle of student-centered learning.

1. *Cognitive dimension*. Canvas K-12 adopts an expansive view of student-centered learning by examining how better teacher-student relationship can help to develop students to be confident and self-directed learners adaptable to the knowledge society. In Canvas K-12, even though teachers still hold the authority in identifying the majority of content that has to be learned, students have the autonomy in choosing when and where to study and are encouraged to reflect on their learning habits. By encouraging students to learn based on their intrinsic motivation and interests, students assume more responsibility for their learning progress and pacing. Teachers are also able to monitor the learning progress to provide timely feedback or to incorporate new ways of engaging students in activities that foster productive learning habits.
2. *Social dimension*. Canvas K-12 seeks to provide and encourage interactive learning through their LMS platform. Teachers can design interactive digital materials that encourage meaningful interactions between teachers and students and among the students. Small group discussions can be set up for peer learning, including practices such as *peer tutoring*, *reciprocal teaching* (students take control to learn a new material and to teach their peers), and *cooperative and collaborative learning* by working on shared documents.
3. *Technological support and infrastructure*. The peer learning capabilities built into Canvas K-12 allow students to work together flexibly, be it ad hoc discussions or structured lessons for reviewing lessons or preparing for examinations. Students can drop in or leave discussion groups whenever there are consultation lessons arranged by schools, participate in synchronous tutoring if required, or engage in asynchronous discussion. Tools such as actionable analytics are also available for teachers, which help to relieve their workload of conducting an individual analysis of students. As reciprocal teaching only with text might risk losing a sense of humanness and personability (Graham 2006), Canvas included audio

and video modalities as options to help students retain connections on personal levels and also enhance their sense of community (Borup et al. 2012).

Brightspace

Brightspace, formerly known as Desire2Learn, is an integrated learning platform that provides support for competency-based education (CBE). It provides e-Portfolio tools for students and assists teachers through the provision of learning analytics and cross-platform support.

1. *Cognitive dimension*. Brightspace is designed to support CBE, where students learn to work on a single competency or a unit topic at a time. In CBE, students learn at their own pace to achieve the learning objective, while the teachers function as a facilitator. Upon evaluation and successful mastery of a unit topic, a student can proceed to develop other competencies within the learning space. Analytical tools within Brightspace can help teachers to assess and gauge the level of competency gained by students. For example, teachers can monitor students' progress in class and adjust their pace of learning or even allow students to skip certain topics if they can display mastery of these topics through quizzes and tests. Personalized e-Portfolio tool allows students to document their learning journey throughout courses.
2. *Social dimension*. Usage of *Brightspace Capture* allows teachers to create interactive events that help guide students toward achieving units' learning outcomes. Online collaborative tools such as video messaging and integrated social media profiles help to connect teachers, students, and peers beyond the classroom. Live polls can be run through Brightspace during lessons to keep students engaged and keep on task to achieve the learning objectives. *Brightspace Pulse*, a mobile app, allows students to participate in discussions between lessons, and information can be pulled from the discussions for the teacher to go over as a group in the next lesson. Students can create, add, and share interesting or personalized content in e-Portfolios and share it with their peers and teachers within their social networks. By working on the e-Portfolio, students can reflect on their accomplishments and use them as part of their social achievements outside of academic settings.
3. *Technological support and infrastructure*. The *Learning Repository* within Brightspace enables wide-scale aggregation of external resources onto a single platform, thereby saving teachers' time in designing courses and conducting searches through open educational resources (OERs) and other online digital libraries. Analytical tools such as *Success System* and *Insights* use data across the entire learning ecosystem to predict and determine evidence-based interventions that teachers can adopt in the lessons. Class-wide performance analysis is displayed with greater visibility on dashboards, together with individualized progress reports for students. Integrated and automated notifications can also provide teachers with timely alerts regarding learner activities and their progress. Also, learner activities can be tracked using *User Progress Tool* to determine

engagement levels of students, while activities can also be rewarded through automatic badging mechanisms.

Comparison Between Online Learning Communities and LMS-Based Online Learning Communities

The two newly reviewed communities (Canvas and Brightspace) are somewhat similar in their designs, goals, and purpose of existence and yet have their distinct characteristics when compared to the four established online learning communities. They are in fact LMSs enhanced with a wide array of social technologies to enhance their capabilities, which can appeal to students to contribute as a member of the community. The common characteristics between Canvas and Brightspace learning communities are discussed below, while the differences with the other online learning communities are summarized in Table 1.

1. Cognitively, like the established online learning communities, both LMS online learning communities base their tasks and activities on pedagogical principles, including student-centered learning and competency-based education. To encourage students to take responsibility for their learning, the online spaces are filled with abundant resources and scaffolds to support students as they interact with challenging tasks. Canvas K-12 provides an open platform where students decide on the best opportunity of learning based on their learning habits, while Brightspace uses mastery learning to help students achieve the competencies stipulated by teachers.
2. In the social dimension, the two emerging communities provide interactive environments in which individual students can seamlessly interact with the community during the learning process. With the affordances of network and

Table 1 Comparisons of the online learning communities

Established online learning communities (KBC, ARX, VMT, and WISE)	LMS-based online learning communities with social technology (Canvas K-12 and Brightspace)
Cognitive dimension	
Goals and tasks are grounded on theories and principles of learning; teachers play the facilitator roles	Learning tasks can be teacher-led or student-initiated, but the onus is on the students to determine suitable learning process and pacing
Social dimension	
Communities strive on the ability to share; the democratization of knowledge and enabling of students in purposeful contributions to the community	Focus shift from learning management to learning as smaller communities, such as groups and peer learning are set up to achieve the common learning goal
Technological dimension	
Leveraging technologies to achieve learning goals beyond face-to-face settings	Built-in learning analytics and synchronous functionalities to support immediate formative feedback

mobile technologies, interaction and learning can occur anytime and anywhere for the individual learner. For example, Canvas K-12 provides online spaces for small group discussion and peer learning, where students can participate at arranged time slots even when they are physically separated. Brightspace's mobile application allows the community to extend beyond the classroom, and students' customized e-Portfolios provide additional sharing and collaboration opportunities.

3. Technologically, algorithmic advances in machine learning coupled with educational technology have led to the development of learning analytics, which can provide advanced visualization of student data for actionable feedback. The two communities can provide insights for teachers (using Canvas graphic analytics and reporting) and also identify knowledge gaps and recommend content for students automatically (using Brightspace *LeaP*).

Pertinent Research and Implementation Issues

With the development of new technologies and enhancement of the established online learning communities, several pertinent research and implementation issues remain in this field of work.

Adaptation of School Infrastructures, Cultures, and Teaching and Learning Practices

There has been an increased emphasis on schools to include information and communications technology (ICT) within the educational setting, with the goals of enhancing the effectiveness of teaching and providing equity of access to education for all students. However, there are still barriers to the adoption of technologies, including costs and sustainability of implementing ICT, especially for schools with fewer resources and prevalent resistance to the adoption of technology. In schools where preparation for high-stakes national examinations takes top priority, it is understandable that teachers tend to revert to tried-and-tested method of traditional instruction in classrooms to achieve their goals, rather than exploring innovative approaches such as online learning communities. Nonetheless, there is evidence of increased usage of mobile computing devices, and students and teachers are increasingly exposed to more ways of connecting and situating their classroom community within the online learning environment. More schools are providing resources such as portable computing devices and are preparing students with the media literacy skills; these practices are conducive to the adoption of online learning communities. As schools begin to reap the benefits of increased participation within online learning environments, there is noticeably some effects of how current developments in technology such as MOOCs and LMSs have helped mold teaching and learning practices in the online communities to become more learner-centric and effective.

There are, however, some pertinent research issues that could still arise in the future, namely, (1) How can schools be better prepared for increasing systemic change due to increasing influence of educational technology that is integrated to facilitate implementation of online learning communities? (2) How would learning practices change and what are students learning from participation in online learning communities? (3) To what extent will the role of teachers change and how professional development could help teachers to transit from formal school settings to online learning communities?

Issues of Acquiring and Assessment of Authentic Knowledge

The participants within traditional classroom learning environments and online learning environments are often the same groups of students but with different learning behaviors and perceptions toward the respective learning environments. Therefore, when traditional learning communities in schools are perceived and criticized as inauthentic communities of practice, the same criticism also applies to online learning communities. As students are often motivated by the opportunity to solve real-world problems and prefer to learn by doing (Lombardi 2007), educators can introduce through the online learning environment authentic content, for example, replace mock-up scientific data with live sensory data, and provide problem-based activities closer to what practitioners for experiential learning. However, all efforts may be nullified if students are still being assessed based on multiple-choice questions and simple tests that only capture easy-to-measure low-level knowledge. There is a need to move away from standard assessment methods and adopt methods that integrate multiple forms of evidence. This evidence need not be limited to just statistics of clicks, views, and binary choices but could consist of qualitative observations and analysis of social interactions between students, the level of engagement within the community, and discourse between students, just to list a few examples. Thus, several issues remain: (1) In the pursuit of authentic knowledge, what entails authentic knowledge that schools can achieve and how could it be consistently acquired? (2) Through what measures could authentic learning be assessed and how could this be conducted?

Learning Analytics: Usage and Ethics

Learning analytics can assist understanding, visualization, and optimization of learning in educational environments. While it is a challenge to implement analytics within individual classes without technical help, most current state-of-the-art LMSs have integrated such capabilities into their platforms for ease of usage across the board. Learning analytics have thus far been used for prediction, personalization, intervention, and information visualization purposes, and these outcomes can benefit teachers and students in identifying knowledge gaps and possible areas for improvement. The best analytical tools could pinpoint lapses and details that may be overlooked among the plethora of data available within online learning communities, but apart from automated feedback through the LMS, the implementation of interventions is still heavily dependent on the teacher. Thus, even though learning analytics might be a great assistance to the teachers, they need to understand the predictive and visualizations data to decide on relevant and meaningful interventions. Also, the abundance of data residing within the online learning communities has led to concerns regarding ethical data ownership and sharing (Slade and Prinsloo 2013). The ethical issues vary among different countries and cultures but inadvertently raise issues regarding trust in data collection processes and the role of humans in the process of research and sharing. Pertinent issues that need to be explored include the following: (1) In what ways could learning analytics be used effectively in improving student learning within online learning communities? (2) What are the skills required of teachers to be proficient in integrating learning analytics with lessons for effective teaching and remediation? (3) In what ways can ethics of collection, analysis, reporting, and accountability be governed and tracked by schools and institutes?

Technological Advances

Finally yet importantly, innovative technologies have never been more accessible to the consumers in many countries and economies, partly due to the integration and embedding of such technologies within mobile devices. Advances in social networks have connected learners to one another efficiently, and advances in technologies such as augmented reality (AR) and virtual reality (VR) continue to provide new possibilities for online learning communities. Even though VR have previously been used for learning purposes (Roussou et al. 2006), the availability and cost of hardware have been a major deterrence. This issue can be resolved with decreasing hardware costs and prevalence of mobile devices. It is currently possible to use such technologies to achieve challenging learning objectives such as emotional learning outcomes (Harley et al. 2016), which are new affordances yet to be leveraged in online learning communities. In addition, there is great promise for disruptive changes with the evolvement of novel technologies such as the Internet of Things (IoT) (Gubbi et al. 2013), which refer to the embedding of electronics within everyday items to create *smart objects* that can be integrated with the physical and digital world for increased interactivity with learners. It is envisioned that the emerging IoTs can provide ubiquitous and context-aware learning. Pertinent research issues that could arise include the following: (1) What are the affordances of emerging technologies that could facilitate and not detract learning within online learning communities? (2) Are there novel learning outcomes that could be achieved through usage of newer technology? (3) How could online learning communities identify and develop themselves within new environments?

Conclusion

Online learning communities build on the foundation of communities of learners supported by networked technologies. The advancement in technologies has facilitated new mechanisms for increased inter-organizational and interpersonal connectivity. The ubiquity of the Internet has also provided affordances that were unfeasible in the past and opens up new frontiers for research and development in creating learning communities within online spaces. Intentional learning through social interactivity has remained as the main staple of online learning communities. This chapter has considered the design and implementation of online learning communities in the cognitive dimension, clarified the purpose and interactive boundaries of the communities in the social dimension, and considered how communities are technologically situated within the online spaces as part of a larger social and cultural framework. Four established online learning communities were examined, including Knowledge Building Communities, Atlantis Remixed, Virtual Math Team, and Web-Based Inquiry Science Environment. This review also took note of the key features and major revamps of these communities that were introduced to help keep the online learning communities relevant to the changing users and contexts. The fact that the four online learning communities are still thriving after more than a decade shows that the common pedagogical principles and intended characteristics of these learning environments are robust and appealing to sustain learners' interest in continuing their learning journey with the respective online learning communities.

On the other hand, the two emerging online learning communities show different characteristics. Mature and stable technologies help to take care of digitization of physical learning materials for online learning spaces, and new tools such as learning analytics and synchronous functionalities help to improve student learning. Emergent LMSs are increasingly providing useful features that could benefit educators and students. Teachers, with increased workload, can be assisted with regard to management of learning resources, while learning analytics provide timely alerts that remind teachers if students fall by the wayside during the process of learning. Student learning progress can also be archived and tracked for future references, and the analytics can augment understanding of the learning community or monitoring individual students. The new platforms can facilitate a shift from organizational and communal knowledge advancements to smaller communities of learning with a greater focus on student-centered learning processes. These changes can catalyze advancement of pedagogical and learning practices of teachers and students.

Research findings have shown the complexity and difficulty in establishing and sustaining online learning communities (Jacobs 2013). In this review, potential issues related to online learning communities are suggested, including infrastructural and sociocultural barriers to technology integration and practical issues from the ground regarding the implementation and assessment of authentic knowledge. In addition, the ethical issues that could arise from the usage of personal data has to be handled securely and in a steadfast manner to ensure confidence in the process of data handling and sharing by researchers.

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Designing Blended, Flexible, and Personalized Learning

52

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Contents

Abstract

Blended, flexible, and personalized learning models are increasingly used to provide a more student-centered approach to learning. This chapter explores these models, and what current research and theory tells us about how to design these forms of learning. The aim of flexible and personalized learning is to meet the needs of student, with flexible learning focusing on how this can be done, and

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personalized learning on the outcomes. A common approach to implementing either flexible or personalized learning has been to use blended learning; that is, learning that occurs both online and in-person. There are many different ways in which blended learning can be implemented, with an expectation that this will continue to expand as new technologies become available. This variation in the way blended learning can be operationalized make creating universal design principles difficult. Current approaches to designing blended learning aimed at delivering flexible or personalized learning largely draw on descriptive studies of blended learning, or on theories and lessons drawn from the online and face-to-face fields. It is also common for design principles to have come from the higher education literature, where more research on the use of blended learning exists. In designing for blended learning, both the physical and online environments need considered, as do the context in which teaching and learning is to occur, the desired pedagogical approach, and what technology is available. A critical part of the design process is to ensure that learning drives the use of technology, rather than the reverse. It seems likely that blended learning will continue be used to deliver flexible and personalized learning and more investigation into how blended learning can effectively deliver flexible and personalized learning in primary and secondary schools is needed.

Keywords
Blended learning · Personalized learning · Flexible learning · Student-centred

Introduction

Current rhetoric regarding teaching and learning has often focused on the needs of twenty-first century learners. While there is still debate regarding whether or not twenty-first century learners are, in fact, different from previous learners, there appears to be a general acknowledgement that the role of education has changed. No longer is education about providing students with skills for particular jobs, rather there is recognition that in their lifetime students are likely to be faced with jobs that did not exist when they completed their schooling. As such, the role of education is increasingly being challenged. The current emphasis tends to be on soft skills, rather than specific knowledge, and this has led to questions regarding how teaching and learning should occur.

For more than a decade, there has been a call for schools to rethink what they do, addressing the needs of diverse students (Alton-Lee 2003; Hipkins 2004), and preparing them for further study in a range of topics, and for work that may not yet exist (Darling-Hammond 2007). This can be summarized as a recognition that a more student-centered approach to learning needs to be adopted. There are numerous ways in which this can be realized and a number of terms for these approaches, including a focus on flexible and personalized learning. In adopting these approaches to learning, technology is often utilized, leading to an increased use of blended approaches to learning.

This chapter will explore these blended approaches to learning, focusing on their ability to provide flexible and personalized pathways to students. It will draw on literature from both the school and higher education sectors to explore issues associated with designing blended, flexible, and personalized learning. It will begin by considering flexible and personalized learning, before exploring the relationship between these and blended learning. Finally, information summarizing current knowledge in regarding to how to design blended learning that is both flexible and personalized will be presented.

Flexible and Personalized Learning

Talking about flexible and personalized learning is part of the rhetoric of teaching and learning in the twenty-first century. The focus of both of them is on the student; it reflects a move towards student-centered learning, where the teacher becomes a guide and support, rather than the director of learning and imparter of knowledge (Chandra Handa 2009; Hannafin et al. 2009; Pedersen and Liu 2003). This section will explore how these terms are defined in the literature, and how they related to one another.

Flexible Learning

The term flexible is likely to be familiar to anyone who understands English; it relates to variation. As the Cambridge dictionary (https://dictionary.cambridge.org/dictionary/english/flexible) explains, flexible means to be able to change or be changed easily according to the situation. Within education, it is a popular term; perhaps increasingly popular in today's rhetoric regarding the twenty-first century learner. What it means, however, in terms of teaching and learning, is less clear.

Discussions of flexible learning are not new; the term has been used with reference to higher education since the 1990s, and Collis and Moonen (2001) refer it as "learner choice in different aspects of the learning experience" (p. 9). It was used with less frequency in the school sector but has been common for some time. In recent times, reference is made to the desirability of flexible learning without the provision of a definition as to what this entails. Further complicating the picture, the term flexible learning has also historically been used synonymously with distance education (Collis and Moonen 2001) and with alternative education models, used with students with special educational needs (Peters 2003).

The concept of flexible learning, while seemingly straightforward, is in fact very complex. Teaching and learning can be more or less flexible along a number of dimensions, and a number of areas within these dimensions. As Nikolov et al. (▶ Chap. 48, "Distance and Flexible Learning in the Twenty-First Century") discuss in detail in their chapter in this book, these areas include the aims and objectives of what is studied, how this is studied (teaching and learning strategies), where it is studied (environment), and when it is studied (time).

Personalized Learning

Personalized learning, as with flexible learning, is not new. As with flexible learning, it is, on the surface, a simple approach to learning, relating to learning that is specific to individual students. While this is true, within the literature it is seen as encompassing a much more complex picture than this in terms of its approach to teaching and learning. A key issue is the differentiation between the process of personalizing learning and the state of personalized learning (Hargreaves 2006). This differentiation obviously impacts on the implications of the term for teaching and learning. In addition, the term is defined differently by different countries and/or researchers. This difference in definitions can be perceived both as problematic and advantageous; differences can make it difficult to understand the implications of personalized learning, while variations can also allow for different interpretations based on context (e.g., see Sebba et al. 2007).

Despite these variations in definitions, in general all users of the term appear to agree that it relates to student-centered or -controlled learning, with additional features being somewhat less consistent. For example, in New Zealand, personalized learning not only refers to student-controlled learning but also means they understand, own, and drive their learning, being co-designers of both their curriculum and their learning environment (http://elearning.tki.org.nz/Teaching/Future-focused-learning). In the United Kingdom, personalized learning refers not only to student ownership of learning but also makes reference to assessment and inclusion (Sebba et al. 2007). This is somewhat narrower than its original conceptualization, when Miliband (2004), the then United Kingdom Schools Standard Minister, identified the guidelines for personalizing education as including: needs assessment for learning and use of data and dialogue to diagnose every student's learning needs:

- The development of the competence and confidence of each learner through teaching and learning strategies which build on individual needs
- Presupposed curriculum choice which engages and respects students
- Demands a radical approach to school organization and class organization based around student progress
- Means the community, local institutions, and social services supporting schools to drive forward progress in the classroom (adapted from Peters 2014, p. 102)

This 2004 definition from the United Kingdom appears similar to a more recent United States of America definition (Jenkins et al. 2016, p. 3), which identified personalized learning as including the following elements:

- Instruction is aligned to rigorous college- and career-ready standards and the social and emotional skills students need to be successful in college and career.
- Instruction is customized, allowing each student to design learning experiences aligned to his or her interests.
- The pace of instruction is varied based on individual student needs, allowing students to accelerate or take additional time based on their level of mastery.

- Educators use data from formative assessments and student feedback in real-time to differentiate instruction and provide robust supports and interventions so that every student remains on track to graduation.
- Students and parents have access to clear, transferable learning objectives, and assessment results so they understand what is expected for mastery and advancement.

Common to definitions of personalized learning is the focus on student needs and ensuring that teaching and learning is focused on meeting these needs. There are also differences; the USA definition appears to focus on students gaining mastery and being prepared for college and careers, while the UK definition focusses more on the student being at the center of the process, with schools' and communities' duty being to support students in their learning needs.

Comparing Flexible and Personalized Learning

As identified, flexible learning focuses on variation in how learning occurs. Implicit in this is its purpose, which is to better meet the needs of students. As such, it shares the focus on the needs of individual students of personalized learning. Although the definitions of this vary, its key component on meeting the needs of students is shared. Where flexible and personalized appear to differ, then, is their focus; while flexible learning focuses on how to meet the needs of students, personalized learning focuses on the desired outcomes and identifies broad goals to guide how this might happen. Both flexible learning and personalized learning, then, are forms of student-centered learning, and indeed, at times the terms have been used interchangeably.

Student-centered learning approaches are usually contrasted with teacher-led approaches and are underpinned by a constructivist approach. This approach focuses on "the meaning-making activity of the individual mind" (Crotty 1998, p. 58). As the name suggests, students are central to a student-centered learning approach, with decisions about teaching and learning made with them, rather than the teacher or curriculum, in mind. It encompasses not only flexible and personalized learning but other approaches, such as problem-based learning.

What is clear is that whatever the focus on student-centered learning is, all aspects of the teaching and learning context need to be considered for it to be implemented effectively. The affordances of technology are such that a number of the conditions for flexible or personalized learning can be more easily met through the use of technology, meaning that the use of a blended learning approach is common.

Blended Learning

Given a long history of distance forms of education, and the newer and still well-established use of information technology to support teaching and learning, it is perhaps unsurprising that implementing both flexible and personalized using a form of blended learning is increasingly popular. Blended learning has been common for some time in the higher education sector but is still an emerging approach in primary and secondary schools (Drysdale et al. 2013; Oliver and Stallings 2014), with the perceptions of its emergence dependent on how it is defined.

The term blended learning has been used in a variety of ways in the literature. For example, Lai et al. (2013) referred to blending formal and informal forms of learning. Generally, however, the term is currently being used to refer to learning that involves both online and face-to-face forms of delivery (e.g., see Alammary et al. 2014; Bailey et al. 2013; Delialioglu 2012; Drysdale et al. 2013; Ma'arop and Embi 2016; Vaughan et al. 2013; Worthen and Patrick 2015). The term hybrid learning has also been used to describe this mix of online and offline teaching (Allen and Seaman 2008). In discussing blended learning, emphasis is also often placed on the intended outcomes (Bailey et al. 2013) and pedagogy associated with it (Michigan Virtual University 2013; see also Alammary et al. 2014, for further discussion of blended learning). This pedagogical emphasis usually focuses on aspects of student control and the personalization of learning. A definition of blended learning that encompasses these key elements is that of Horn and Staker (2011). They explained that,

> Blended learning is any time a student learns at least in part at a supervised brick-and-mortar location away from home *and* at least in part through online delivery with some element of student control over time, place, path, and/or pace (p. 3).

There have been a number of attempts to classify models of blended learning. In line with the SAMR (substitution, augmentation, modification, redefinition; see Cavanaugh et al. 2013; Puentedura 2009) model of using information technology to enhance education, Alammary et al. (2014, p. 443) identified three levels of use of online activities in their classification of blended learning models:

- Low impact: Online activities added
- Medium impact: Online activities replaced existing ones
- High impact: A new course is developed, utilizing both online and offline activities

Another similar classification is that of Bonk and Graham (2005, cited in McGee and Reis 2013), who identified blended learning models as enabling, enhancing, or transforming learning

Within the primary and secondary sectors, Staker and Horn (Christenson et al. 2013; Horn and Staker 2011; Staker and Horn 2012) have identified a number of different models of blended learning in primary and secondary schools. Initially they identified six models, reducing these to four after discussions with and feedback from those working in this area, with one model subcategorized to include four different subtypes. These four models are briefly described in Table 1.

These models show the dynamic in the blended learning area of research, as well as the common understanding that the main feature of blended learning is a

Table 1 Classifications of models of blended learning (based on Christenson et al. 2013)

Model	Key elements
Rotation	Students move between activities, including at least one that is online and one that is face-to-face. Movement occurs either on a predetermined schedule or as the teacher determines
Station-rotation	All students move between all activities, as identified previously
Lab-rotation	All students move between all activities, with these located in different physical spaces
Flipped-classroom	Students choose a time and place to receive much of their content, often in the form of videos, with face-to-face activities focusing on applying the content
Individual rotation	Students move between the activities, with the activities to be completed, and the timing of the movement between them determined on an individual basis
Flex	The majority of learning is completed online, although the teacher is physically present. The activities to be completed and the time spent on each are determined on an individual basis
A la carte	Students take a combination of face-to-face and online classes
Enriched-virtual	A school-based approach to blended learning where students do not attend a physical school on a daily basis, instead dividing their time between learning online and in a face-to-face environment

combination of in-person (the term “in-person” is becoming increasingly popular in the fields of K-12 online and blended learning, as the term face-to-face could be deemed to incorporate videoconferencing, where students are online and at a distance but still seeing their teachers and classmates) and online classes. In identifying and describing the models of blended learning currently being used, Staker and Horn (2012) noted that they expect this taxonomy to be further refined, as this relatively new field continues to develop.

These blended models are commonly used in courses that include distance elements but are less common in predominantly in-person classes. The exception to this is the Flipped Classroom Model, which has been gaining traction and attention in primary and secondary schools. This model is typified by students receiving the majority of their content at a time and place of their choosing, usually while they are alone, with in-class activities focusing on discussion about and application of this content (Christenson et al. 2013; https://flippedlearning.org/). This is often seen as flipping the traditional place of homework and in-class work. The underlying principle associated with this model is considering the most effective use of teaching and learning opportunities and utilizing the affordances of technology to implement them.

Advantages of Blended Learning

An obvious benefit of blended learning is that it can utilize the strengths of both online and face-to-face modes of learning (e.g., see Gerbic 2011; Schoonmaker 2014). In addition, as noted previously, a key benefit of blended learning approaches is their ability to provide a more personalized and flexible approach to learning for students (Horn and Staker 2011). A number of learning advantages of blended instruction have been noted, with Oliver and Stallings (2014) summarizing these in their article exploring what teachers should know about blended learning. They noted that students gained skills and experience in managing their time, monitoring their own progress and success, and in self-motivation. Students also gained skills in using technology for learning and benefited from the ability to work at their own pace.

Research generally supports the claims made regarding the effectiveness of blended learning approaches (e.g., Alammary et al. 2014; Means et al. 2013; Murphy et al. 2014; Oliver and Stallings 2014). In their meta-analysis of published research that covered students of secondary age and older, Means et al. (2013) found that blended learning was more effective for students than face-to-face learning based on a comparison of effect sizes. This compares favorably to findings regarding online learning, with this meta-analysis supporting previous studies that have reported “no significant difference” between online learning and face-to-face learning (e.g., see Delialioglu and Yildirim 2008; Oliver and Stallings 2014).

As important, though, as identifying whether or not blended learning is more effective than alternative approaches to learning, is understanding what it is about these approaches that make them more or less effective. Blended learning approaches do not simply involve teaching and learning occurring in a mix of online and face-to-face environments but changes in what teachers and learners are actually doing. In general, they involve more learner-learner interaction and more resources than face-to-face teaching and learning (Means et al. 2013). As Powell et al. (2015) noted,

> the importance of blended learning models [is] a significant shift toward optimizing and personalizing learning for each student. Digital content is only one part of the equation, albeit an important one, and the focus should be on the *shift in instructional models toward student-centred learning* (p. 15, emphasis in original).

Designing Blended, Personalized, and Flexible Learning

To date, there is limited research exploring the effectiveness of the different models of blended learning, particularly at the primary and secondary levels (McGee and Reis 2013; Shand and Glassett Farrelly 2018). What is clear is that blended courses need to be carefully designed.

As Means et al. (2013) noted,

> [the] meta-analysis findings do not support simply putting an existing course online, but they do support redesigning instruction to incorporate additional learning opportunities online while retaining elements of face-to-face instruction. The positive findings with respect to blended learning approaches documented in the meta-analysis provide justification for the investment in the development of blended courses (p. 36).

The care needed in designing a blended course needs additional consideration if it is also to meet the requirements of being flexible and or personalized.

Many of the design principles being used in primary and secondary schools have come from the higher education literature, where the majority of studies relating to blended learning are situated (Oliver and Stallings 2014). While there are certainly lessons that can be learned from higher education, and parallels between higher and compulsory education, there are also key differences. The nature of primary and secondary school students, and the contexts within which they and their teachers work, differ in several key ways from students and teachers in higher education (Drysdale et al. 2013).

A number of researchers have worked to develop design principles for blended learning. In general, these are based either on theories and principles related to teaching and learning, or to technology use and online learning. Theories of blended learning (see Table 2 for an overview) have been developed based on the constructivist theories of cognitive apprenticeship and anchored knowledge in authentic situations (Abdelaziz 2012; the Four Dimensions Instructional Strategy) and on the work of Vygotsky (Béres et al. 2012; the CECIP model). In contrast,

Table 2 Examples of theories of blended learning and their key elements

Model	Key elements
Four dimensions instructional strategy (Abdelaziz 2012)	Instructor as coach Instructional strategy has four dimensions: “Designing a shared vision, developing a shareable e-learning task, delving learning through scaffolding and distributing learning through salvaging students’ knowledge” (p. 227)
CECIP (Béres et al. 2012)	Project based online collaborative student-centered learning model Collaboration – Evaluation – Critical thinking – Individual assessment – Learner profile (capitalization indicates origin of acronym) Begin by understanding who the learners are and ensuring they know one another Utilizes group, individual, and project work Achievement of learning goals assessed based on Bloom’s taxonomy Everyone involved in the evaluation of material and students’ attitudes and development
Complex adaptive blended learning system (Wang et al. 2015)	Based on the complex adaptive systems approach developed in science disciplines, treating learning as a complex system. Explores the relationships between the learner, teacher, content, technology, learning support, and the institution
Co-evolutionary framework (Davis et al. 2013; Zaka 2014)	Utilizes an ecological perspective Classroom was viewed as nested within the school, district, region, and nation, with teachers as the “keystone species”; with change not occurring until they were impacted

Wang et al. (2015) argued for the use of a complex adaptive systems approach to understand blended learning. Other researchers have focused on principles and theories related to the use of technology in teaching and learning in general (Davis et al. 2013; Zaka 2014; a co-evolutionary ecological model).

Work by Halverson et al. (2014) identified a number of other blended learning design models within higher education. In their thematic analysis of blended learning research from 2000 to 2011, they identified 19 articles, books, or book chapters related to theories or models of blended learning. Of these 19, only 2 pieces of literature used the same theory, which was Garrison and colleagues' (e.g., Anderson et al. 2001; Garrison et al. 2010) Community of Inquiry framework. They noted while diversity has its benefits, "theories and models should be driving the conversations in the domain of blended learning, providing the language and variables around which those conversations coalesce" (Halverson et al. 2014, p. 28). As the models described in Table 2 are all additional to those identified by Halverson et al., it is clear that researchers in this field still have some way to go before this can occur.

A key difficulty in identifying best practice in terms of designing blended learning is the number of ways in which online and in-person activities can be blended. While much is yet to be agreed upon in terms of how best to design blended learning so that it promotes flexible and personalized learning, as shown by the number of models and theories currently being used, there is agreement about some aspects.

In general, it is recognized that designing blended learning is more complex than other approaches, because of the need to consider not only issues related to face-to-face teaching and learning, but also issues related to online learning, and how to combine the two in ways that ensure the two work to complement one another, providing students with an enhanced experience (Bailey et al. 2013; Oliver and Stallings 2014). Despite being utilized for over a decade, there is currently no one accepted design process or principles of best practice. A number of researchers have, however, identified design processes and/or principles based on multiple case studies or literature reviews. For example, based on multiple case studies of blended learning in primary and secondary schools, Powell et al. (2015) noted that although the schools used different models of blended learning, four key lessons emerged. Firstly, they noted the importance of the school culture. The importance of school culture has previously been identified in terms of implementing change, such as the integration of information technologies into learning (e.g., see Gunn and Hollingsworth 2013; Neyland 2011), so it is perhaps not surprising it is also a key to successful implementation of blended learning. They noted that the school culture had to not only be open but also committed to change and to ensuring that the learning approaches used reflected current research on learning, particularly in terms of effectively personalizing learning. Knowing why they were using blended learning, understanding it as a vehicle for personalized learning, was also seen as key. As part of this, they needed to work with students to ensure they knew how to make the most of this environment. The third key Powell et al. identified was ensuring staff received ongoing professional development; ideally in the form of blended, personalized learning, so they gained experience of the model while also learning about it. Finally, they identified a number of barriers to implementation. Many of these related to technology and showed the importance of technology that supports the school's goals of blended and personalized learning. Another key barrier was ensuring that the community understood why they were choosing to implement blended learning and how teachers and students could be supported to be successful in this environment.

Shand and Glassett Farrelly (2018) explored the higher education literature on blended learning and identified three areas that were "fundamental in effective blended course design" (p. 4). These were the need to:

- Plan course objectives
- Plan for content delivery and student engagement
- Plan the blend of in person and online components

These areas highlighted the importance on focusing on content and engagement, rather than on the technology. Shand and Glassett Farrelly (2018) emphasized the need to identify your course objectives, and then think about your content and your students, and identify what available technology tool will be the most appropriate for which activity, given its affordances. The final step should be to ensure you consider both online and in-person aspects of your course and ensure that they are blended; this ensures you will have a coherent course where online and in-person activities complement one another, rather than online activities being an add-on.

Also working in higher education, McGee and Reis (2013) conducted a qualitative meta-analysis with the aim of identifying best or effective practices in blended course design. After conducting their meta-analysis, they recognized that the blended learning design process "is a modified instructional design process in which consideration is given to learner needs, instructional outcomes, instructional strategies, and instructional scope" (p. 12). They identified five areas where best practices in course design were identified, noting key points about each. As Table 3 shows, they highlighted areas related to the design process, pedagogy, utilization, assessment, and implementation.

Although looking at different contexts, using different literature, and focusing on different elements, some similarities can be identified within these three examples of blended learning design approaches and principle. Something that is clear is that implementing blended learning, particularly with the aim of supporting personalized learning, requires consideration of all aspects of both the physical and online environments. These aspects can be classified into three interrelated categories: context, pedagogy, and technology (Oliver and Stallings 2014).

Context

In deciding whether, how, and what to blend, teachers need to consider the context in which they and their students work. This includes consideration of the topic, the available learning environments and any challenges associated with these, as well as

Table 3 McGee and Reis' (2013) summary of areas to consider when designing effective blended learning courses

The design process	Focus on designing a course, even if you are adapting an existing one; this stops you from simply using existing activities or transferring in-person activities online
	Start by defining the course objectives, with these written from a student perspective
	Then develop the course content, including activities and assessments. As this is done, ensure that activities that are developed are complementary; online activities should not be able to be perceived as extra
Pedagogical strategies	These are critical to the course and need to reflect an integration of in-person and online activities
	There is general agreement that: A range of interactive activities and prompt feedback are key In-person activities that are be both formal and informal should be considered Active learning is key
	Instructional strategies should be: Process driven Product oriented Project oriented (p. 14)
Classroom and online technology utilization	It is agreed that this is critical, but there is no clear agreement as to what this should look like
	There is general agreement that the technology should support the content and the pedagogy, not drive it
Assessment strategies	Few recommendations were found, with no general agreement. This may be due to contextual issues such as requirements of assessment policies.
Course implementation and student readiness	General agreement that students need: To know what is required of them and how to be successful To be/be encouraged to be independent learners, with good time management, communication, and study skills; if they don't have these, they need to be supported to develop them Basic technology understanding

what support students would need to succeed in these environments (Oliver and Stallings 2014; see also Bailey et al. 2013). For example, if students are working in an environment where they have limited access to technology outside of class time, blended approaches with in class online activities will be required.

The physical layout of classrooms also impacts on which model of blended learning is most appropriate; for example, rows of desks facing a whiteboard do not always lend themselves to student-centered forms of learning, and the rotation models of blended learning require students to have access to different spaces, either within a classroom or external to them while at least one of these spaces must have internet access. In some schools, however, blended learning has become an integral part of the learning experiences through changes in the physical environment. These changes, known as modern, innovative, or flexible learning environments are large, open teaching spaces, designed to be used as the teaching and learning requires, rather than dictating it (Benade and Jackson 2017). In designing learning spaces, Monahan (2000) thus proposes five properties of space flexibility:

> "fluidity represents the design of space for flows of individuals, sight, sound, and air. . .Versatility indicates the property of space that allows for multiple uses. . .Convertibility designates the ease of adapting educational space for new uses. . .Scalability describes a property of space for expansion or contraction. . .[and] Modifiability is a spatial property of fluid convertibility: spaces that *invite* convertibility" (para. 2–6).

However, the effectiveness of this change in classroom design is, as yet, unproven. It may be that just as adding technology to a teaching and learning environment does not necessarily result in pedagogical change, so too, changing the physical environment does not necessarily lead to changes in teaching and learning, although it may make change simpler.

Pedagogy

If blended learning is to be successfully adopted, the pedagogical approach to be used also needs considered (Bailey et al. 2013; Oliver and Stallings 2014). For example, teachers who prefer a didactic style are likely to struggle in a blended environment, with its focus on students, and on a role that is more focused on supporting and guiding students than providing content information. If blended learning was introduced with the aim of providing flexible or personalized learning for students, then pedagogy needs to be chosen to match this aim.

Ensuring that there is a balance of activities, with these carefully matched to learning mode is also important. What this should look like will vary depending on the contextual variables, but these are all issues that should be considered. The desired outcome of the blended learning experience, whether it be understanding of key concepts or the sharing and building of knowledge, will also impact on what pedagogical approach and what forms of blended learning will be most appropriate.

Technology

Perhaps the most obvious category to consider when blending learning is that of the technology itself. While the term blended learning was not originally used to indicate the use of online technologies, it has evolved to represent this mix of the use of online and in-person activities. As technology has developed, and its affordances have subsequently expanded, so too has the ability of blended learning to truly represent personalized learning. As Shand and Glassett Farrelly (2018) noted, key benefits of using technology to provide blended learning include the potential for the differentiation of instruction, and the range of online tools and activities that are available. All forms of blended learning, as categorized by Christenson et al. (2013), require the use of technology; how effectively this is done depends on a range of factors.

Technology can be used in a range of ways to support blended learning. Christenson et al. (2013) identified how technology can be used alongside in person learning; others have identified a range of technology-supported activities that can be used within Christenson et al.'s models. For example, teachers have access to a range of technological tools, including multimedia activities, games, tutorials, videos, virtual field trips, experts, overseas classes (e.g., so students can talk to native speakers of languages they are learning); interactive activities, tools that provide for outside interaction (e.g., wikis, blogs) and simulations (Keengwe and Kang 2012; McGee and Reis 2013; Shand and Glassett Farrelly 2018). In order for this technology to be effective, however, the availability of the technology, both in and out of class, and the affordances of that technology need considered and aligned with the blended learning approach and activities. Cloud computing has become popular in recent years, and some researchers (e.g., Donert and Kotsanis 2015) maintain that it can be a driver for transforming teaching and learning. However, it is important to note that technology should be used to support the chosen pedagogical approach, and to meet the needs of the students, rather than the reverse (Bower et al. 2010; Oliver and Stallings 2014).

Teacher Competencies

Supplementing the design processes and models previously described, a number of authors have identified the skills needed by blended learning teachers. Although the skills students need to be successful at blended learning, and indeed, that blended learning encourages students to develop, have been considered by a number of authors, less focus has been placed on the skills and dispositions required by blended learning teachers, although this has been identified as critical (Halverson et al. 2014; Ma'arop and Embi 2016). One piece of work that has focused on this issue is iNACOLs (the International Association for K-12 Online Learning) "*Blended Learning Teacher Competency Framework*" (Powell et al. 2014). Recognizing the ongoing development of blended learning, they called their framework "an evolving tool" (p. 6) and identified 12 competencies within 4 domains: mindsets, qualities, adaptive skills, and technical skills.

Conclusion

It seems clear that the focus on flexible and personalized leaning will be here for at least some time and likely that blended learning will continue to be used to deliver it. It is also clear that using blended learning to deliver flexible and personalized learning is complex and requires consideration of all aspects of teaching and learning. It should be noted that, as pointed out by Bartle (2015), designing flexible and personalized learning environments has significant implications on the curriculum, pedagogy, and assessment, and it is essential to provide teachers with support in professional learning, as well as developing a supportive school culture and effective infrastructure.

There is limited research focusing on blended learning in primary and secondary schools, and current blended learning theories have largely been extrapolated from research based in higher education, distance education, or related to the use of information technologies in general (McGee and Reis 2013). Further exploration of how blended learning can effectively deliver flexible and personalized learning in primary and secondary schools is needed (Futch et al. 2016; Oliver and Stallings 2014), with a focus on blended learning as a distinct approach, different from both in-person and online learning.

In addition to further research, policies need to reflect and encourage flexible and personalized learning. They need to be able to cope with variation in how learning occurs, as well as uncertainty, as the affordances of technology changes and continue to allow how learning occurs to change. Technology in and of itself will not change learning, but it does offer opportunities for learning to change and be truly flexible and personalized.

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Section IX

Mobile Learning

Section Introduction: Mobile Learning 53

Elliot Soloway and Cathleen Norris

Abstract

Mobile learning has continued to evolve since our state-of-the-art assessment in the first edition of this Handbook. As documented in the "mobile learning" section of this 2nd edition of the Handbook, (1) mobile learning per se is seeing limited adoption in classrooms in the USA, the UK, and in 17 countries in Asia, (2) while the young learners themselves are adopting mobile learning in a significant way outside the classroom. While the developing nations struggle with issues of device access, the developed nations struggle with seeing the value of mobile learning with respect to increased student achievement. Thus, while other educational technology trends (e.g., personalized learning, flipped learning, online learning) are attracting attention, mobile learning continues to evolve below the "radar" – with a comeback *into* the classroom occurring when educators better understand the significant impact mobile learning is having on this generation of young mobile learners.

Keywords

Mobile learning · Educational technology · Millennials using technology · Teachers using technology · Technology use in K-12

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In the first edition of this Handbook (Voogt et al. 2008), mobile learning commanded significant attention in the education community. Up until about the year 2000, under the heading of Computer-*Assisted* Learning, computers were being used to *direct* a learner down a learning path. But, with the coming of the Palm and the Pocket PC handheld devices, learners could actually hold a computer in their hand and use it to truly *assist* them in learning. Indeed, the handheld devices – morphing into Internet-connected, mobile devices – raised expectations about the transformative role that mobile learning might now be able to play in the classroom (▶ Chap. 57, "Mobile Learning in K-12: Roadblocks to Adoption" by Norris and Soloway).

Fast forward 10 years to the publication of the 2nd edition of the Handbook (this volume), K-12 has moved on to new trends, e.g., personalized learning, blended learning, flipped learning, and online learning. What happened to mobile learning? While the trendsetters in educational technology are off exploring these new uses of computing, mobile learning, as documented in the articles in the mobile learning section of the Handbook's 2nd edition (this volume), has continued – with less fanfare – to empower real learners to do real learning *the world over*:

- Evans (▶ Chap. 54, "From Engagement to Empowerment: The Evolution of Mobile Learning in the United States"), drawing on substantial survey data collected by Project Tomorrow, provides a detailed picture of the current state of mobile learning in the USA.
- Whyley (▶ Chap. 55, "Barriers to Mobile Learning Advancements in the United Kingdom"), drawing on the insights of 16 educational consultants, describes the state of mobile learning in the UK – England, Northern Ireland, Scotland, and Wales.
- Churchill et al. (▶ Chap. 56, "The Implementation of Mobile Learning in Asia: Key Trends in Practices and Research"), drawing on mini-reports on the state of mobile learning in 17 countries in Asia, provide a summary of the current state of mobile learning in the developing and developed countries in Asia.
- And, complementing these empirically based reports, Norris and Soloway (▶ Chap. 57, "Mobile Learning in K-12: Roadblocks to Adoption") provide a historical perspective on mobile learning – looking back at the early days of mobile learning to better understand the roadblocks that impeded adoption and looking to the future and how those roadblocks can be addressed.

Interestingly, as documented in the four chapters in this section, the following three statements are true for the students, teachers, and administrators in the USA, the UK, and the 17 countries in Asia.

- Since the arrival of the modern smartphone – the iPhone in 2007 – and the production of smartphones for all budgets, learners from 5 to 18 years old have been absorbing these "phones" as fast as their budgets (and the budgets of their parents) have allowed. And, these young people have been using their phones, on a regular basis, to engage in a variety of important learning activities *outside* of the classroom.
- Meanwhile, while school administrators and governments appear to be supportive of integrating these devices into the curriculum, classroom teachers are less

convinced of the need to transform their pedagogical practices and integrate computers in general and mobile devices, in particular, into the curriculum.

- And, without a demand for pedagogical change, it is not surprising that there is a dearth of curricular resources that truly exploit the affordances of the computers (and the mobile devices). Similarly, there is a dearth of opportunities for professional development to help classroom teachers transform their pedagogical practices.

Direct instruction pedagogy – teachers standing at the front of the classroom and lecturing – used by the Romans and the Greeks (Bonner 2012), still holds sway in classrooms in the USA, the UK, and Asia.

Still further, there are more findings that hold true across the three geographical areas:

- All three empirically based chapters find that educators want more research to be carried out. And, indeed, the teachers claim that they are reluctant to adopt mobile learning because of a lack of evidence that mobile learning (or computers in general) does lead to increases in student achievement. But, in fact, there are many studies that show the positive impact of technology on student achievement (Zheng et al. 2016; Project Red n.d.), and those studies are not hidden away in a closet. Why then do educators hold this belief about the lack of evidence? Will carrying out more research, as the educators have requested, help to change their belief?
- In all three geographical areas, the data suggest that the teachers all start using technology by substituting "a digital tool for a non-digital tool" (▶ Chap. 54, "From Engagement to Empowerment: The Evolution of Mobile Learning in the United States" by Evans). But, in all three geographical areas, teachers feel that "digital and mobile technologies are seen as having potential value across a whole range of subject areas" (▶ Chap. 56, "The Implementation of Mobile Learning in Asia: Key Trends in Practices and Research" by Churchill et al.).

While the teachers may well be reluctant to use technology inside the classroom, the young people are zooming ahead, using their mobile devices for learning outside the classroom:

- ". . . 58% of students in grades 6–8 and 54% of students in grades 9–12 say that they use technology more outside of school for learning than they do in school" (▶ Chap. 54, "From Engagement to Empowerment: The Evolution of Mobile Learning in the United States" by Evans).

Neither Whyley nor Churchill make comparable observations, which is understandable since they don't have access to the sort of data available to Evans. However, based on other sources, it is clear that there is widespread adoption of mobile technologies by students, especially in grades 9–12 in the U.K.: almost 80% (Doyle, 2015) of 12–17 year-olds use a smartphone daily. In Asia, a comment about the use of mobile devices by millennials, from the Ericsson Mobility Report (n.a., 2017), a global survey, is most telling:

- “Born between the early 1980s and the early 2000s, millennials have grown up in the age of the internet and mobile communications. This age group is not only leading the way in terms of the adoption of digital devices but also will most likely set the demands on future digital networks and services due to its technical knowledge and skills, as well as its high expectation level.” (n.a., 2017, p. 26)

Assuming that U.K. and Asia teens are similar to U.S. teens, teens in the U.K. and Asia are probably using their smartphones much like their counterparts in the U.S., i.e., for learning outside the classroom.

A major roadblock to the use of mobile learning in the classroom noted by Whyley (▶ Chap. 55, “Barriers to Mobile Learning Advancements in the United Kingdom”), and Norris and Soloway (▶ Chap. 57, “Mobile Learning in K-12: Roadblocks to Adoption”), is the lack of curricular materials. However, Norris and Soloway (▶ Chap. 57, “Mobile Learning in K-12: Roadblocks to Adoption”) see that there are new opportunities for developing curricular materials that can exploit the affordances of mobile devices. For example:

- The agreement by the World Wide Web Consortium on a standard for HTML5 means that device independent apps can be developed that will run in any browser that is W3C standards-aligned. Safari, Firefox, and Chrome tend to keep their browsers up to date, and thus mobile-exploiting curricular materials will run, in a compatible browser, on current devices and future devices.
- There are worldwide efforts to make OER – Open Education Resources – available for use in education for free. Currently, there is a great range of quality in the OER, and studies find that teachers are spending inordinate amounts of time searching for OERs for their classroom. However, new tools on the horizon, based on machine learning, promise to make OER more accessible.

In summary, while the fanfare surrounding mobile learning has fallen away, mobile learning, as documented in this section, continues to empower learners worldwide, at least *outside* the classroom. Now, for mobile learning to move *inside* the classroom, a number of events need to take place. Teachers will need to change a strong belief – not a simple task – and see that mobile learning can and does have a positive impact on student achievement. To move mobile learning inside the classroom, teachers will need curriculum they can use that incorporates mobile learning and professional development on that new curriculum. Fortunately, as Norris and Soloway (▶ Chap. 57, “Mobile Learning in K-12: Roadblocks to Adoption”) argue, the tools to create curriculum to support the broad range of devices that are now considered to be “mobile” have come available. The final piece to the puzzle is this: a new cohort of curriculum developers/publishers needs to arise to provide teachers with the needed curriculum and the PD. Given the shifting trends in educational technology, it isn’t clear that such an industry will develop. One trend, however, is not shifting: teens are wedded to their “phones” which will continue to empower their learning – outside the classroom.

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From Engagement to Empowerment: The Evolution of Mobile Learning in the United States

54

Julie A. Evans

Contents

Abstract

In the initial phases of mobile learning, the emphasis in US schools was on the magic of mobile device usage in the classroom. Education leaders were bedazzled by the potential of these Internet-connected devices to grab students' attention in ways that other learning materials had fallen short. The primary objective espoused by many school and district leaders was solely to leverage these highly compelling devices to stimulate new levels of student engagement in learning. Student engagement has long been the elusive magic bean in American education; if nurtured appropriately, the belief has been that test scores and achievement outcomes would soar toward the heavens like the magic beanstalk when students were more engaged in learning. In this flurry of excitement around the potential of

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mobile devices, education leaders placed only minimal emphasis on the hows or whys associated with the effective use of mobile devices and wireless connectivity within a learning environment. Real-world challenges associated with mobile device usage such as classroom management strategies, protecting student data, and the enterprise management of so many screens stifled innovation in too many classrooms and unintentionally locked in the perception that the only value of the devices was for engagement, not real learning. However, an interesting thing happened on the way to a new era of mobile learning. While educators have continued to chase the elusive magic bean of engagement over the past 10 years, students from kindergarten to high school have been using their own and school-provided devices as tools of empowerment, not just engagement. With a mobile device grasped firmly in the palm of their hand, students are self-directing learning beyond the sponsorship of teachers or pacing guides, personalizing learning paths that take into account their interests and passions as well as their strengths and weaknesses, and extending learning beyond the four walls and regimented desks of their classroom. As a result of these experiences, students now have a clear vision of what learning could be and articulate that vision around a guiding principle: learning should be social-based, untethered, and digitally rich. This new vision puts a stronger emphasis on the active “verbs” of the learning process while at the same time gently moving the passive “nouns” associated with mobile learning to the back burner. In this chapter, we will discuss this evolution of mobile learning from nouns to verbs by examining 10 years of longitudinal data from a large-scale quantitative study of the mobile learning activities, attitudes, and aspirations of K-12 students, educators, and parents. The study findings document the past and present environments for mobile learning in the United States and through the analysis of the corresponding trend lines provide an interesting glimpse into the future as well.

Keywords
Mobile learning · Engagement · Empowerment · Self-directed learning · Personalized learning · Wireless connectivity · K-12 students

Introduction

Findings for this chapter come primarily from a widespread representation of US stakeholders in education. The Speak Up survey collection, organized by Project Tomorrow®, has conducted national and international data gathering initiatives since 2003. Speak Up is a unique research project designed to collect and report on the authentic, unfiltered ideas and views of K-12 students and their parents, teachers, and administrators. The primary focus of the Speak Up project has been on education stakeholders in the United States though schools in Australia, Canada, and around the world have participated in the surveys for many years. The survey data comes from more than 10,000 school communities and more than 400,000 individuals including students, teachers, administrators, parents, and community members annually.

Many recent studies including from the education nonprofit group, Project Tomorrow, report that within the past few years teachers in the United States in particular are using more technology in the classroom than ever before (http://www.tomorrow.org/speakup/from-print-to-pixel.html). The number of teachers who report using online videos within instruction increased 39% from 2013 to 2016 (http://www.tomorrow.org/speakup/speakup-2016-ten-things-teachers-national-digital-learning-november-2017.html). The use of online curriculum increased as well. In 2013, one-fifth (20%) of classroom teachers reported using an online curriculum with their students; in 2016, 36% of teachers report usage of such products (http://www.tomorrow.org/speakup/speakup-2016-ten-things-teachers-national-digital-learning-november-2017.html). And following other well-documented trends, teachers have embraced classroom cloud-based tools such as the Google Suite for Education and Office 365 to a much greater degree than in the past years. Student access to mobile devices in the classroom has also increased in the past 3 years. In 2016, 26% of teachers reported that their students were personally assigned a mobile device to use in class, an increase of 10 percentage points over the 2013 reporting (http://www.tomorrow.org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html). Closer examination however of the types of digital activities undertaken by teachers, especially in support of new student learning environments, reveals that sophisticated usage leading to transformative activities is still in the emergent phase. In the United States, many school districts have adopted the Substitution Augmentation Modification Redefinition (SAMR) model to guide and assess teacher progress in integrating technology within learning. This model stipulates four distinct phases of technology adoption through which teachers gain proficiency and comfort in using digital tools to support new vistas for student learning. Practice has shown however that some teachers get stuck at a particular developmental level and do not progress to the more sophisticated phases of usage (http://www.stephaniedemichele.org/blog/category/samr; http://www.stephaniedemichele.org/blog/the-problem-with-substitution). Consequently, in many cases the valuation on the digital learning experience is more a reflection of that limited usage level rather than the potential it can provide for transformation in the classroom. Such is often the case with mobile learning implementations as well.

The adoption process for the use of mobile devices in the American classroom has followed a traditional technology adoption pattern. A teacher's journey in the use of mobile devices in their classroom usually starts with a decision by school or district leadership to implement devices in a particular grade level or to support specific subject matter or curriculum. Mobile devices are procured, and plans are devised to provide students and teachers with access to those devices, either personally assigned access or through a shared collection that can be scheduled for classroom usage. The teacher's awareness of best practices for usage starts with a professional learning class supplemented with possible support of an instructional coach or technology coordinator at the school. In some cases, the training builds on the teacher's own prior personal experience with the operations of devices such as a smartphone or tablet. The typical steps in the implementation process include the identification and installation of specific mobile apps, putting in place device check in and check out procedures, scheduling of device charging times, and the collection of parental permission slips. The first exposure that most students have to their new mobile learning tool is often instruction about all of the things they are not allowed to do with the device (i.e., download games, access social media, use the devices for nonacademic tasks). For both students and teachers, the foundational context for using these highly interactive, convenient, and portable devices focuses on the "nouns" of usage: what device, what apps, and what policies. Too little emphasis is on the more important aspects of mobile learning usage – the "verbs" that enable and empower new learning modalities and approaches that transcend traditional learning practices. While some implementations eventually move to a greater emphasis on the verbs, the initial positioning on the nouns limits teachers to seeing these devices not as gateways to greater learning and teaching efficacy but as vehicles for sporadic student engagement or to access online information with limited legitimate educational value. The students' perspectives, even with the initial overemphasis on the policy nouns of what you cannot do with the devices, prove to be radically different, and this sets up a dichotomy of usage by teachers and students.

Many technology adoption models including the SAMR model encourage a substitution activity as a starting place for classroom integration. The teacher identifies a traditional classroom practice and substitutes a digital tool for a non-digital tool to support that classroom task. A common substitution practice in a mobile learning implementation is to have students take class notes using a tablet or laptop, rather than writing those notes in a spiral bound paper notebook. Another is to have students read an online document on their device, rather than reading a printed document like an article or news story. If the substitution is deemed successful (most often defined as students being more engaged in learning with the digital tool than the traditional tool), the teacher continues to use that substitution and may even add new substitutions into his/her practice. The goal in this process is two-pronged: for the teacher to acquire comfort in the mechanics of device usage in class and for him/her to gain an appreciation for how the extra effort of using the devices results in new benefits for the teacher and students. The aspiration is that through these efforts the teacher will instinctually move beyond the mere replications of the traditional methods and visualize new ways to take advantage of the unique features and functionalities of the devices to transform the learning process. While the aspiration is commendable, the process of transformation is not necessarily instinctual for all teachers. In most cases, this transformation process requires a deliberate and strategic reimagination of the teacher's instructional practice to design new technology-enabled activities that cannot be undertaken without the access to the devices and supporting tools. This often necessitates that the teachers suspend their belief set on the importance of the "nouns" of mobile learning (what devices, what apps, what policies) to shift their mind-set to the "verbs" (how will the transformed practice empower and enable my students to learn differently than before). While these traditional adoption strategies can result in changes in practice, too often the focus on substitution or replacement activities as the starting point only results in a continuance of those practices, not the reimaging of the entire instructional practice. The process of strategic reimagination of one's instructional practice to use mobile devices effectively is a much more difficult venture in the real world than in theory or academic discourse. School principals appreciate this reality everyday as they work with their teachers on technology adoption. Principals consider their most significant challenge with technology use in the classroom is how to motivate their teachers to change their instructional practices to use digital tools and resources available on a regular and seamless basis.

This early focus on the nouns and the reliance upon adoption models that emphasize substitution presents another challenge to sustainable, effective mobile learning. Both ultimately mask the identification of real benefits associated with student usage of the devices to support learning. When asked about the valuation of student use of mobile devices in the classroom, both teachers (75%) and administrators (83%) identify increased student engagement as the primary benefit (http://www.tomorrow.org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html). This spotlight on student engagement is not unique to mobile device usage as educators also highlight that benefit when enumerating the value of other technologies in the classroom as well including interactive digital content, online videos, and game-based learning experiences. The predominance of substitution type activities within the adoption process provides rationale for this perspective. In most substitution activities, the "innovation" employed through the use of technology is only one-dimensional in that the underlying learning process is not transformed, just the methodology for doing the traditional task is slightly altered (taking notes on a tablet rather than in a spiral notebook). The increased engagement that students demonstrate when using a digital tool or resource may actually be more of a reflection on how non-engaging the traditional learning process was, than a real statement about the high levels of engagement with the digital methodology. Taking notes in class is boring. Using a tablet to take those notes may be slightly more engaging than using a pencil and paper, but the overall academic task is still not compelling to the student; taking notes remains a perfunctory but boring classroom task. The adult perception however is that the inclusion of the device elevated student interest and engagement in taking notes. That may be a premature or false assumption. Since too many technology implementations, including mobile device projects, have not evolved to the point of changing the underlying processes of learning (moving beyond substitutions to redefining the learning process), the outward appearance of increased student engagement in learning has emerged as most common litmus test for measuring technology effectiveness. Almost two-thirds of district administrators (62%) say that their district uses appearances of student engagement as the metric for evaluating the impact of technology projects. The seemingly lower percentages of district administrators who cite quality of student work (30%), depth of student collaborations (24%), and student interest in extended learning (21%) as indicators of technology project impact demonstrate the current lack of maturity or sophistication in assessing digital learning today.

Researchers have long documented a positive relationship between student engagement and academic outcomes. Student engagement in the K-12 classroom certainly remains an important criterion for learning efficacy. However, in the context of understanding the impact of mobile devices and other digital tools on student learning, it is inherently an insufficient measure. The reason for this insufficiency rests with how the students themselves value a mobile learning experience. While educators talk about the devices, the apps, and the policies that they have put in place to create mobile learning environments, the students focus on how and why all of those "nouns" of mobile learning have the potential to change their learning environment and outcomes. For today's students the use of mobile devices is first and foremost about personalizing learning and learning effectiveness and efficiency. Given their vision that their learning world should be social-based, untethered, and digitally rich, the mobile device and accompanying apps and tools serve as a highly productive gateway to realizing that vision. The students appreciate the inherently engaging and compelling nature of these devices, but because their primary focus is on the empowerment of their learning potential, they have unique sight lines to look beyond what they view as simplistic engagement to see the unrealized benefits that would enable more personalized, contextually relevant learning experiences. Their ongoing frustration is with the lack of visionary acuity by the adults that oversee their formalized educational lives.

Beyond the increases in access to devices, many changes in perception and policies around mobile learning in K-12 education have emerged in the past 10 years. Over this time period, Project Tomorrow's Speak Up Research Project on Digital Learning has had a front row seat in documenting many of these developments (http://www.tomorrow.org/speakup/speakup_data_findings.html). The Speak Up Project annually polls a geographically and economically diverse set of educational stakeholders, notably K-12 students, their parents, and teachers, to reveal not only how these audiences are using emerging digital tools to support learning, communications, and collaborations but also their attitudes about those activities and their aspirations for more effective usage. Since the project's launch in 2003, over five million K-12 students, teachers, librarians, administrators, parents, and community members have reported on their digital learning views and ideas through this process. The Speak Up national data findings are used regularly to inform policies and programs at every level of education governance from the US Congress to the local school board. Most notably, Speak Up has provided a vehicle for the authentic, unfiltered voices of K-12 students to be part of these discussions. In many cases, the ways today's students are using digital tools, particularly outside of school, and their aspirations for greater usage within the classroom, stand in stark contrast to the methodologies employed by their teachers to support classroom learning. In this chapter, we will explore the evolution of mobile learning in the classroom and then contrast those key trends with how students are leveraging mobile devices to self-direct learning outside of school. Additionally, we will examine the purposes and benefits associated with students' use of mobile devices from the perspective of the student. Understanding the hows and whys behind these alternative development paths provides a new context for appreciating the disconnect between students and educators on the value of mobile learning and to offer new insights into the future trends on the horizon.

The Evolution of Mobile Learning in the American Classroom

A common refrain within education policy circles is that the American classroom has changed little since the 1950s (https://www.fastcompany.com/1826287/we-know-our-education-system-broken-so-why-cant-we-fix-it). While the physical structure of a classroom with students sitting at desks may look familiar to most, the explosion of Internet-accessible, mobile devices in the hands of those students has definitely changed the way students interact with each other, with their teachers, with the greater education community, and with instructional materials. This is especially evident over the past decade, as schools have increasingly adopted mobile learning as a signature initiative using students' own devices as well as investing in tablets, laptops, and increasingly Chromebooks to provide their students with access to a wealth of relevant educational content and learning opportunities. Students having access to a mobile device to use in and outside of class – their own or a school-provided device – is now the norm rather than the exception. In 2013, only 38% of teachers reported that their students had regular access to technology through a 1:1 mobile device program within their school (http://www.tomorrow.org/speakup/SU13DigitalLearningPlaybook_EducatorReport.html). Two-thirds of district administrators (63%) now report that within their district students are personally assigned a laptop, tablet, or Chromebook to use at school to support classroom activities and tasks, almost doubling the number of students with mobile device access in just 3 years. This frenzied adoption of mobile devices within learning has presented many new challenges for education leaders. Understanding the challenges schools continue to face in the implementation of mobile devices in the classrooms lays the groundwork for greater appreciation of the changes in mobile learning over the decade as well as the unfilled promises afforded by the mobile tools and content.

Challenges: Encouraging Innovative Classroom Practices and Evaluating Investment Return

As school technology use has become more ubiquitous, school and district leaders have increasingly placed a higher value on the role of digital learning, particularly as it pertains to the preparation of students to compete and contribute in a global economy. Seven of ten school district administrators consider the effective use of technology as *extremely important* for their students' future success. This represents a significant increase of 34% in the number of administrators holding that view since 2011 (http://www.tomorrow.org/speakup/ConnectingDots2012_pres.html). Additionally, 85% of both school principals and central office administrators agree that it is important for students to be able to use a mobile device during the school day to support learning (http://www.tomorrow.org/speakup/Ten-Year-Retrospective-on-Mobile-Learning-Leveraging-the-Past-to-Invent-the-Future.html). Given that administrative support is considered a critical factor for effective technology use in schools, this strong endorsement of mobile learning from educational leadership should provide an optimum environment for effective mobile learning in the classroom. But why is that not the case?

Despite endorsements and edicts, incentives, and investments, school and district administrators report that they continue to struggle with how to elevate the use of the digital tools from sporadic, engagement-intensive activities to instructionally rich and sustainable learning experiences for students. When asked to identify the most significant challenge they face with technology use in the classroom, a majority of administrators report that motivating teachers to change their teaching practices is the number one obstacle to more effective usage. Librarians echo a similar frustration based upon their work supporting teachers with new classroom strategies for using devices and digital content.

Evaluation of teachers' use of technology and, in particular, their attitudes about that usage demonstrates the depth of this challenge for school leadership. In contrast to the 71% of district administrators who indicate that the effective use of technology is extremely important to student success, only 43% of classroom teachers share that same valuation. While the number of teachers' appreciating the value of digital learning has increased since 2010 by 10 percentage points, the same period saw a more substantial increase by administrators from 51% to 71% . This lower valuation by the teachers on digital learning appears to be a universal teacher phenomenon that is not affected by years of experience in the field or community type (urban, rural, or suburban) and only slighted altered by grade level assignment. Rather, it is a reflection that in most teachers' classrooms, despite the physical changes associated with student devices, the day-to-day operations of teaching and learning have not really changed. Without a solid proof case as to the benefits, many teachers remain reluctant to reimagine their instructional practices to enable more sophisticated uses for the digital tools.

The limits of the transformation beyond the outward appearance of students with devices in hand are evident when the teachers report on the actual impact of technology use in the classroom on their students. While 49% of classroom teachers say that their students are more motivated to learn and are gaining a better understanding of class materials because of their use of technology within instruction, only 15% noted that their students demonstrate higher proficiency on tests as a result of the technology usage (http://www.tomorrow.org/speakup/speakup-2016-ten-things-teachers-national-digital-learning-november-2017.html). Additionally, only one-third of teachers ascribe students' enhanced abilities to understand difficult concepts, apply knowledge to practical problems, develop workplace skills, or take ownership of learning to the use of classroom technology. This challenge of motivating teachers to change their instructional practices to better leverage digital tools is therefore a chicken-egg dilemma. Without the tangible benefits that are core to teachers' self-efficacy, teachers are reticent to reimagine their teaching strategies. However, the paucity of those tangible benefits may be because the teachers are not seamlessly or effectively integrating the digital tools within instruction and, thus, not reaping the benefits of transformed learning strategies. The reality is that motivating teachers to transform their practice and integrate mobile devices and digital resources within their instructional plans remains a significant challenge even with the strong presence of administrative support and direction.

The dizzying pace in which mobile devices have infiltrated the classroom has obscured in many ways thoughtful evaluation of the efficacy of current mobile learning strategies or the examination of how and why certain types of implementations and interventions affect outcomes such as student achievement. Increasingly, governance organizations including school boards and funding

Table 1 Metrics for evaluating the impact of digital initiatives

Metrics being used in school districts as reported by district administrators	% of district administrators in 2016 ($N = 603$)	% of district administrators in 2013 ($N = 933$)
Student engagement in learning	62%	64%
Teacher feedback	62%	37%
Student achievement results	60%	47%
Student feedback	53%	40%
Parent feedback	44%	21%
Student skill development	37%	31%
Quality of student projects	30%	28%

agencies are seeking more quantitative outcomes from the use of these tools within learning to justify the return on those investments. Consequently, administrators are starting to think differently about not only the metrics around digital initiatives but also the role of those metrics in community engagement. As illustrated in Table 1, while school leaders continue to rely upon student engagement in learning as the primary vehicle for evaluating impact, other factors such as student achievement results and feedback from key constituencies have increased in importance since 2013.

The recognition of the impact of these devices on achievement in particular lags behind the implementation statistics. While 52% of school site administrators report that their students are assigned a mobile device to use at school, only 41% acknowledge that the access has resulted in positive academic outcomes for those students (http://www.tomorrow.org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html). One-tenth state that it is too early to document those results. A smaller number of administrators (24%) see positive academic outcomes from students using their own mobile devices in school. Limited outcomes are also noted for online classes (42%), blended learning implementations (28%), and flipped learning models (18%). Contrastingly, administrators see positive outcomes already from the use of online assessments (52%) and using data to inform instruction (69%), tasks that more closely resemble substitution activities than the redefinition or transformative activities potentially enabled by mobile devices. While administrators may be highly supportive of mobile learning in the classroom, more work is needed at both the school, district, and governance levels to address how to best support teachers in the process of reimagining their instructional practices and how to meaningfully evaluate the impact of mobile devices in the classroom.

Inside the Classroom: How Students and Teachers Are Using Mobile Devices

American students and teachers today have unprecedented access to mobile devices to support classroom learning. With that access comes an expectation that the devices will be used to open up new learning vistas that will engage and extend learning beyond the classroom walls, for both students and teachers. For teachers, mobile devices support professional tasks by eliminating the traditional isolationism of the classroom and provide new ways for teachers to engage with peers in professional learning communities, strengthen communications with students and their parents through more frequent and timely interactions, and leverage mobile apps that can support their effectiveness as a teacher. Evidence of that reduced isolationism exists in terms of teachers' likeliness today to share online a homegrown lesson plan, graphic organizer, or other classroom aid. In 2008, only 5% of teachers had shared a lesson plan online; in 2016, 42% said they were likely to do that during the school year (http://www.tomorrow.org/speakup/speak-up-2016-k12-administrators-and-teachers-speak-up-about-open-education-resources-march-2017.html). The access to a mobile device not only makes communications and professional learning more easily accomplished but it also provides a unique opportunity for teachers to support student collaborations and investigations, and an increasing number of teachers are taking advantage of that potential for their students (Table 2).

Student access to mobile devices in the classroom today varies not only by grade level but also by product type or category, access location, and who owns the device as depicted in Fig. 1. Elementary students in grades 3–5 are almost four times more likely to be using a tablet in class than their older high school siblings (http://www.tomorrow.

Table 2 Teachers' digitally enhanced activities in the classroom – comparative view 2008 versus 2016

Digitally enhanced classroom activities	% of teachers in 2008 ($N = 29{,}715$)	% of teachers in 2016 ($N = 37{,}018$)
Learn something from an online video	27%	66%
Review data reports to inform instruction	12%	58%
Facilitate collaborative projects between students	22%	42%
Create investigations for students	20%	30%

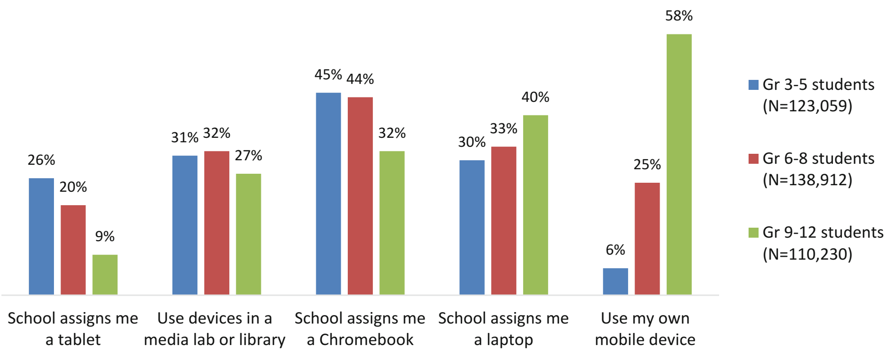

Fig. 1 Student access to mobile devices to support learning in school. (© Project Tomorrow 2017)

org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html). Chromebooks have established a strong foothold in the upper elementary and middle school years though twice as many high school students report being assigned a Chromebook in 2016 than in 2014, indicating that the web-based laptop may soon have a predominant base in high school classrooms as well (http://www.tomorrow.org/speakup/speak-up-2016-ten-things-everyone-should-know-about-k12-students-may-2017.html).

As illustrated, approximately one in three students in grades 6–12 still relies upon the school library or media lab for technology access when in school though that modality is on a steady decline. Contrastingly, in 2014, the media lab was used by 47% of students in grades 6–12. Reflecting the relaxation of many schools' policies around student use of their own mobile devices (called BYOD or bring your own device policies), 58% of high school students say they use their own devices to support learning when in class (http://www.tomorrow.org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html). Interestingly, one-third of those BYOD students are also using a school-assigned laptop or Chromebook, meaning that they are accessing multiple devices in class as needed to accomplish different academic tasks. This differentiated use of various devices for specific academic tasks is an emerging trend that represents how students may be taking a more sophisticated approach to mobile device usage than what educators might assume.

Since the advent of the first laptops, educators have been on the hunt for the holy grail of mobile devices for the classroom: a singular, uniform device that will serve all student academic needs and address institutional requirements for support, training, security, safety, and longevity. Administrators talk about one-to-one (1:1) programs within the context not just of one device per student but also as the identification of one product that can be used universally throughout their entire school or district from kindergarten through 12th grade and work equally well in the science lab as in Spanish class. For a period of time, that holy grail device was a smartphone, then a tablet, and more recently a Chromebook. The reasons why administrators want one device are understandable, but the goal is not realistic and directly thwarts efforts for greater personalization in learning. And yet in many districts, the hunt for that holy grail continues.

Students realize that their ideal learning environment should not be bounded by the limitations of one device per student but rather that ideal environment should support devices based upon what features and functions is best to meet the needs of a particular task. Instead of trying to make one device be all things, they want to use the right tool for the right academic task. This awareness stems from their familiarity with using various devices in their personal lives and appreciating the pros and cons of differentiated usage. Through those experiences, students have developed their own highly personalized typology for device usage that is not dependent simply upon the engagement level of the interaction per se but rather on the efficiency of the tool to meet the needs of a particular task. For example, a smartphone may be a highly convenient device to update your Instagram account with a photo of your lunch but is not the optimum tool for completing the application for that coveted summer internship at a local biotechnology company. Contrary to conventional wisdom, today's students are highly savvy about the utility and efficiency of digital

Table 3 Student typology for differentiated mobile device usage to support academic tasks

Academic task	Preferred mobile device for that task ($N = 238{,}813$ students in grades 6–12)
Create multimedia presentation or content	Laptop or Chromebook
Take online tests	Laptop or Chromebook
Write reports or essays	Laptop or Chromebook
Take notes in class	Tablet
Read an e-book or online article	Digital reader
Communicate with peers or teachers	Smartphone
Create and/or watch online videos	Smartphone
Use social media tools	Smartphone

tools to support their interactions and activities. With increased access to mobile devices in class, students are now overlaying a similar typology on schoolwork activities. Table 3 describes the preferences of students for a differentiated approach to mobile device usage for academic tasks.

Just as within their personal lives, students want to use the right tool for the right task to increase the efficiency of their work. Tablets even when equipped with external keyboards are a poor substitute for a laptop with a full keyboard when you need to write a ten page report for history class. Digital readers are designed to have optimum screens for online reading and prevent less eyestrain than reading on a tablet or laptop. The in-built cameras in smartphones support better content creation than other devices, especially when combined with mobile apps that support editing and streaming. Students highly appreciate the value of personalized learning that is customized to their needs, and using the right tools to support their learning tasks is a key part of that personalization formula.

The importance of the differentiated tool-task typology and its relationship with personalized learning provides a fresh new explanation for students' interest in using their own mobile devices in school. Students want to use their own smartphone, laptop, or tablet for three fundamental reasons: (1) their device is already personalized to support their needs with custom apps, bookmarks, and programs, (2) they can leverage their tool-task typology by using their personal devices in addition to school-provided devices, and (3) their personal devices may be more current and fully featured products than what the school can provide. Initially, school leaders' impression was that students only wanted to use their own devices so that they could circumvent school policies for social media access or to cheat on tests. Again the administrators' focus on the nouns of mobile learning, the policies in this case, blinded them to understand the relationships between personalized learning and using a personal mobile device.

School policies on student use of their own mobile devices have changed dramatically in the past 5 years. In 2011, 65% of school principals did not allow students to use their own devices at school. By 2016, only one-third of school administrators report having no BYOD policy in place (http://www.tomorrow.org/

speakup/Speak-Up-2016-Mobile-learning-June-2017.html). This change in policy however does not mean that students have greater access to their own devices to use for learning. New policies in 44% of districts stipulate that the use of student owned devices in the classroom is at the discretion of the classroom teacher; in 2011, only 21% of districts left that decision to the teacher. This shift in decision-making authority means that students may be able to use their smartphone to research alternative views on the First Amendment in their American history class, but not be able to access Kahn Academy videos on their tablet in math class during the very next class period. While many districts were intrigued with BYOD policies initially to avoid large-scale investments in devices for student usage, that need is no longer paramount as increasingly schools are providing their students with devices, notably the lower cost Chromebooks. Correspondingly, 44% of middle school students and 38% of high school students continue to identify the inability to use their own mobile device at school as a significant obstacle to school technology use (http://www.tomorrow.org/speakup/Top-10-Things-Everyone-Should-Know-about-Todays-Students-and-Digital-Learning_pres.html). This obstacle is not fully appreciated by the technology leadership in most schools however. Only one-quarter of school and district technology coordinators and directors acknowledge that their students could still have a problem using their own device at school, even with BYOD policies in place.

Another interesting by-product of the increased access that students have to mobile devices in school is the reluctance of schools to allow students to take the devices home. Only 14% of teachers say that their students are allowed to take home their assigned, school-provided mobile devices to use for homework or to continue learning (http://www.tomorrow.org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html). The increased use of digital resources in the classroom and implementation of new classroom models such as blended and flipped learning often requires students to have out of school access to appropriate devices and the Internet. While some students may have appropriate, safe, and consistent technology access when they are at home, approximately one-fifth of students in grades 6–12 report being impacted by the "homework gap" where they are unable to do schoolwork due to a lack of access beyond the classroom (http://www.tomorrow.org/speakup/speakup-2016-addressing-homework-gap-september-2017.html). Despite advances in access to mobile devices at school, today's students are too often caught in a mobile device dilemma. If they have a personal mobile device, they may not be able to use it in the classroom if their teacher prohibits student-owned device usage in his/her classroom. And if they have a school-provided device, they may not be able to take it home to continue or extend their learning. The result is a patchwork of disjointed access and unrealized potential that does not take into account what the students already know about mobile learning:

- Using the right tool for the right task improves efficiency and effectiveness.
- Personalized learning is dependent upon the ability to choose your own best tool.
- Mobile devices support untethered learning that extends the potential of learning beyond the classroom and the school and outside the hours of the school day.

- Mobile devices empower self-directed learning and the creation of a healthy ethos for lifelong learning.
- It is not about the devices. It is about what the devices enable you to be able to do.

Empowering a Student Vision for Learning Through Self-Directed Mobile Learning Experiences

For today's students, learning is a 24/7 enterprise. The school day encompasses just a small part of the learning continuum that students experience every day. In many ways, the school and classroom has lost its long-held positioning as the exclusive purveyor of knowledge. Today, students have access to information and knowledge at their fingertips through the ubiquitously connected mobile device in the palm of their hand. This access has certainly transformed the way students access information, but in addition, it has also created a new ethos around learning, whereas students feel they have a right and a responsibility to self-direct their own learning enterprise. Students feel that untethered learning that is not bound by the limits of their teachers' knowledge or the resources of their local physical community is the best way for them to be prepared for inclusion in a global society. Mobile devices enable untethered learning and provide an easy and convenient way for students to not only supplement what they are learning in school but also to be able to self-direct a new, personalized learning process around areas of their own interest and address individualized purposes. In many ways, how students are utilizing mobile devices on their own to access content, to communicate and collaborate with experts, and to develop workplace skills is a truer representation of the potential of mobile learning than what is exhibited today in many classrooms. The examination of how students are empowering a new vision for learning through their self-directed mobile experiences beyond the sponsorship or facilitation of their teachers has the potential to provide significant new insights into what could be possible in America's classrooms. Appreciation of these insights requires that students are respected and listened to not just because of their status as technology savants but as essential stewards of their own learning innovations.

Student Personal Access to Mobile Devices

Over the past 10 years, students have been increasingly coming to school with a personal familiarity with mobile learning that outpaced current usage in their classroom. This familiarity is based upon students' better access to mobile devices outside of school. Whereas the types of devices changed over time from 2007 to 2016, a common thread during this period was the steady increase in personal device access for students from kindergarten through high school as noted in Figs. 2 and 3.

Like the rest of society, students migrated from cell phones without Internet access to smartphones with Internet connectivity. The declining costs and increased functionality enabled a new tipping point in mobile access with 90% of high school

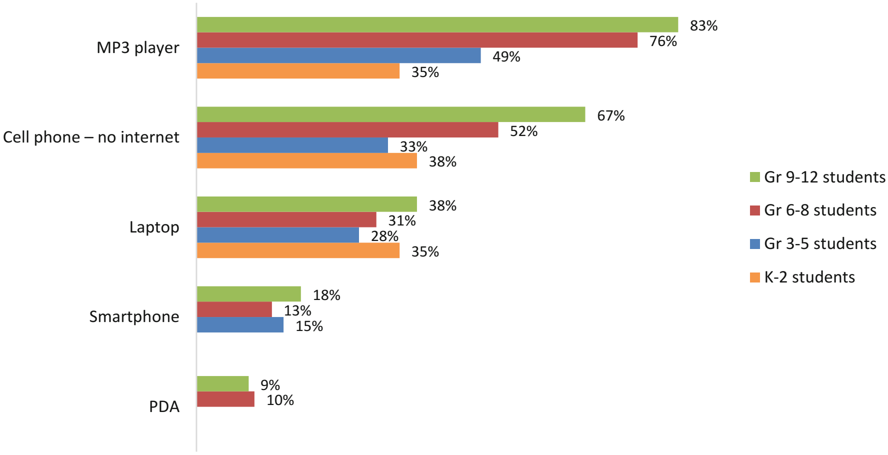

Fig. 2 Students' personal access to mobile devices in 2007. (© Project Tomorrow 2008)

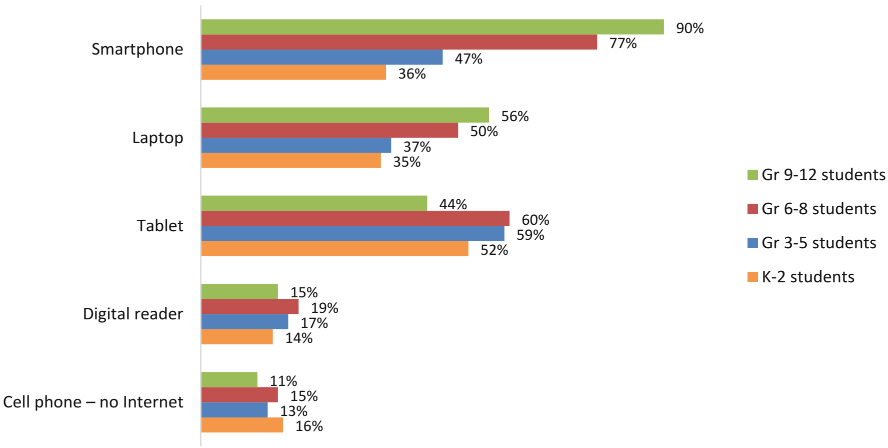

Fig. 3 Students' personal access to mobile devices in 2016. (© Project Tomorrow 2017)

students having a smart device in 2016 (http://www.tomorrow.org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html). The advent of tablets and digital readers within the market is reflected in the students' increased access in 2016 as well. New mobile product offerings are appearing within the students' portfolio as well with 12% of students in grades 6–8 and 8% of students in grades 9–12 also reporting that they have a personal smart watch (http://www.tomorrow.org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html).

Beyond the shock and awe of the percentages of students, particularly younger elementary students, with personal mobile devices, several key characteristics of this access are important to note as it supports self-directed learning. First, in most cases, students do not have only one device but rather they have multiple devices they can access depending upon task, preference, or convenience. Second, access to Wi-Fi through their devices is an enabling agent. It is not just about using the calendaring function to organize activities but rather how the Wi-Fi access enables the sharing of calendars with friends and family, thus increasing efficiency and connect-ability. Third, this new ethos of self-directed learning is not limited to just older students as many adults may presume. Rather, the increasing equity of access to devices empowers students of all ages to self-determine the direction of their own extended learning outside of school. Finally, the perception that student access to personal devices is only prevalent or pervasive in suburban communities where economic conditions support students having the latest Apple iPhone is incorrect. Students from urban or rural communities or from school identified as Title 1 schools (a common proxy for serving high-poverty families) were only slightly less likely to have access to these devices. For example, 77% of all middle school students reported having a personal smartphone (http://www.tomorrow.org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html). In urban, rural, and suburban communities, those percentages are 75%, 75%, and 80%, respectively. Additionally, 76% of students in Title 1 schools say they have a smartphone. While it is possible that product models or currency may differ, the fact that students across all of these communities and school types have access to a mobile device with Internet connectivity supports the idea that the potential for self-directed learning is not just for the privileged. As demonstrated in other sectors of society, personal mobile devices can be tools of equity.

Self-Directed Mobile Learning Experiences: Beyond the Classroom

Many educators are often unaware that students are regularly using their own personal mobile devices to support self-directed learning outside of school. This lack of awareness can be traced to adults' perception that the value of mobile devices in the classroom is centered almost exclusively on engagement and a lack of recognition of other benefits valued by students including the development of workplace skills, extending learning, and career exploration opportunities. Given this bias toward seeing engagement as the only benefit, teachers and administrators therefore question why students who are presented with so many other engaging activities outside of school would use their devices for learning purposes. Unfortunately, they are blinded by the engagement valuation.

As reported by the Speak Up Project, 58% of students in grades 6–8 and 54% of students in grades 9–12 say that they use technology more outside of school for learning than they do in school (http://www.tomorrow.org/speakup/speak-up-2016-ten-things-everyone-should-know-about-k12-students-may-2017.html). While their mobile devices provide the access to unlimited sources of online information and content, the impetus for these self-directed learning experiences rests firmly with students' desires to determine their own educational destiny and pursue academic passions beyond the classroom. A key characteristic of these self-directed learning

Table 4 Students' self-directed digital learning experiences using their mobile devices

Self-directed learning activity	% of students in grades 6–8 ($N = 138{,}912$)	% of students in grades 9–12 ($N = 110{,}230$)
Review websites about topics I am interested in	77%	79%
Watch a video to learn how to do something	75%	76%
Tap into social media to learn what others are doing or thinking about a topic I am interested in	37%	51%
Tap into social media to identify people who share my interests	42%	49%
Play an online game to learn more about a topic	53%	44%
Find experts online to answer my questions	33%	41%
Watch a TED Talk about people's ideas	40%	38%
Use online writing tools to improve my writing	38%	31%

experiences is that the activities are purposeful. In general, four purposes or motivations drive students' use of various digital tools within these self-directed experiences:

- Self-remediation: interest in self-improvement in an academic subject
- Skill development: desire to learn skills they consider important for future success but not necessarily taught in school
- Curiosity: inquisitiveness about an academic subject or learning more about something discussed or learned in school
- Career development: exploring various career fields or future educational opportunities to assess personal fit

Beyond homework and assigned schoolwork, students are tapping into a wide range of online resources to support these purposeful self-directed experiences and to fuel their own academic interests as illustrated in Table 4. Despite some differences between middle school and high school students such as with online games and social media tools, the central theme prevails that beyond teacher sponsorship or direction, students are leveraging digital tools to support a new type of learning paradigm, one where the student is directing the process, outcome, and valuation.

From videos to websites, students are resourcefully seeking skills and ideas to support their own learning processes and to address very specific goals or purposes.

With so much emphasis nationwide on college and career readiness and preparation, students' use of mobile devices to support self-directed research on different career fields is particularly interesting. Traditional career exploration activities such as summer camps, afterschool programs, competitions, or even career technical education classes at school hold less interest for students today. However, new emerging uses of digital tools, including mobile-enabled experiences, are gaining and retaining student attention. Such experiences include playing an online or digital game about a career field (42% of students in grades 6–8 endorse this concept), watching "day in the life" videos about different careers (39%), and using mobile apps or websites to learn more about careers (34%) (http://www.tomorrow.org/speakup/speak-up-2016-ten-things-everyone-should-know-about-k12-students-may-2017.html). The key characteristic in these emerging exploration methodologies is that the student is in charge of the experience and self-directing how they interact and consume the content on a highly personalized basis. The mobile devices therefore not only enable self-directed learning but also provide opportunities for a more personalized career exploration experience than traditional means. The self-directed learning experiences that students are facilitating through their mobile devices have another unintentional effect. Increasingly, through these experiences, students realize not only that they enjoy and benefit from the self-determination process but their aspirations for better in-school experiences become clearer as well.

For the students, the evolution of mobile learning, and the assessment of the value of using mobile devices to support learning, is not predicated on the experience they have using these devices in school. Rather, their valuation on mobile learning is based upon how they are using their own devices outside of school and beyond teacher sponsorship or direction, to empower a new learning paradigm, one in which they are in control of the learning process and that process subsequently, is both purposeful and personalized to address their interests and needs. The mobile-enabled, self-directed learning process is the embodiment of the student vision for learning where social interactions and collaborations are paramount, the learning is untethered and open, and the use of the digital resources supports context and purpose. It is with this mind-set that students envision their ultimate classroom experience.

The Ultimate Classroom: How Does the Student Vision Align with Educator Expectations?

Students articulate the value of using technology to support learning very differently than educators. Teachers (75%) and administrators (83%) emphasize that the use of digital resources and tools in the classroom including mobile devices increases student engagement in learning as the primary benefit (http://www.tomorrow.org/speakup/Ten-Year-Retrospective-on-Mobile-Learning-Leveraging-the-Past-to-Invent-the-Future.html; http://www.tomorrow.org/speakup/Speak-Up-2016-Mobile-learning-June-2017.html). A smaller percentage of teachers (65%) see value in using the devices in the classroom as a way to prepare students for college or a future job. Approximately 50% of teachers acknowledge that students have greater access to digital content when mobile devices are in the classroom. While these are all important outcomes, the students' assessment on value of digitally based learning is more focused on how these tools support a transformed learning experience for them personally. As stated earlier, the educators' assessment of mobile learning value is insufficient when the student perspective is taken into account. Students report the following types of outcomes that they associate with digital learning:

1. I am able to learn at my own pace.
2. I am developing creativity skills.
3. I understand what I am learning better.
4. I am learning in a way that fits my learning style.
5. I am applying what I am learning to practical problems.

Students acknowledge a level of increased interest or engagement in what they are learning when digital tools are employed effectively, but that benefit is of lesser importance than the ones identified.

It therefore follows that when envisioning the ultimate classroom or learning environment, students and the adults in their learning lives including teachers, administrators, and parents are on very different pages as illustrated in Fig. 4. Students in concert with teachers and administrators appreciate the importance of every student having access to a mobile device, be it a Chromebook, laptop, or tablet. The same is true for school-wide Internet access.

However, having a mobile device and Internet access does not fully support the students' vision for a new learning paradigm or their ultimate classroom. Within that vision, students want access to mobile apps and game-based environments to support contextual or experiential learning, virtual reality experiences and media creation tools that present opportunities for untethered learning, and the use of social media vehicles that promote collaboration and communication with experts and thought leaders even beyond the classroom. These are examples of the types of tools that students will use to create content, understand context, and develop

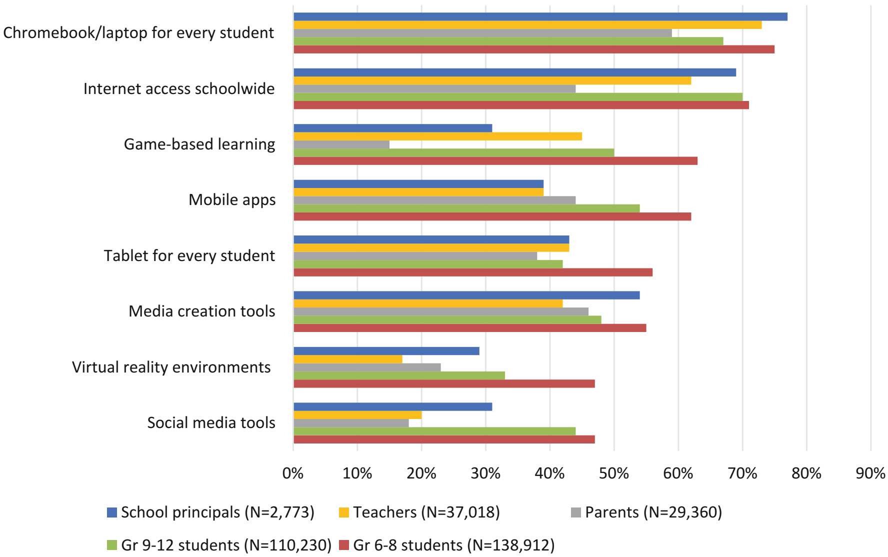

Fig. 4 Envisioning the ultimate classroom – different perspectives from education stakeholders. (© Project Tomorrow 2017)

collaboration skills, both in the classroom and on their own. For the students, these creation/context/collaboration tools are not optional but essential as they bring the verbs of mobile learning to the forefront. These tools when used in conjunction with the nouns of mobile learning (the devices, the apps, the policies) stimulate outcomes such as personalizing learning, developing workplace skills, and extending learning beyond the school day.

Some administrators, teachers, and parents want to see these creation/context/collaboration tools in their ultimate school vision as well. The percentages of adults supporting these tools except for principals' endorsement of media creation tools are less than the students, however. That translates into a potential lack of support or motivation for making such tools available to students for classroom usage and decreased teacher interest in changing their instructional practices to integrate these tools effectively. However, trend analysis of teachers' perceptions indicates that changes in valuation around these tools may have a precedent. Using this ultimate school scenario as a barometer of changes in perceptions, teachers have made large strides forward in their valuation of mobile devices in the past 8 years. In 2008, only 40% of teachers included a laptop for every student in their ultimate classroom vision, and only 14% visualized a time when a tablet for every student would be optimum (http://www.tomorrow.org/speakup/2008NationalFindings.html). Today, 73% of teachers endorse a 1:1 laptop program, and 43% feel the same about assigning tablets to students. Three insights from the students' experiences may help teachers (as well as administrators and parents) see the value of the tools of creation, context, and collaboration within a mobile learning environment: (1) how students are using these and similar tools outside of school to self-direct learning, (2) thinking beyond engagement to include benefits that support personalized student learning, and (3) suspending the focus on the nouns of mobile learning so that the verbs can drive more efficient and effective usage and, subsequently, more meaningful outcomes.

Conclusion

In so many ways, the real journey of mobile learning is just beginning. For the past 10 years, the focus in many schools and districts was on the nouns of mobile learning, the devices, the apps, and the policies that had to be in place before any meaningful assessment of value could take place. Along that implementation path, too many educators became fixated exclusively on the engagement value of putting a mobile device in the hands of a student, without carefully examining the benefits from the perspective of the student. As access to devices has steadily increased in both schools and homes, a curious thing happened on that frontier land of mobile learning. Beyond the sight lines of educators, and without deliberate prompting from their teachers, students from kindergarten to high school began using their own and school-provided devices as tools of empowerment, not just engagement. With mobile devices grasped firmly in the palms of their hands, students embraced self-directed learning beyond the sponsorship of teachers or pacing guides, personalizing learning paths that take into account their personalized interests and passions as well as their aspirations and purposes, extending learning beyond the four walls and regimented desks of their classrooms. As a result of these experiences, students have a clear vision of what learning could be and articulate that vision around a guiding principle: learning should be social-based to support relationships and collaborations, untethered from the physical limitations of their classroom or community, and digitally rich to provide meaningful context and purpose. Empowered by their devices and tools that help them create content, context, and collaborations, the students have transcended what is happening in their classrooms. This presents a unique opportunity for educators to put aside traditional norms and to learn from their students. As we dawn on a new era in mobile learning, the prospect exists for educators to think beyond the nouns of mobile learning and to fully embrace the verbs that bring context to new mobile-enhanced learning environments by focusing on the types of meaningful outcomes our students are already experiencing. As the new journey begins, we should be assured that our students will be there to help us.

Barriers to Mobile Learning Advancements in the United Kingdom 55

David Whyley

Contents

Abstract

Since its ambitious, visionary beginning in 2003 in Wolverhampton, mobile learning continues to expand and evolve in the UK. Mobile technologies, as well, continue to expand and evolve with tablets, Chromebooks, and even laptops viewed as "mobile" devices. Drawing on a range of resources (e.g., interviews with 16 influential practitioners), then, this chapter addresses the question: what is the status of mobile learning in the UK some 15 years later? In developing an answer, we explore mobile devices, models of mobile device ownership, and the pedagogical uses of mobile devices for mobile learning.

Keywords

Mobile technology · Digital strategy · BYOD1:1 · Cloud storage · E-books personalized learning

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Introduction

In 2003, the belief was that mobile learning would change education in the UK. This belief was fuelled, at least in part, by the city of Wolverhampton launching the Learning2Go Project (Whyley 2014) which was "the largest collaborative Mobile Learning initiative for pupils in the UK" (Wolverhampton e-Services 2009, para. 2). The goal of the project was to give students "anywhere, anytime access" to an Internet-connected computing device, regardless of their financial circumstance. To that end, over 1,500 students in 18 schools were provided with mobile devices. After discussing the ambitious, visionary beginning in 2003, this chapter will address the evolution that led to the current status of mobile learning in the UK.

The definition of mobile learning developed in the Learning2Go Project can still serve us well: "Mobile Learning is the type of learning that takes place when the learner has some kind of mobile computer, making use of its connectivity, location awareness, content and applications to learn at a time and place of the learner's choosing" (Whyley 2014). What has changed, however, is the definition of "mobile computer." Initially, in the Learning2Go Project, a mobile computer meant a handheld computer. But, the definition of what counts as a mobile computer has since broadened to include laptops, tablets, netbooks, Chromebooks, and, of course, smartphones. Given their ubiquity and reduced dimensions, all of these devices still enable a learner to learn at a time and place of the learner's choosing.

Inasmuch as there is a paucity of reports on the current state of mobile technology and mobile learning in the UK, during the first 3 months of 2017, the author interviewed 16 influential practitioners in the field of educational technology in the UK. This chapter, then, is based on those interviews and provides a first-hand, qualitative picture of mobile technology and mobile learning in the UK. Because of their current positions, some of the individuals preferred not to be quoted directly, so summaries of the observations of those "influencers" (Gladwell 2000) are presented as they align with the following themes:

- Mobile technology: types of devices
- Models of mobile technology ownership
- Mobile learning: pedagogical uses of the mobile technology

It is important to point out that the UK is made up of four different countries – England, Northern Ireland, Scotland, and Wales. Each country has its own government and education policy even though their Members of Parliament meet in Westminster to govern the whole of the UK. However, the way in which education is supported in each of those countries is different.

1. Northern Ireland, Scotland, and Wales have a centrally supported school system which can provide a more coherent, strategic focus to the use of educational technology in general, and mobile learning, in particular. In Northern Ireland, the provision of mobile technologies is part of a strategic approach with a 5-year managed service which provides core infrastructure and systems, allowing

schools more freedom to explore their own mobile learning initiatives. Scotland and Wales similarly have a countrywide learning platform: Glow in Scotland (Glow Digital Learning for Scotland n.d.) and Hwb in Wales (Hwb Digital Learning for Wales 2017). These latter two platforms allow for a consistency of approach across schools wishing to implement mobile devices. Scotland also provides strategic support for those schools that choose to embrace mobile learning.

2. In 2010, the UK closed the government-funded British Education Technology Agency (Government to close BECTA 2009). Since then, there is less centralized coordination in England, with autonomy being given to schools and school leaders via the Academy and Free School initiatives (BBC 2010). Unfortunately, many schools in England have not received the impartial advice needed to deploy today's complex technological solutions in general and mobile learning in particular. This has made pedagogical and technological innovation more challenging in England compared to the other three UK countries.

Mobile Technology: Types of Devices

Mobile learning in the UK is now characterized in schools by the use of tablet and laptop devices. The 2016 British Educational Suppliers Association (BESA), National Association of Advisors for Computers in Education (NAACE) Leadership Briefing Paper showed that 68% of primary and 59% of secondary schools felt that they were under resourced with tablet computers, indicating that they were interested in improving on that situation. Spending on laptop computers was also regarded by schools as a priority (BESA NAACE Leadership Briefing Paper 2016).

In the UK, over the past six years, the devices used for mobile learning have shifted from being predominantly small portable handheld technologies to being predominantly tablet-based, finger input devices. Of these devices, iPads predominate, with fewer deployments of Android devices. (Learning2Go 2.0 opens doors to iPads and Android 2012). Many respondents articulated the view that the ease of use of the iPad had made it a favorite with teachers and learners alike. However, there is also a general view that as schools have gained experience in the use of iPads, they are beginning to understand its limitations. And, with requests for the iPads fading, there is fresh interest in the Microsoft Surface device due to its keyboard and digital pen input. Laptops, of course, are commonplace, and there is recent interest in Chromebooks.

Today's smartphones are the closest relative to the Pocket PCs which started the mobile learning revolution in the UK in 2003. They are now very powerful personal computers with excellent cameras (still and video), built in global positioning systems (GPS), and highly efficient browsers that can easily connect to the internet. Paradoxically, it is the very efficient way in which smartphones connect to the Internet and social networks that has made almost all schools in the UK wary of allowing their use in class for learning. Being an effective school leader requires balancing the risks for the learners in the care of the school. At the present time, the overwhelming majority of school leaders regard the benefits of smartphones far outweighed by the risks they pose (Barkham and Moss 2012).

This position has been further reinforced by popular newspaper headlines such as “Schools that ban mobile phones see better academic results” (Doward 2015) or “Banning smartphones from classrooms could damage education, warn researchers” (Knapton 2016). School leaders are confused and generally have school policies that ban smartphone use in lessons, and some schools even ask for smartphones to be handed in to teachers at the start of the school day.

Models of Mobile Technology Ownership

The most common device ownership model in schools in the UK is where the school itself has purchased the devices for use in school and the devices remain in school. The majority of schools purchase shared sets of devices. These are usually purchased in sets of 30, and placed on mobile carts, for primary school so that 1:1 (one computer for each student), 1:2, or small group access can be provided. In secondary schools, shared devices on mobile carts for a department or learning areas are commonplace.

Typically, learners are not allowed to take the devices home. Prior to 2010, there was active UK government support via the “Home Access” initiative (BECTA 2010) to enable families and learners to gain access to devices and the Internet in order to enable them to engage in education and the wider social and economic benefits of being online. This was supported and enabled via a charity, now called the Learning Foundation (Learning Foundation 2018a). The Learning Foundation states that “For 15 years we have been providing independent advice and guidance to a wide variety of schools on the best way to introduce 1:1 technology, where every child has their own device to use in class and at home. During that time we have reached 250,000 children by helping 1,000 schools and all of this has been supported by 40,000 parents” (Learning Foundation 2018b).

1:1 – One Computer per Student

The overwhelming view of the 16 experts interviewed is that 1:1 (Penuel 2006) in the UK is only seen in a very small number of schools. One experienced technologist who supports a large number of schools in the Midlands of England went so far as to say, “*I don’t know any working 1:1 schemes in primary schools. I’m aware of secondary schools that have tried 1:1 and failed. I feel the lack of success has to do with the teachers/staff not actively preparing to teach with devices. As well, there are still some issues with the reliability of devices themselves, for example, long charging issues and work flow challenges.*” Also, all respondents agreed that funding for 1:1 remained a challenge for all but fee-paying private schools.

Specific points relevant to the less-than-rapid transition to a 1:1 mobile learning model in various parts of the UK include:

- In England, between 2010 and 2013, there was a surge of 1:1 projects centered around iPads but this has faded out as changes to funding have squeezed school finances, making the majority of head teachers risk averse. Some private schools have begun to make it compulsory for parents to provide a tablet device for each new student when parents enroll their children.
- Since 2010, there has been very little independent cost-benefit analysis or analysis of benefits to school improvement research to assist school leaders in their decision to go the 1:1 route. This has been a contributory factor in the slow adoption of 1:1 devices in the schools in England.
- In Northern Ireland, there are very few examples of 1:1 initiatives primarily due to budgetary issues. Some local authorities are engaging with projects targeting social deprivation.
- In Scotland, 1:1 is not widespread, but there are pockets of 1:1 use particularly in Edinburgh City, with some schools engaging with 1:1 device rollouts.

Bring Your Own Device (BYOD)

The experts in educational technology interviewed for this chapter were of the overwhelming opinion that "bring your own device" (BYOD) (Paddick 2016) was not very widespread in UK schools. In 2016, Steve Forbes (Forbes 2016), head of RM Networks, commented that, in his opinion, 29% of high schools and 9% of primary schools have some form of BYOD in place. Research for this chapter would seem to indicate that this is an overly optimistic point of view.

A number of reasons for the lack of uptake of BYOD exist. The premise seems so simple; many learners already own their own laptops, tablets, and mobile phones, so allowing them to bring them to school and use them in lessons would solve the budgetary problems for the schools. However, based on the initial projects, the reality is much more complex. Reasons cited for lack of greater BYOB success include:

- Many respondents cited leadership fears regarding e-safety as a major barrier. School leaders are not confident of the security of the data, information, images, and video contained on devices being bought from home and the accompanying risk that this poses to other learners and the school network.
- There are also practical, unresolved issues around liability for insurance, equipment breakages, and responsibility for the learning devices when carrying them to and from school. The question of "If a school asks for a device to be brought in to deliver the education at the school, then is it liable for the device?" has not yet been answered.
- There is also the question of how a teacher might prepare lessons for multiple device types and multiple operating systems being used in any lesson at any time? How might the school ensure that each student has the required apps or programs required for the lesson?

- How do schools address the question of inequality if a learner brings in his or her device and it is obsolete and incapable of running the necessary software or content? That learner may also have inadvertently been put in a potential bullying situation caused by device envy. In September 2016, the Midlothian Council in Scotland introduced an ambitious digital learning strategy which aspires to enable BYOD for all of its learners over the next few years (Midlothian Council 2016). It tackles the inequality problem head on by stating that schools will provide high-powered devices for use by learners from more disadvantaged socio-economic backgrounds.
- In the present state of educational technology development, the software and applications have not yet reached the nirvana of being truly device agnostic and platform independent. The result is that where BYOD is implemented, it is only able to support the lowest common denominator in learning – the browser. For the majority of UK schools, then, BYOD has been put on the "too hard to do" pile, for the moment.

Mobile Learning: Pedagogical Uses of the Mobile Technology

The devices may be mobile – but are they being used for mobile learning? While access to suitable devices has been on the increase, their use and the development of appropriate mobile learning pedagogy is extremely variable. As one leading expert in educational software development explained "*When I work regularly in schools – I do occasionally see transformational lessons - for example learners developing their own apps, but all too often the devices are used to deliver the weekly iPad Lesson.*"

The following perceptive analysis was provided by another long-standing expert in the field of mobile learning who currently works with a number of schools across a region in the north of England:

> I think that tablet learning is pretty widespread, but describing it as mobile learning is wrong. Most schools using devices are as class sets, sometimes 1:1 and only used by that child, but rarely allowed to go home. Many schools do have shared class sets; this typically occurs in about 2–3% of schools. The majority of tablet uses are as research devices and accessing web games for the children and use of the camera or assessment apps by teachers. Using cloud services such as "Showbie" (Showbie 2018) does add a great cohesion to work; but teachers tend to use it to replace handing stuff out, rather than exploiting it as the digital classroom, with the physical classroom being a place they just happen to meet during the week. Unfortunately, the focus of their use does not begin with pedagogy, rather with 'what the device can do'. Yes, it makes some lessons a bit more engaging and makes some traditional organisational ways of working more efficient, but few pupils are expected to use mobile devices in the way that an adult mobile worker would so that idea of developing independence and personal agency is rarely exploited.

The mundane use of expensive tablet devices was echoed by the majority of those interviewed.

Many respondents reported that they observed classes using the devices mainly for Internet searching – but then wrote up the research in exercise books with pen or pencil. Use of the camera for documenting learning and recording activities was seen as being low, at 10% of all use. Educational apps and content were seen as between 20% and 30% of use.

The use of E-books was central to the early development of mobile learning, and it is still a mainstay of the use of mobile devices in the UK. Apps such as the British Educational Training and Technology (BETT) award winning "Book Creator" (Kemp 2015) form the mainstay of use on the whole range of mobile devices used in UK classrooms. In comparison to the past, currently it is much more straightforward to create an E-Book on a device and incorporate videos, sound files, and even automatically turn pages. Publishing to a shared library is also possible in order to build an audience for the E-book creations of learners.

In Northern Ireland, Scotland, and Wales, it was reported that where the devices were used in conjunction with the countrywide, cloud-based services (e.g., Microsoft Office 365), the use of devices was much deeper. In Scotland specifically, the view expressed was that deeper use was achieved when the school moved beyond just providing access to Internet reading apps to providing a wider range of document creation tools such as Microsoft Sway, Microsoft OneNote, or Google Apps for Education.

Since the inception of mobile learning, managing the assigning of work and its subsequent tracking and assessing is crucial to its effective implementation. In the pioneering days before cloud services arrived, a range of mechanisms were employed (e.g., beaming using the devices' infrared capabilities) to keep track of the work that teachers assigned and learners subsequently created. The introduction of cloud services and storage, such as Microsoft Office 365 and Google Classroom (Keeler n.d.), have made the potential of seamless integration of digital work across all platforms a distinct possibility.

Unfortunately, that seamless integration has not yet occurred. A myriad of factors are limiting the uptake of efficient workflow on mobile devices, for example:

- Sharing devices among multiple students makes syncing each student's work significantly more complex.
- iPad apps tend to store a student's creations inside the app – not inside the device's file system.
- Each manufacturer (e.g., Apple, Microsoft, and Google) tends to have its own "ecosystem" and each ecosystem is relatively unfriendly to the others.
- Schools in the UK, in order to comply with data security laws, need to be very careful about where data from using an app is stored – especially when some of the ecosystems do not guarantee that storage of data will remain inside the UK.
- The UK does not have a cohesive, strategic framework for the storage of student work (e.g., there is no standard, agreed-upon student digital portfolio).
- While "single sign-on" is the goal, currently, students – and thus teachers – must keep track of multiple login names and passwords.

For example, one expert who works across schools in the North of England observed that: "*Where cloud services are used well it becomes the first focus of their work with the devices. This tends to be in schools where there is a degree of 1:1 use* *with the same class and the same teacher. Most shared sets [of devices] are simply handed out for a specific task like they would have handed out a piece of paper and a text book!*"

Another expert summed up the way in which the majority of his supported schools approach the use of the iPad. "*Workflow is mainly based around the camera roll where children may have taken a screen shot or taken a photo and this is used as evidence or assessed manually when printed off. Children are being encouraged to print off their photos for the teacher to view. Other workflow solutions such as Apple Classroom, Google Classroom, and Microsoft Classroom, allow teachers to manage workflow for their students*" (Laycock 2017).

Working as an independent consultant across a range of UK schools, another expert observed, "*Every school I come across seems to find their own solution that works for them. Examples include using cloud solutions such as Google Classroom, Apple Classroom* (Apple 2016*, March*) *or Office 365. Others use tools for iOS such as SeeSaw* (SeeSaw 2018) *or Showbie.*"

Conclusions: Mobile Learning in the UK

There is still a great deal of enthusiasm for mobile learning in the UK. There are a number of teachers, technologists, and school leaders who continue to carry out pioneering work, and mobile technology is increasingly becoming available in the UK schools. However, the mobile learning transformation that the Learning2Go Project is still a work in progress.

As mobile devices have become more ubiquitous, a blurring between the concepts of mobile learning and simply using mobile technologies in the classroom has taken place. However, there is a difference between the two concepts. True mobile learning, as defined earlier in this chapter, cannot easily be delivered if personal, 1:1, ownership of mobile technology is removed. Benefits to using shared devices can be great, but the specific learner characteristics such as personal organization, absorption, decision-making, responsibility for learning, self-esteem, and communication will be difficult, if not impossible to achieve without personal, 1:1, ownership.

Still further, until the key issue of seriously valuing learners' digital work is tackled, it is difficult to see how mobile learning can become more widespread. Learners' digital work is not currently valued by school management systems and formal inspection services as highly as pupils' work created using traditional pen and paper methods. Indeed, the teaching profession has had over 100 years to develop highly efficient and sophisticated ways of marking and assessing work written in exercise books or in cardboard folders. In contrast, while students seem to be producing digital artifacts, it is difficult to find robust examples of the effective assessment of those digital materials.

In Northern Ireland, Scotland, and Wales, there is a glimmer of hope for the future of mobile learning, as their school inspection services are beginning to recognize and report on the way in which schools integrate technology into teaching and learning. On an international level, the 2015 PISA tests (OECD 2015) showed that large scale sophisticated digital assessments could take place without the need for a biro (ballpoint pen) and an A4 writing pad.

The debate surrounding mobile learning goes to the heart of the question that should be asked by all school leaders. How are we preparing our students to thrive in the world in which they will live and work? Mobile devices (and their connection to the associated personal services) are clearly becoming an essential part of everyday life. Their use and the integration with work and social interaction will continue to increase. Personalized, 1:1, ownership of mobile devices with a fully integrated digital curriculum could provide the learner development that future adults of the mid-twenty-first century will need.

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The Implementation of Mobile Learning in Asia: Key Trends in Practices and Research

56

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Contents

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Abstract

This chapter explores the implementation of mobile learning in Asia, with a particular emphasis on K12 education. A series of 17 individually authored or co-authored country-by-country reports gives an overview of the penetration of mobile devices and the mobile Internet in society and in education. These reports indicate the ways in which such technologies are and are not being employed in teaching and learning, reflecting on the roles of the public and private sectors as well as schools and teachers in their implementation. Common mobile educational practices and their pedagogical underpinnings are outlined, as are associated research projects and publications. The chapter concludes by integrating insights from these reports to establish key regional trends and make recommendations for future mobile learning research.

Keywords

Mobile learning in Asia · K12 mobile learning · Mobile devices in education · Mobile technologies for teaching and learning · Mobile educational practices · Mobile learning research

Introduction

Mobile learning is rolling out at considerable speed across the world. Taking as its springboard the global overview in Churchill and Pegrum (2017), and the associated special issue of *Interactive Technology and Smart Education* (vol. 14, no. 2) on the theme of "Mobile learning, emerging learning design and learning 2.0," this chapter zeroes in on Asia, digging more deeply into mobile learning practices and research in 17 countries and locations across the region.

Scholars and practitioners from a large number of countries in Asia were invited to contribute short reports on the state of mobile learning in their various contexts, with reports being received from: Brunei, Cambodia, China, Hong Kong, India, Indonesia, Japan, Laos, Macau, Malaysia, Myanmar, the Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. It should be noted that for the purpose of this survey of mobile learning in different locations, it was logical to treat Hong Kong and Macau (each a Special Administrative Region, or SAR, of China) as well as Taiwan as separate contexts, each with its own distinctive trends and practices.

In order to ensure some commonality between reports, while simultaneously avoiding imposing too many restrictions on the diversity of views, general guidelines were provided in the form of key points which respondents were invited – but not required – to consider. It was suggested that respondents could comment on mobile Internet penetration and educational access in their locations; general trends in mobile technology adoption; major educational platforms or apps used or developed; major government or university educational initiatives, including in teacher education; major research projects and publications; and predictions for future mobile learning developments.

Individual authors or co-authors remain responsible for the reliability, comprehensiveness, and representativeness of their reports, as expressed in their own particular voices. It is important to recognize that each report represents a unique view of a given country or location, dependent on the perspectives and positionality of its authors or co-authors. As such, the reports should not be seen as complete accounts of mobile learning in each location, but rather as snapshots taken from the viewpoints of informed educators with significant local experience. It is hoped that bringing together such viewpoints will enlarge the understandings of a global audience of educators who may have had little personal contact with some of these widely varying settings.

The reports have been edited as minimally as possible for consistency, style, and length (though considerable variations in length are still present, reflecting differences in the original reports). Once the reports had been edited, they were coded for key themes by the three main authors of this study, who then collaboratively agreed on the presentation of these themes in the final discussion. The entire chapter, including all country reports and the culminating discussion, was then sent back to report authors for checking and to allow them to make additions, adjustments, and suggestions in light of the companion reports and the discussion themes identified. This led to a final review of the article by the main authors.

Country Reports

Brunei by Saiful Omar and Afzaal Seyal (Universiti Teknologi Brunei)

In 2016, smartphone penetration in Brunei reached 99%, total tablet ownership reached 62%, and laptop ownership increased to 93% (AITI 2016). The top four social media applications used via mobile technology are: WhatsApp (97.3%), Facebook (91.7%), Instagram (87.4%), and YouTube (80%). Individuals in the

15–34 age group have been the most active mobile and Internet users, engaging primarily with WhatsApp, Facebook, and gaming, and accessing content such as movies and TV series. At the same time, individuals in the 35–54 age group are more active with Internet banking and government e-services.

More than 90% of the Internet subscribers have access to fixed and mobile broadband (AITI 2016). Most users spend significantly more time accessing Internet information and social networks, taking pictures, sending emails, and accessing entertainment via mobile technology than via any other Internet-enabled device.

The use of mobile technology for learning is still at early adoption stage in Brunei. Nevertheless, the Ministry of Education Brunei Darussalam has been keen to explore possibilities for implementing mobile learning in schools, while the higher education sector appears to be exploring possibilities more actively. For example, the Universiti Teknologi Brunei (UTB) is taking a leading role in the adoption of e-learning. The School of Computing & Informatics of the UTB has been focusing on developing various learning apps through their undergraduate students' final year projects. Some examples of recent mobile app projects are: "Phonic Learning App," "Islamic Etiquette Mobile Game," "Enhancing the Learning of Malay Vocabulary," "Learning Numbers 1–20," "Year 1 Science," and "Gulintangan Kitani."

From a research perspective, more studies are needed to develop frameworks and explore the adoption and effectiveness of mobile technology. Such research might focus on exploring user perceptions, acceptance, and other critical factors for the successful implementation of mobile learning. A number of studies of student adoption of mobile technology in education at the UTB produced interesting results. Seyal et al. (2014) used a standard instrument to capture students' responses on the three basic constructs of the Technology Acceptance Model (TAM), including Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Attitude. The results suggest that PU remains the significant determinant of attitude, which in turn predicts intention for adopting mobile learning. Furthermore, Seyal et al. (2015) investigated student mobile learning adoption attributes based on the Diffusion of Innovation (DOI) framework and constructs including relative advantage, compatibility, complexity, observability, and trialability. The results suggest relative advantage and compatibility are the key determinants of adoption. Finally, Seyal et al. (2017) applied the Theory of Planned Behaviour (TPB) framework to the study of adoption attributes of mobile learning, including Subjective Norms (SN), Attitudes, and Perceived Behavioural Control (PBC). The results suggest that only attitude remains a significant determinant of adopting mobile learning technology. The results of these three studies suggest that the DOI framework is the most suitable predictive model of students' adoption of mobile learning in Brunei.

Cambodia by Kurt Bredenberg (Kampuchean Action for Primary Education) and Javier Solá (Open Institute, Cambodia)

The technological context in Cambodia is changing rapidly. By 2014, the number of mobile subscribers had topped 20 million users (Sokhean 2014). In 2016, the Open

Institute reported that 94% of Cambodians aged 15–65 had a phone and 48% of them a smartphone, a number that has grown very fast over the last 4 years (Phong et al. 2016). Urban youth under 25 are the group that is growing fastest in the use of smartphones and the Internet. For the education sector, this is opening up the possibility of schoolteachers and high school students using technology for teaching and learning.

The Ministry of Education, Youth and Sport (MoEYS) has decided to introduce Information and Communication Technologies (ICTs) as a subject starting in Grade 4 (it is currently only in Grades 11 and 12). It will be very difficult to access any devices at primary level, and even at lower secondary level (Grades 7–9), but the lower secondary part will be keyed to mobile devices, not computers, as no computers will be available for more than 1,000 lower secondary schools. Computers have already been partially introduced in upper secondary levels, and this will continue. At lower secondary level mobile devices, probably mostly used by the teachers, will support the teaching of Science, Technology, Engineering, and Maths (STEM) subjects.

Interesting work is also being carried out with early grade literacy. Nationwide tests of reading in Cambodia over the last several years have shown very low scores, with 54% of children failing a test of basic reading. As a result, the MoEYS is now revising its reading curricula; in addition, a number of civil society organizations have started to invest heavily in developing literacy software programs in the Khmer language with close linkages to the newly revised national reading curriculum. Notable educational software products in this regard include “Aan Khmer” (Grades 1–3) and “Smart Books” (Grades 2–3), which are closely linked with reading benchmarks set out by the Ministry’s Department for Curriculum Development. The profusion of mobile devices and use of social media networks in the country offer another new opportunity for dissemination of e-book applications.

Khmer language reading instruction in Cambodia has never really involved the use of differentiated classroom literacy structures that can give struggling readers the confidence they need to acquire reading skills (Abadzi 2010). The current readers are structured as a one-size-fits-all approach for children of all levels, with little guidance provided to teachers about how to address the needs of such children. Even if the MoEYS had developed print-based readers as a supplement, printing costs would be problematic, with textbook availability ratios for core subject textbooks hovering at around 69–70 per 100 students in Grades 1–3. The development of software programs such as Smart Books, which are electronic basals supplementing the core readers, offers significant promise for modulating reading programs according to the needs of individual readers. These basal e-readers possess special interactive features (e.g., digitized quizzes, animations, and audio to promote “multisensory” reading), combined with teacher protocols to promote leveled instruction that will help address the lack of differentiated literacy structures in classrooms (e.g., reading groups), which in turn will aid struggling readers.

Some of the key development partners supporting the MoEYS on literacy have also made significant strides in the electronic administration of Early Grade Reading

Assessments (EGRA) by using a well-known software application called "Tangerine," developed by USAID and the Research Triangle Institute.

One promising set of developments concerns teacher education. As more than 50% of teachers have smartphones and access to Facebook, this has become a priority channel to reach them with microtraining; indeed, the MoEYS has a Facebook page with over 1.8 million followers. A targeted intervention can be seen in a set of applications from the Open Institute and Voluntary Service Overseas (VSO) which are aligned to the English curriculum in Grades 4–6, and allow teachers who lack confidence in English to listen to what they are supposed to say in English during class; there are menus which allow them to go to any lesson or activity and listen to what they have to teach. Moreover, a new Master Plan for ICTs in Education is currently in development. This will place mobile at the center of the Ministry's teacher training efforts for in-service training. All materials will be designed in a microtraining format (1–2 min per video) so that they can be flexibly used in different channels.

China by Tianchong Wang (The Education University of Hong Kong)

The number of smartphone users in China has been skyrocketing and is estimated to reach 601.8 million by the end of 2017 (Statista n.d.). With penetration of smart devices continuing to rise, mobile learning in China is rapidly moving from concept to reality in basic education and beyond.

One of the most noticeable government-led efforts towards mobile learning in recent years has been the introduction of the e-Schoolbag for improving education quality. The e-Schoolbag was first established in Shanghai in 2010 with support from the East China Normal University, then in Beijing and several other major cities in 2011, as an overarching concept of large-scale one-to-one implementation of tablets with preloaded digital textbooks for selected K12 schools. It was intended to provide a multimedia, interactive, and collaborative learning environment where students could access digital content that is more pleasurable and conducive to learning, either inside or outside of classrooms. At the start, the initiative suffered from content being dominated by textbook publishers (Wang and Towey 2012). However, with the hype around the streaming video-based Wei Ke (微课, literally "Micro-Course") in the last few years, a growing number of grassroots, teacher-designed learning materials have been developed for use via the e-Schoolbag platform (Gu et al. 2016). Despite the growing availability of learning materials, and an increasing number of schools joining the e-Schoolbag initiative, there is still hesitation among school leaders concerning students becoming distracted in class, as well as possible negative effects on eyesight (Li 2013). Students' abilities to use mobile technologies to learn vary due to the socioeconomic status or the sociodemographic origins of their families, thus reinforcing the resistance of the school leaders to the introduction of the e-Schoolbag in many areas (Li 2013). Hesitation aside, it must be admitted that in a culture of classroom practice that is perceived by many educators as often being teacher-led, the effect of this project seems to be less pedagogically transformative than expected (He and Wray 2017).

Despite the regional disparity of development in China, there have been mobile learning field projects in the provinces of the Central-Western Region to explore how mobile technology can expand access to education and advance literacy and numeracy. For example, a pilot program, spearheaded by a government think-tank called the China Development Research Foundation, aimed to bridge the education gap between the country's urban and rural communities with the aid of a mobile-based learning platform, Mobiliya Edvelop (Aki 2015). Conducted at eight schools in the Qinghai and Guizhou provinces, the pilot program equipped students and teachers with tablets loaded with a system that allowed them to tune into live-streamed or prerecorded video-based learning resources provided by teachers of partner schools in urban areas. It was expected that such a model could be scaled up in order to address the issue of the lack of highly qualified teachers in rural schools, although the outcomes of this program have yet to be reported and analyzed.

In parallel with these government-led or government-supported initiatives and programs that target formal education, the last few years have seen the emergence of a new digital ecosystem, notably incorporating apps from the private sector, as a platform of knowledge distribution with "bite-sized" pieces of learning content. While a small number of educational apps are mapped to national or regional curriculum targets, and designed for use in classroom or homework settings, the majority are intended mainly for informal, personalized, on-demand, self-directed learning. Among these apps, the most popular category is English language learning, which also mirrors the huge English language learning demand in the country (Ambient Research 2015). One reason such a category is favored by students is because the use of apps for language learning is not only effective but also fun: many apps come together with a smattering of gamification, rewarding students for accomplishing their goals, and encouraging them to keep up with their peers.

Social media, most notably Tencent's WeChat (微信), have also been playing a significant role in mobile learning in China. As China's most widely used instant messaging platform, with 768 million monthly active users at the end of 2016 (WeChat 2016), it was never designed to act as a Learning Management System (LMS). However, through a WeChat subscription account (微信订阅号), learning content providers can broadcast information to their followers. For example, the British Council posts English language learning content; Miracle Mandarin delivers Chinese language lessons; and Xueda Education distributes K12 subject tutoring materials through this channel. This social platform creates an organic way for students to communicate with their teachers in one-on-one sessions or to collaborate with peers in webinars. It now appears that WeChat subscription accounts, as a learning platform, have succeeded where many traditional LMSs have failed: in promoting social interaction and taking education to where students already are.

To sum up, although mobile learning in China is still far from an integral part of K12 teaching and learning, it has already started to play an important role in improving access to education, as well as improving educational quality and efficiency. Students' favorable responses to learning apps, learning platforms, and social media confirm the positive impact of mobile learning. In light of such developments, the adoption of mobile learning will continue to grow.

Hong Kong by Yanjie Song (The Education University of Hong Kong)

Hong Kong SAR has one of the highest smartphone penetration rates in Asia. In 2015, 76.9% of 10–14 year olds, 97.9% of 15–24 year olds, and 98.8% of 25–34 year olds had access to smartphones (Census and Statistics Dept, HKSAR 2016). Most users spend more time using their smartphones than any other Internet-enabled devices for accessing information, using social networks, taking pictures, sending emails, and for entertainment anytime, anywhere (GO-Globe 2014).

Taking advantage of the high penetration rate of smartphones in Hong Kong, the government provides more than 100 mobile apps covering different kinds of services (GovHK 2017). Beyond Campus is one of the popular educational mobile apps designed and developed by the Education Bureau (EDB) of Hong Kong. It allows teachers to design their own mobile activities for outdoor learning, using the Global Positioning System (GPS) to display routes and tasks. Another large-scale EDB-supported e-learning venture that includes mobile learning practices has been initiated in 100 schools; it includes the development of curriculum-based e-textbooks aimed at fostering students' twenty-first-century skills. These schools have acquired sufficient mobile devices and have Wi-Fi access in all classrooms for using e-textbooks and e-learning resources.

In addition, universities in Hong Kong are conducting studies on developing apps to support school education, such as EduVenture and LearningVillages. EduVenture is a context-aware mobile learning system developed by the Chinese University of Hong Kong, which supports teachers and students in conducting outdoor field trip learning activities (Jong and Tsai 2016). Students' learning trails can be documented in the learning system. Supported by the built-in GPS system on mobile devices (such as iPads), learning tasks in a certain location are triggered when students walk through the physical target area. LearningVillages is an integrated mobile learning system operating in the form of a Massively Multiplayer Online Role-Playing Game (MMORPG) (Jong 2014); each virtual learning village represents an issue of inquiry to facilitate students' engagement in outdoor inquiry-based learning in social sciences and humanities education.

In addition to developing mobile apps, studies on mobile and seamless learning pedagogical design and practices are prevalent in Hong Kong. Various existing mobile apps have been integrated into pedagogical designs to support students' learning anytime, anywhere. For example, a series of studies on inquiry-based learning have been conducted in Hong Kong schools, employing mobile apps like Skitch (annotation app), Evernote (note-taking app), and Edmodo (a social networking platform) to support students' science and mathematics inquiries across multiple spaces (e.g., Song 2016). Innovative pedagogical designs have been tested, such as the integration of a Bring Your Own Device (BYOD) model into inquiry-based collaborative learning (Song 2014), and a "productive failure-based flipped classroom" pedagogical approach to support students' learning in a mobile learning environment (Song and Kapur 2017), which are effective in motivating students to learn and develop problem-solving skills.

To increase teachers' capacity in implementing e-learning, the EDB has developed a community of practice among teachers to share best practices and encourage collaborations between schools to renew the curriculum and transform pedagogical practices (EDB 2014). The EDB is continuing to enhance IT infrastructure, including providing Wi-Fi access in all public-sector schools since 2014 and building school professional leadership and capacity to foster ubiquitous learning in school education in Hong Kong.

India by Aji Divakar (Murdoch University)

With more than 1.51 million schools and a student population of over 254 million (MHRD 2016), India has one of the largest education systems in the world. With more than one billion mobile phone subscribers, of whom 20% are smartphone users, India is also one of the fastest growing nations in digital consumption (Rai 2016). As India is expected to overtake China in population by 2022 (UN 2015b), growth in the number of mobile technology users can be taken for granted. The Digital India initiative from the national government has not only secured supporters in Silicon Valley but has also acclimatized the nation for educational technology incubation. Recent investments in a learning content provider, Byju's, by Facebook and Sequoia Capital has led to high hopes for technology startups in the K12 market in India. With more than five million downloads, Byju's is a clear example of a success story to emerge from the Indian educational technology sector.

The Ministry of Human Resource Development (MHRD) has launched apps like ePathshala to make textbooks available online for students. The government has also launched digital initiatives like Saransh, a platform to unify data on student performances from schools across the states. In a diverse nation like India, where schools may operate under central or state examination boards, students can choose a local language or English as a medium of study. With policy differences among states, technology can be a unifying solution if it can manage these diversity challenges. Learning and teaching in the Indian education system is mainly about preparing students for various board examinations. That trend is also reflected in subscriptions to mobile learning applications among students in India, with examination-oriented apps like Meritnation and myCBSEguide being popular.

India stands to gain a great deal from ICT innovations related to ubiquitous learning environments (Kinshuk and Huang 2015), which could offer appropriate educational solutions in this massive country. On the hardware side, the manufacturer Datawind, which has local offices in India, entered the market with a $35 tablet and has become the market leader in affordable tablets in India. In a country where one in five is poor (Narayan and Murgai 2016), but 61% of the poor own a mobile phone, if advancement in mobile learning is coupled with impact investing (Cronin 2017), there is considerable hope for education in India. However, the lack of academic research on these issues in India remains a concern.

Indonesia by Linawati Udon (Udayana University)

A survey by Indonesia's Internet Operator Association in 2016 showed that around half of the population has some form of Internet access. Most people use a mobile device, such as a smartphone, for this purpose (Widiartanto 2016). In 2014, 64.7% of senior high school students were using the Internet, while 2 years later, in 2016, this had increased to 69.8% (compared to 89.7% of university students who were Internet users) (MoCI 2016). Digital marketing research organization eMarketer speculates that in 2018 the total number of smartphone users in Indonesia will exceed 100 million. This could make Indonesia the fourth largest smartphone market in the world, after China, India, and the USA. At the same time, Indonesia is a leader in the adoption of Facebook via mobile devices (Noviandari 2015). In addition to social networking, messaging and web search activities have been widely adopted by mobile technology users in Indonesia (Auliani 2015).

There have been a number of initiatives in Indonesia that relate to ICTs in education and mobile learning. The Indonesian Government's Computer-Based National Exam initiative has been attempting to implement a technology-supported assessment strategy since 2013 (Pakpahan 2016). However, only 42 junior high schools, 135 senior high schools, and 379 vocational high schools have adopted this strategy. Taking into consideration the fact that Indonesia has 26,380 senior secondary schools, the 135 schools that have adopted this strategy represent a tiny minority. In simple terms, most Indonesian schools have to develop a suitable technology infrastructure and capacity to embrace such an initiative (MoEC 2016). Furthermore, the Ministry of Education and Culture (MoEC) has introduced an initiative to regulate and support the implementation of online learning (Abidin et al. 2015). There were previous attempts to integrate online learning technology in teaching and learning in Indonesia. For example, in 2007, the MoEC launched the Jardiknas National Education Network project with the aim of connecting senior high schools in a network of educational innovation and online learning (Yuliani 2010). However, the project was later suspended, due to what some suggest are political reasons.

More specifically with regard to mobile technology, the MoEC has developed the e-Sabak application that runs on tablets and offers access to e-textbooks for schools (Husada 2015; Mahardy 2015). The e-Sabak project provides more than 1,300 e-books which can be accessed through a dedicated app available for download via iTunes or Google Play. At the same time, the Ministry of Research, Technology and Higher Education has established a number of open Moodle-based courses since 2014 (MoRTHE 2017). Furthermore, other mobile learning applications have been developed by universities with the assistance of government research funding, or in rare cases by private companies such as Kalese (Husada 2015).

A number of interesting studies on mobile learning have been conducted in Indonesia, including studies relating to mathematics (Abidin et al. 2015; Tifani et al. 2016), language learning (Darmanto and Hermawan 2016; Seangly et al. 2016; Susanti and Tarmuji 2016; Ulfa 2013), media studies (Astra et al. 2015; Sulisworo and Toifur 2016), and students' learning strategies with mobile technologies (Sulisworo 2017). These studies largely focus on the obstacles to the implementation of mobile learning in Indonesia. One obstacle that stands out is that the majority of schools prohibit the use of mobile devices in the classroom due to concerns over inappropriate uses by students, negative effects on students' mental health, and possible disturbances to students' learning. On a positive note, some studies have explored ways for Indonesia to become one of the pioneers in the field of mobile learning (Padmo et al. 2015).

Mobile learning in Indonesia can offer many opportunities to improve education quality. Mobile technology penetration in Indonesia is high, and it is continually increasing. Furthermore, emerging findings from international and local researchers, and experiences from implementations in other countries, are likely to encourage mobile learning adoption in Indonesia. However, the implementation needs strong backing from the government to overcome existing obstacles and provide support in areas such as access to electricity; the development of telecommunications and Internet infrastructure across the vast territories of the country; and encouragement to stakeholders to support mobile initiatives. Finally, it must be noted that the implementation faces challenges related to perceived ethical concerns and school regulations.

Japan by Eric Charles Hawkinson (The University of Fukuchiyama)

The timing of Japan's economic bubble and its rise to technological mastery at the end of the twentieth century set the tone, for better or worse, for the current state of mobile technology development and use. Japan saw rapid and widespread use of mobile technology from the 1990s. In 2002, over 40% of the population was in possession of an Internet-connected mobile device (Ishii 2003). When the iPhone came to Japan in 2008, it did not take too long before Japanese developers flooded the market with mobile applications as the market was ripe and ready for mobile purchases, so that iOS application revenue from Japan ranked second in 2012 (Arthur 2012).

Unfortunately, this wide-scale adoption of mobile technology has not made its way into public education to the same extent. Regulations and policies from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) have prioritized student privacy over free use of mobile phones in schools (MEXT 2015). This has left an opportunity for the private sector to fill the needs of learners. The Japan Massive Open Online Education Promotion Council (JMOOC) started an online learning platform in 2013 that has become a large collection of learning content in Japanese (Yamada 2015). SoftBank's Cyber University is an interesting attempt to harness learning content for mobile phones by one of the largest communication network carriers in Japan (Zhang 2008). Other companies have sought to bring educational content to the Nintendo 3DS and other similar game systems, as they still have high market adoption among young Japanese. Software development companies have licensed textbook content and created supplementary resources for mobile Nintendo devices, including *New Horizons*, an English language textbook used by most Japanese middle schools. Japan's cram-school industry has also been much more open to mobile learning than public schools.

The combination of the timing of technological advancement with other cultural phenomena in Japan has produced a strange paradox of high tech environments, but radically traditional thinking. This "Galápagos Effect" (ガラパゴス化) has had a profound impact of the development of mobile learning in Japan. The clearest example is the extended use of flip phones in Japan. These phones required a specific design of webpages with minimal graphical content and a need for only a little bandwidth. This still has an influence on web design today in Japan (Hawkinson 2017). It has, in a way, put Japan at a disadvantage compared to other Asian countries, because it can be harder to update all users and technology, especially in respect to behavior, rather than starting from zero.

There are some interesting things in store in Japan. There are still a very large number of developers and technology companies looking to fill the needs of learners, mostly in informal learning environments. One promising development is the use of augmented reality (AR) and virtual reality (VR). There are many fascinating projects, and there is accompanying research going on into these technologies for learning. It remains to be seen if they can overcome societal and policy barriers to be implemented at larger scales in Japanese schools (Hawkinson et al. 2017).

Laos by Phonekeo Chanthamaly (National University of Laos)

In recent years, Laos has been adopting 3G and 4G technologies, and the Internet user base has grown impressively from 6,000 in the year 2000 to 1.4 million in the year 2016, constituting about 20% of the total population (Internet World Stats 2016a). However, the cost of Internet access remains relatively high compared to the average income, and most people still cannot afford it easily. Those who use the Internet in Laos are predominantly young people in the city areas and/or people from high income families. The cost of Internet access has seriously affected schools, and many are struggling to secure any funding for this. The Ministry of Education and Sports (MOES) has its national master plan that addresses some of the critical issues. However, the nature of the support for ICT integration is not entirely clear.

All teaching and learning in schools in Laos is conducted in a traditional face-to-face mode, and until now there has not been any additional e-learning adoption. From 2010 to 2015, the Laos Government, through the MOES, launched a project to support and extend educational opportunities across the country, piloting it in 17 provincial secondary schools, and enabling these schools to set up ICT centers with equipment provided. However, the strategy has been seriously constrained due to a lack of Internet access, a lack of e-content, and the overloading of teachers with regular teaching and administrative duties. At the same time, private companies specializing in ICTs in education and equipped to effectively support schools are almost nonexistent in Laos.

Until the present time, little data on K12 school students' use of ICTs for their education have been available in Laos. However, in 2010, the IT Centre at the National University of Laos implemented a study of the use of digital technologies in higher education institutions in Laos, and the results showed that only 39% of students owned notebooks. The majority of students were accessing the Internet in Internet cafés, not through computers at home or at their institutions. Nevertheless, since the introduction of 3G to Laos in 2012, many students, especially in the capital, Vientiane, have been using smartphones to access the Internet. Thus, smartphones are a primary means of accessing the Internet for learning, but as yet there are no institutions in Laos providing full e-learning or m-learning systems.

Macau by Christopher Fulton and Spencer Benson (University of Macau)

Here we describe the current state of mobile learning in K12 schools in Macao SAR. Our focus is on case studies of teachers working in a limited number of schools from the pool of 77 K12 schools in Macao (DSEJ 2015). The K12 school system in Macao is unique in that the majority of the schools are private, the primary language of instruction can be Portuguese, Putonghua, Cantonese, or English, and there is no government-mandated curriculum per se. A survey of school websites in Macao and conversations with teachers have revealed that the integration of mobile devices and computers into classroom activities is occurring in a limited number of schools. In our 2017 survey, only seven schools were identified as having established classroom environments in which laptops or tablet devices are used by students on a daily or weekly basis. Two Chinese-medium private schools have implemented a one-to-one laptop or tablet initiative. Other private schools are experimenting with laptops and tablet devices.

A one-to-one mobile learning initiative that was implemented at St. Paul's School (one of the larger K12 schools in Macao) in 2012 has been chronicled in the press (Lam 2012) and in a case study (Garcia et al. 2014). The initiative sought to change teachers' pedagogy from primarily didactic and transmission-based teaching to a form that was more collaborative and to increase student motivation and interest. One of the major changes involved replacing textbooks with touchscreen tablet computers (Lam 2012). However, the change from textbooks to laptops can be challenging for teachers, who often struggle to find time to prepare content and interactive activities for learners that capitalize on the devices' affordances. Garcia et al. (2014) listed potential issues with the school-wide mobile learning initiative and its impact on St. Paul's School's mission statement.

An issue of primary importance is the need to communicate to parents the purposes and advantages of mobile learning and the benefits of implementing an ICT initiative with a Learning Management System (LMS). LMSs allow schools to disseminate and document student learning activities and enable communications among stakeholders. When teachers use an LMS, learning activities can be better monitored and assessed. However, features, capabilities, and affordances of laptops, mobile devices, IT infrastructure and, most importantly, the LMS, all shape and influence pedagogies that are implemented within an institution's classrooms. Learning activities using LMSs, often during class time, involve students accessing the LMS and learning activities via tablet devices, laptops, or Chromebooks; this allows for students to construct, write, and share ideas online. To create opportunities for social learning among young students, schools in Macao have experimented with Moodle, Edmodo, iClass, and DyKnow.

The development, setting up, and deployment of innovative learning activities using LMSs is generally perceived by teachers and students as time-consuming. For many teachers, a potential risk of conducting learning activities with mobile devices and networks is the feeling that the time is not used efficiently, while pedagogical objectives do not align with the technology available to teachers and students. These can be major obstacles to mobile learning integration. Moreover, conversations with school teachers in the surveyed Macao schools suggest that the support provided by IT departments often does not meet their needs. Additionally, the cost of the LMS is seen as an obstacle.

The types of mobile devices (e.g., iPads, tablets, Chromebooks, or laptops) that are supported and employed vary among the schools. For instance, the majority of teachers at one private school were allocated a touchscreen laptop with the Windows operating system, and at another school, teachers were able to choose, with a preference for Apple laptops. Conversations with teachers overseeing IT systems at the latter private school indicated that low-cost, portable devices such as Chromebooks, which have limited functions and can only display content in a web browser, were also used by teachers and students. The hidden costs of supporting multiple types of mobile devices, for example, laptops and tablets, and the practical issues of training teachers using those devices, have to be evaluated before implementation of any mobile learning initiative.

This limited exploration of Macao K12 teachers' practices indicates that, to a large degree, Macao schools are not capitalizing on the use of the most ubiquitous mobile device, i.e., smartphones, and thus the greatest opportunity for mobile learning is overlooked. Moreover, in nearly all K12 schools, smartphones are banned. One primary Macau teacher, from a school with a one-to-one tablet program, predicted that eventually students would be able to use their own smartphones at school as long as the smartphones met certain requirements. For instance, each phone would need to be registered and have an application installed to give schools or parents control over the smartphone. In Macao, like many other places, the learning potential in smartphones is not capitalized upon. This is a missed opportunity for young learners to gain experience and guidance at school on how to use their smartphones as devices that can augment and enhance their learning experiences, in and out of the classroom.

Malaysia by Rozinah Jamaludin (Universiti Sains Malaysia)

Malaysia has developed the Learning Beyond Boundaries concept, launched recently by the Ministry of Education (MOE). It is aligned with the Malaysia Education Blueprint 2013–2025, which incorporates ICTs in education under Shift 7 (involving leveraging ICTs to scale up quality learning across the country) (MOE 2013). This is in turn linked to the 1BestariNet project that aims to provide 4G

Internet access and the Frog Learning Management System (LMS) to over 10,000 Malaysian schools. Teachers have reported that with use of the Frog LMS, both students' academic progress and their communication skills have improved (Chonghui 2016). Online assessments are marked straight away and students receive their marks and feedback immediately. The platform also motivates students to express their views and is thus helpful to more introverted students who are shy to ask questions.

For primary and secondary school students in Year 6 to Form 1 (aged 12–13 years old), Scratch, a free programming language, has been introduced. In Form 4 (where students are 16 years old), they are introduced to the Windows Operating System, Microsoft Office, StarOffice, Microsoft Visual Basic, HTML, Java, JavaScript, Microsoft Access, WAMP-PHP, MySQL, and XAMPP, and they are encouraged to develop multimedia applications (Penang Education Department, personal communication). Web 2.0 tools such as Kahoot!, Padlet, and TodaysMeet, along with green screen technology, have been introduced to students in primary and secondary schools. This has also exposed students to game-based learning and introduced gamification into teaching and learning, as in Kahoot!, for example.

Some private schools such as Cempaka Schools Malaysia have been among the first Apple Distinguished Schools (ADS) in South Asia, as well as pioneers of the ground-breaking LMS Schoology in the Asia Pacific region. Since 2009, Cempaka Schools have been the leading schools in Malaysia to use a one-to-one learning environment where each secondary student has a laptop. Other international schools such as Nexus International School and Garden International School are accredited as ADS. Fairview International School in Penang introduces the use of iPads to children aged 5–7 years as a medium through which to learn about the world around them. Students from Grade 3 (7–9 years) in the International Baccalaureate program showcase to parents the use of iPads in school. Some fully residential schools funded by the government, like the Malay College Kuala Kangsar and Tunku Kurshiah College, also have a strong commitment to one-to-one iPad programs.

It should be noted, however, that because of issues such as discipline problems and disturbances during lessons due to the presence of mobile phones in schools, the MOE, under circular policy 2/2009, prohibited all students from bringing mobile phones into the classroom (Office of Director-General of Education Malaysia 2009).

The future of Malaysian education will involve online learning or blended learning as part of teaching and learning. Currently, learning with school-approved devices is seen as potentially the best way to maximize the use of ICTs for distance and self-paced learning, regardless of location or student skill level. Although there are some challenges faced by schools, like unstable connectivity, they must be resolved as quickly as possible if Malaysia is to move ICTs into the classroom to support twenty-first-century education (Soon 2014).

Myanmar by Thazin Lwin (Yangon University of Distance Education)

The Myanmar Government aims to enable every individual to acquire basic education. In order to meet the Millennium Development Goals (UN 2015a) and ensure full access to quality primary education in Myanmar, there is a high demand for government expenditure on education, training and recruitment of teachers, better education standards, and increasing the number of schools and their facilities. Education is essential to end poverty in Myanmar. Many young people in developing countries, particularly girls, continue to lack access to education. Myanmar has laid down a policy of compulsory primary education with the aim of achieving 100% enrolment (Kyaw 2013). However, there are many challenges for Myanmar to improve its education. The average adult in Myanmar has received just 2.8 years of schooling, and only 36.5% of students who are eligible for secondary education actually enroll (Arohana Scholarships 2013). Today, two-thirds to three-quarters of children drop out of elementary school before Grade 5. It is foreseen that ICTs, including mobile learning, can significantly improve access to education across the country.

Only few years ago, less than 2% of the population in Myanmar had access to the Internet. Today ICTs are at the center of discussions related to education reforms in Myanmar. UNESCO is working with the Myanmar Ministry of Education (MOE) to support adoption of ICTs in schools. Since early 2015, UNESCO and the MOE have been implementing a multistep program to support ICTs in education, focusing on development of qualified teacher educators to lead the integration of ICTs into preservice programs, connecting schools to mobile broadband networks, and allowing teachers and students to benefit from access to twenty-first-century learning and applications (UNESCO 2015a). Through this UNESCO initiative, selected schools were provided with ICTs such as laptop computers, tablet computers, and projectors and support to enable teachers to best utilize this technology in the classroom.

Recently, mobile technology in education initiatives has begun to emerge in Myanmar; for example, UNESCO, Ericsson, the MOE, and other partners are collaborating on the Connect to Learn project with the aim of improving learning outcomes in literacy and numeracy via the use of mobile technology. Some 33% of households in Myanmar have mobile phones and many of them use mobile phones to access the Internet (UNESCO 2015b). This represents a starting point to explore the use of mobile technology in improving the quality of education. Yet there is still a need for more projects to promote mobile technology for learning. Mobile learning should serve as another important milestone for the MOE in the education reform process. UNESCO is continuing to support Myanmar as it enters the world of smartphones and Internet access, aiming for greatly increased mobile penetration rates in the near future to bring it into line with neighboring countries (UNESCO Bangkok 2015).

The Philippines by Melissa Orencia (Philippine Normal University)

The Philippines is a rapidly growing smartphone market in Southeast Asia, with 20% year-on-year growth (IDC 2016). The upsurge is attributed to the emergence of locally produced, cheap, low-end smartphones accessible to low-income Filipinos.

Smartphone penetration is expected to rise to 70% in 2018 from 40% penetration in 2015 (Camus 2015). In June 2016, Internet usage in the Philippines involved 52% of the total population (Internet World Stats 2016b). The majority of Filipinos use mobile phones to go online, and they commonly engage with social media platforms like Facebook and Twitter, watch digital videos, play games, engage in location-based search, and shop online. However, low connectivity, the necessity for higher memory capacity, and the cost of Internet access are challenges that must be addressed (Medenilla 2016). The Philippine Government established the Department of Information and Communications Technology (DICT), which crafted the National Broadband Program to ensure that problems of access and speed are tackled and to guarantee faster and wider Internet connectivity (CNN Philippines 2017; DICT n.d.-b; Telco.Ph 2016).

Teachers' continuing professional development, fast and reliable Internet connections, and regular updating of technology infrastructure characterize the private schools. Xavier School (XS) and De La Sale Santiago Zobel (DLSZ) are pioneers in effective K12 adoption of mobile technologies. Within a one-to-one device-to-student approach, mobile devices are used to promote personalized and authentic, experiential learning, making students more engaged, productive, and responsive. In XS, for instance, students engage in photo-blogging, podcasting, audio-recording, and v-logging in different subject areas. They use Puppet Pals and Toontastic apps for storytelling, Idea Sketch, and Mindomo to generate ideas and connections, Socrative and Nearpod for literature classes, and FaceTime for communication (Lee-Chua 2013a, b). In science, students create and extend their learning through virtual experiences, enrichment, and interactions via LMSs like McGraw-Hill's CINCH Learning (Bernabe 2013). In Science, Technology, Engineering and Maths (STEM) subjects, students explore experiences enhanced by mobile devices using 7D Experience, robotics, visual programming with Sphero, and 3D printing (Demegillo 2017). In DLSZ, teachers are even creating iTunes U courses to promote learning of science concepts (National Teachers' Month 2016).

In poor and marginalized public school contexts, learning resources tend to be scarce. Access to high-end mobile devices, Internet connections, and teachers' competence in applying mobile learning are generally inadequate. To address this, the government has initiated partnerships with the private sector. Text2Teach is the government's longest-running joint project with the private sector to date. The Department of Education (DepEd), Ayala Foundation, Nokia, Globe Telecom, Pearson Foundation, Toshiba, and Microsoft, along with local government units, are collaborating on the local implementation of the Global Bridge IT program conceptualized in 2003 by Nokia, Pearson, the United Nations Development Programme and the International Youth Foundation (Cristano 2014). Rich digitized teaching resources are delivered through mobile technologies, which has improved the quality of education in at least some far-flung and under-served public schools.

The University of the Philippines Open University (UPOU) has spearheaded mobile learning initiatives in both formal and nonformal education settings. In 2003, the UPOU implemented the TXT 700UPOU mobile learning program involving SMS-based mobile courses for English, maths, and science (Librero et al. 2007;

Pena-Bandalaria 2007; Valk et al. 2010). Then the UPOU partnered with the Molave Development Foundation and the DepEd's Alternative Learning Services and received research funding from the International Development Research Center in 2005–2008 for the Project MIND to train learners in English and mathematics in the nonformal education context (Ramos et al. 2007). In 2013, the Abot-Alam program, through the DepEd and the Technical Education and Skills Development Authority, involved collaboration with mobile operators using mobile-enabled learning services to reach out-of-school youths. In 2013, the UPOU investigated the impact of using tablet computers in selected public secondary schools with support from the Australian Agency for International Development (AusAID) (Australian Embassy 2013). The study revealed that teacher training and access to mobile devices affects learning improvement (UPOU Trailblazers 2015).

Specific policies and laws support mobile learning. The e-Government Master Plan 3.0 (eGMP 3.0) emphasizes strengthening of educational reforms (MITHI n.d.). The Philippine Digital Strategy 2011–2016 encourages public-private sector education stakeholders' exploration of mobile technologies for education (DICT n.d.-a). The DepEd ICT4E Strategic Plan supports new modes of delivering education including mobile learning (DepEd 2008). The Republic Act 10650, or the Open Distance Learning Act, identifies mobile learning as a mode of delivery for distance learning (Congress of the Philippines 2014).

The development of mobile apps has grown steadily in higher education in recent years. For instance, Cheng (2003) designed a framework for mobile learning development; Santos et al. (2010) created an augmented reality system for situated vocabulary learning; Red et al. (2013) developed Word Infection, a game-based app to learn about synonyms, antonyms, and homonyms; Odilao and Bautista (2014) used mobile learning devices for early interventions with children with an Autism Spectrum Disorder; Tuliao et al. (2015) created iSuro, a kindergarten tool for teaching and learning aligned with the K12 curriculum; and Monzon et al. (2016) designed Maestra for beginning readers in Filipino. The increasing development of mobile apps provides much potential for enhancing learning and improving the overall quality of education.

Singapore by Kumaran Rajaram (Nanyang Technological University)

A recent Deloitte Technology, Media and Telecommunications survey revealed that Singapore has the highest smartphone penetration rate in the world; nine out of ten respondents had access to a smartphone (Today 2015). Some 98% of households with children who are enrolled in preuniversity education have access to the Internet (IMDA 2014).

Mobile technologies in Singapore have superseded their fundamental functions such as communications, entertainment, and social networking and have now extended their affordances into educational settings. The well laid-out infrastructure and easy accessibility of mobile technologies make the integration of mobile devices into classroom learning designs at schools seamless. Global startups such as

Quipper, SkillPixels, and Duolingo are developing applications and bringing mobile learning to classrooms across the region. SmartKid, an iOS game to teach maths for preschool, Grade 1 and 2 learners, emerges on the top 10 download lists in Singapore and other markets in the Asian region. The partnership of Singapore-based Marshall Cavendish Education with the award-winning mobile game developer Kenneth Tan produced Brainy Arkies, a mobile game designed based on the latest Singapore Ministry of Education (MOE) syllabus to supplement mathematics learning for primary school students.

Back in the 1980s, Singapore initiated the School Link Project for computers in schools (Koh and Lee 2008a). The Professional Computing Support Program commenced in the 1990s to develop teachers' IT skills. The MOE has launched four Masterplans for integrating ICTs into teaching practices and learning experiences in schools, covering the years 1997–2002, 2003–2008, 2009–2014, and 2015–2020, respectively. Masterplan 4 is an ongoing project that focuses on quality learning and aims to develop "Future-ready and Responsible Digital Learners" (MOE n.d.). FutureSchools@Singapore, a government-led initiative, endeavors to enhance the diversity of educational offerings to cater to learners' needs and integrate technology into the delivery of materials. The strategic partnership with infocomm industries has resulted in many new tools and applications that have transformed experiences, for both teachers and students. Notable examples include the augmented reality mobile learning trails developed by companies such as LDR and Rockmoon and deployed in many schools as well as tertiary institutions, with teachers and even students now designing their own app-based multimedia mobile learning activities (Pegrum 2016c).

Research and development (R&D) plays a crucial role in Singapore's endeavors to promote itself as a global education hub, explicitly integrating ICTs in learning. Several explorative pilot studies were conducted by the MOE in primary and secondary schools and junior colleges in the mid-1990s to comprehend the adoption of ICTs in education. These served as the basis for the development of the ICT Masterplans (Koh and Lee 2008a). The eduPAD project was launched in 1999 by the MOE and its industry partners in collaboration (Koh and Lee 2008b). In 2003, Microsoft Singapore and the Infocomm Development Authority of Singapore, with support from the MOE and the National Institute of Education (NIE), launched the collaborative project BackPack.NET, in which tablet-based applications were developed and tablets were deployed to secondary schools to study the potential of ICTs in education. One of the highlights of this project is the Classroom of the Future Live! (COTF Live!) that showcases applications of new technologies in everyday teaching and learning, set up at NIE in 2005. The BackPack.NET center was also launched, serving as a research and training center to integrate ICTs into education (Koh and Lee 2008b). Other R&D initiatives include FutureSchools@Singapore, LEAD ICT@Schools, Edulab, and the Learning Sciences Lab at NIE.

Continuous advancement and prevalence of mobile technologies is evident in Singapore, thanks to wide-ranging governmental support backed up with reliable technological infrastructure. The possible challenges include the sustainability of mobile learning projects. It is hoped that involvement by other stakeholders – such as industry leaders in mobile learning, parents who have the purchasing power, and educational institutions that embrace the ecosystem of mobile learning – will create a smooth pathway for sustainable development.

South Korea by Michael Gallagher (The University of Edinburgh)

The technological infrastructure of South Korea, driven by massive government infrastructural investments of the late 1990s (Frieden 2005) and a thriving domestic mobile industry, underpins many of the mobile learning developments taking place in the country today. Some 97.5% of all households in Korea have broadband access (OECD 2016); there are 56.9 million mobile connections for a population of 50.4 million people (GSMA Intelligence 2015), and 99% of the population enjoys mobile broadband connections.

As a result, mobile traffic accounts for 37% of all web traffic in South Korea (We Are Social 2017). A total of 87% of the South Korean population actively uses social media, and 83% of that population is doing so through mobile as of 2017. Along with this connectivity comes a local capacity for digital software, applications, and social media environments; South Koreans are accustomed to using technologies and applications developed in and for South Koreans, from earlier social media (CyWorld, or 싸이월) to modern messaging applications (KakaoTalk, or 카카오톡), all accessed through domestic mobile technology (Samsung, LG, and more). Further, they use mobile at an early age, with 80.6% of Korean adolescents having their own mobile phone and, for example, 87.7% of 12-year-old Korean adolescents using mobile phones, far more than in other countries (Ok 2011, p. 330). These numbers have surely increased since 2011, and data collection has extended further into younger demographics as Internet use is measured to include children as young as three (Harpur 2017).

Korean students in primary and secondary education are using mobile technology in predictable ways: to reinforce a local sociality and maintain peer relationships, to reference or research, to take notes, to create and consume media, and more. They do this largely through domestic applications, such as KakaoTalk, in such a way that it reinforces the cultural landscapes in which these students find themselves. Jin and Yoon (2016) write: “the KakaoTalk-scape does not simply signify a radical rupture from young people’s ordinary cultural landscape but rather implies the possibility that smartphone technology is incorporated into the rhythm of young people’s everyday lives” (p. 520). These students, through their use of KakaoTalk, are reinforcing in the digital space the Korean environment they see in their daily lives through chats, texts, emoticons, and media.

This extends into social media with some slight idiosyncrasies: Korean social networks tend to be much smaller than their Western counterparts and people’s motivations for participation (social support, some information seeking, less casual relationships) speak to a close-knit social network that reinforces peer communities (Ok 2011). Social media, like mobile technology, “reconfirm young people’s peer networks, which continue traditional modes of sociality and cultural identity rather than encroach on them (Na 2001)" (Ok 2011, p. 329). KakaoTalk continues the trend advanced in earlier Korean social networks, such as Cyworld (Hjorth 2007).

For education, this saturation of access and mobile technology has produced an environment where mobile learning is part of a larger interrelated whole. Smart learning involves "learning with resources and content available from both the public and private sector, including social learning as found through social media," and "technology-embedded learning where technology is available to support anytime, anywhere learning" (Noh et al. 2011; translation by author). Mobile learning initiatives for primary and secondary education reflect this, such as the South Korean government's USD 2.4 billion effort to digitize all educational materials by 2015, making them accessible through computers, tablets and smartphones (Pandit et al. 2012).

Research, however, on the effects of mobile learning is sparse and speaks to quantitative measures of acceptance and willingness to use mobile technology in K12 classrooms, rather than to learning impact. Considerable research exists in the informal mobile learning space of social media use and KakaoTalk (Hjorth 2007; Jin and Yoon 2016), but rarely is that bridged with formal learning in the K12 classroom. Some recent examples provide optimism for renewed interest in impact, such as Bae and Lee's (2016) discussion of a mobile learning application for creative problem solving activities, but this research is limited in the larger body of mobile learning in Korea.

The use of mobile technology for formal learning will garner more attention and resources as Korea's mobile industries continue to thrive and greater amounts of Koreans' sociality is enacted in mobile spaces. Whether that transfers into research demonstrating the impact of mobile learning in formal education remains to be seen.

Taiwan by Chun-Yen Chang (National Taiwan Normal University)

There is an increasing prevalence of Internet usage in Taiwan (Internet World Stats 2017). Taiwan's Internet users accounted for 88% of the total population in March 2017, as opposed to 67.4% in 2008. A survey of students' Internet usage conducted by the Taiwanese Ministry of Education (MOE) in 2015 revealed that the percentages of students who possess their own smartphone devices include: 38.8% of elementary school students, 78.8% of junior high school students, and 93.3% of senior high school students (MOE 2015). In addition, the average time spent on the Internet per school day for these groups of students is: 45.1 min, 67.1 min, and 75.2 min, respectively, and 57.8 min, 115.8 min, and 147.2 min on the weekends. These statistics reveal that Taiwanese students, in general, spend a great deal of time surfing the Internet.

In response to global trends in information technology and mobile technology development, tablets and smartphones have gained increasing popularity. The MOE has developed the Teachers' Teaching Application, which provides a platform for in-service teachers to share their innovative experiences and feedback about mobile teaching. The application has so far received more than 2 million hits, provided

700 varied teaching examples, and compiled a list of about 1500 teaching applications screened and recommended by teachers around the country. In addition, the MOE has taken the initiative of encouraging collaborations between the academic community, county and city governments, and the private sector. Examples of their efforts include the 2014–2016 Taiwan Mobile Learning for High Schools (http://mlearning.ntust.edu.tw/) and the 2014–2017 Mobile Learning for Elementary and Junior High Schools (http://mlearning.ntue.edu.tw/) projects. The purpose of these projects has been to encourage schools to actively integrate information technology and digital resources into teaching, and develop student-centered innovative instruction. In doing so, it is hoped to enhance students' domain knowledge and to help them develop important skills, such as communication, critical and innovative thinking, problem-solving, collaborative learning, and the like.

Higher education institutions in Taiwan are also actively developing new mobile technology systems to facilitate teaching and learning. The National Taiwan Normal University (NTNU), for example, has developed its mobile application CloudClassroom (CCR) to enable students to give feedback or responses to instructors' questions in real classroom settings in an instantaneous manner on a mass scale. CCR is written in HTML 5.0 and, without additional software or plug-in installations, it works on every mobile device such as laptops, PDAs, smartphones, and tablets. Once connected to CCR through their own mobile devices, the instructors can pose various types of questions to the entire class. Students are then able to use their devices to give responses to the instructors in the form of digits, texts, pictures, animations, or even multimedia. Since there is no pressure for the students to speak out their answers or to raise their hands when volunteering to speak, it creates a safer and more comfortable learning environment for quiet students to participate in during the class. On the other hand, verbal students' needs for interacting with teachers and peers may be met as well. Furthermore, CCR can automatically aggregate a report for the teacher to gauge students' learning in a timely manner. The usability of CCR has been validated in science classrooms in Taiwan (Chien and Chang 2015; Chien et al. 2015). Having developed this efficient mobile teaching and learning system, NTNU has made great efforts to share the system with primary and secondary school teachers and provide workshops and teacher training to assist them in making good use of the system to facilitate their teaching. At present, approximately 15,000 users have been registered in CCR. More than 120,000 classroom activities have been conducted by using CCR. It is anticipated that CCR will become more cost-effective as more and more schools start embracing Bring Your Own Device policies.

As wireless communications and mobile technologies continue to advance and gain popularity, increasing numbers of institutions are taking active roles in incorporating mobile technologies into educational settings, such as classrooms, museums, and labs, to enhance students' learning motivation and achievements. While it is important that schools and educators keep pace with the times by employing effective educational technologies in teaching, it is also essential to be reminded that technology, by itself, does not improve teaching and learning. It is only by taking into consideration learners' needs and implementing careful learning designs and effective teaching strategies, that educators can use innovative technologies to truly facilitate and enhance teaching and learning as a whole.

Thailand by Vorasuang Duangchinda (Sripatum University)

Thailand is a fast-growing country with a population of over 68 million (Worldometers 2017). According to Veedvil (2016), there were 83 million mobile phone subscriptions in Thailand at the end of 2015, but only 4.3 million of them connected to a 4G network. However, the number of mobile subscriptions had increased to 90.94 million by January 2017, representing 133% of the population (Kemp 2017). A mobile phone of any type is the most common digital device, used by 96% of Thai adults, with some 70% using a smartphone, 26% a laptop or desktop computer, and 11% a tablet; most web traffic in Thailand is generated via mobile phones (66%), followed by laptops/desktops (29%), and tablets (5%) (Kemp 2017). Kemp (2017) indicates that 62% of the Thai population is active in using mobile social media, which is well above both the global and the regional average. Veedvil (2016) specifies that 74% of Thais use instant messaging every day, with smartphone users spending on average 94 min on communications and 62 min on apps, out of a total of 4.2 h per day spent on their smartphones.

Thailand is at a very early stage of adoption of smartphones in education. Currently, the predominant way of learning through technology in Thailand is by watching online teaching videos and searching for relevant information. However, the Royal Thai Government has introduced the Government Application Center (GAC), a centralized platform hosting freely downloadable mobile applications for all Thais (http://apps.go.th/). As of May 2017, there are 256 applications in 13 categories, including a dedicated section for education with more than 10 apps available. Each of the apps has been developed by a designated governmental department or a leading public university and serves a specific purpose, for example: “Thai Language Dictionary,” “Digital Learning Television App,” and “Museum Pool App.” These applications can be utilized to support learning in K12 education.

For K12 education, overseen by the Office of the Basic Education Commission (OBEC) of the Ministry of Education, there is a dedicated portal called the “OBEC Content Center,” housing educational apps as well as authoring tools for K12 (http://contentcenter.obec.go.th/m/). In addition, there is a collection of K12 apps under the One Tablet Per Child (OTPC) project established in 2012. This ambitious national project aimed to provide a free tablet device with quality educational content to all K7 students. However, the project has now been suspended, and OTPC applications have not been developed any further.

Reform of education, at all levels, is much needed in Thailand. This reform should include not only an improvement of the government’s strategic policies, but also strategic partnerships across public, private, and educational institutions. There has been strong support for such partnerships from international organizations including UNESCO. Examples of current initiatives promoting mobile learning in Thailand include Mobile Literacy for Out-of-School Children, a co-operative project between Microsoft, True Corporation, and the MOE (UNESCO Bangkok 2016); the Thailand Cyber University Project (http://www.thaicyberu.go.th); Thai Massive Open Online Courses (MOOC) (http://www.thaimooc.org); and Thai Open Educational Resources (OER) (http://oer.learn.in.th/). In addition, the government has been working very closely with universities around Thailand. A national project under the theme of "Teach less and learn more" saw universities voluntarily assisting the development of schools near their campuses.

Looking to the future, the national online education credit bank system is in the final stages of development, and the UniNet initiative has been successfully implemented to include dedicated high-speed fiber optic networks linking all higher education institutions throughout Thailand (Nasongkhla et al. 2015). High speed Internet connectivity, mobile devices, and the explosion of Artificial Intelligence (AI), Virtual Reality (VR), and Augmented Reality (AR) will shape Thailand's education in the near future. There is a strong need for research to examine the adoption of mobile and other technologies in education. Further research and development in AI, VR, and AR is also important to the advancement of the country under the Thailand 4.0 model (MOC 2016). Such technologies are likely to be integrated with mobile technologies, and thus together they will potentially shape the future of learning in Thailand.

Vietnam by Dang Hai Dang (Hanoi Open University)

In January 2016, internet penetration in Vietnam reached 50%, while the mobile phone subscriber base reached 152% of the population; among 35 million active social media users, there are 29 million active mobile social media users (Nguyễn 2016). With such growth in access, mobile technologies have a significant opportunity for adoption in K12 education in Vietnam.

In Vietnam, the K12 education system, with the total number of students exceeding 15 million, pursues rigorous academic goals. Its primary purpose is to equip students with the ability to attain a Secondary School Certificate (Grade 9) or Secondary School Diploma (Grade 12). All additional teaching and learning activities are adapted around the core curriculum designed to achieve such an end. This is the case with the adoption of educational technologies that make these additional teaching and learning activities possible. In 2012, Vietnam's education authority issued Decision No. 711/QD-TTg approving the Education Development Strategy 2011–2020 (Nguyen 2012). In this decision, the government emphasized the important role of ICTs in building a learning society. However, the use of educational technologies in this strategy has been criticized for a lack of research, practical orientation, and quantitative indicators that show advancement in learning.

In the business sector, there are a number of innovative companies focusing on education, and these have been playing a critical role in spearheading the adoption of technologies in Vietnamese classrooms. Hocmai is the largest K12 online education provider with 2.5 million users. It provides both basic knowledge and exam preparation tests at competitive tuition rates. The learning content is mainly provided through media such as videos and slides accompanied by multiple-choice questions, notes, and discussions. However, the provider lacks interactive content and live or synchronous courses. Another platform is Rockit Online, which focuses on content and tests in mathematics, physics, chemistry, and English for Grades 7–12. Furthermore, there are large online test-taking and practice platforms including Violympic (for mathematics and science) and IOE (for English). Other platforms include the Monkey Junior mobile application for children from kindergarten to 10 years of age. In addition, there are companies like Topica and Kyna, interested in developing K12 mobile learning products in addition to their existing adult e-learning courses. The private sector, especially via startup companies, is likely to play an important role in the development of the mobile learning market. If the universities and educational research institutions in Vietnam remain in their current rigid mode of operation, they may well be left behind in these developments. Nonprofit organizations are less likely to join and contribute to these.

With the radical reform of the national education system in the near future, the core K12 curriculum will be designed in a more flexible and sustainable way. There has been a general focus on cross-curricular and life skills courses. It appears that there is a positive atmosphere for mobile learning to enter education, and in particular to support initiatives related to Science, Technology, Engineering and Maths (STEM), language learning, and life skills courses.

Discussion

While there are certainly differences in the mobile learning possibilities in the 17 locations covered in the country reports, a striking number of commonalities emerge. Key themes are outlined below. It should be noted that the broad distinction made between developed and developing countries in the following discussion is based on the countries which do, and do not, feature in the United Nations Human Development Index as having a very high level of human development; the countries in the study which fit within this category include Brunei, Hong Kong, Japan, Singapore, and South Korea (UNDP 2016); non-UN members generally included in this category are Macau and Taiwan (“List of countries” 2017).

Availability of Mobile Technologies for Learning

Thanks in large part to governmental infrastructural development over many years, developed locations in the Asian region have some of the world’s highest rates of Internet penetration, mobile – especially smartphone – penetration, and mobile Internet penetration. Indeed, in many such locations, smartphones have become the usual way to access the Internet, with 3G/4G (and soon 5G) networks complemented by robust Wi-Fi access, including within educational institutions.

While it is unsurprising that developed locations have higher mobile and Internet penetration rates, a common theme in developing countries is that penetration is growing rapidly. Unlike developed countries, where mobile Internet access is an alternative and complement to fixed Internet access, in many developing countries mobile phones – which increasingly means smartphones – are the primary or sole means of Internet access for large sections of the population. This becomes clear in a context like Laos, for instance, where students are now increasingly accessing the Internet through smartphones rather than needing to visit Internet cafés.

Countries like China, India, Japan, and South Korea have a number of local hardware and software companies, and some have a produced a considerable amount of well-known software, with examples including South Korea's KakaoTalk (카카오톡) and China's WeChat (微信). This local focus may have the effect of reinforcing users' everyday "cultural landscapes," as noted in the South Korea report, while having the educational advantage of allowing teachers to bypass unpopular institutional LMSs in the process of "taking education to where students already are," as noted in the China report.

In terms of hardware, most country reports focus on laptop computers, tablets, and smartphones, which form an ecosystem of digital technologies that can be exploited for education, especially with the expansion of Bring Your Own Device policies across the region. Interestingly, however, the early entry of a country into hardware (and software) markets may not always translate into a long-term advantage, as seen in the case of Japan with its now famous Galápagos Effect (ガラパゴス化) where, for example, mobile phones evolved in a direction different in some ways from the rest of the world, placing certain limitations on future developments. Nor does a large-scale, government-sponsored hardware program, such as One Tablet Per Child in Thailand, have any guarantee of longevity, with this project now having been suspended. None of the reports make explicit reference to newly emerging and educationally promising hardware like smartwatches or smart glasses (e.g., Bower and Sturman 2015; Pegrum 2016a), but in line with current educational interest in independently or semi-independently mobile learning technologies such as robots (e.g., Hung et al. 2013), it is noteworthy that robotics rates a mention in the Philippines report.

In terms of software, in everyday life in both developed and developing contexts, there is a strong focus on the use of web 2.0/social media services (like Facebook, Instagram, Twitter and YouTube) and/or messaging services (like KakaoTalk, WeChat and WhatsApp), including the social networking facilitated by these platforms, flagged up in South Korea as reinforcing "traditional modes of sociality and cultural identity" (Ok 2011, p. 329). Games and gaming, often with educational purposes, surface in many of the country reports, including a reference to a Massively Multiplayer Online Role-Playing Game (MMORPG) format in Hong Kong.

The current international educational interest in virtual reality (e.g., Lewis 2016) is reflected in the Japan report, and as a future trend in the Thailand report. Meanwhile, the international educational interest in augmented reality (e.g., Bacca et al. 2014; Dunleavy and Dede 2014; Radu 2014) is evidenced in the Japan, Philippines, and Singapore reports, is present by implication in the Hong Kong report, and is again mentioned as a future trend in the Thailand report. Curiously, despite growing global interest in artificial intelligence (AI) – including in countries such as China and Japan (Hsu 2017; Jolley 2015) – the Thailand report is the only one to mention its role, alongside other future projections.

Teaching and Learning Activities with Mobile Technologies

As mentioned in a number of developed and developing country reports, and implied in many others, the widespread use of digital and mobile technologies in society at large does not necessarily equate to the widespread use of these devices in education. This naturally leads to the question of what additional factors are necessary or helpful in supporting educational deployment of these technologies.

It is interesting to note that in most countries the government is taking a role in promoting digital and sometimes specifically mobile learning. This is often done via the governments' educational arms, such as Hong Kong's Education Bureau, which provides mobile apps to teachers; Singapore's Ministry of Education, which is now in the midst of executing its fourth five-year ICT Masterplan; and Taiwan's Ministry of Education, which provides a platform for teachers to share mobile learning experiences. In the developing world, the Philippine Department of Education's five-year ICT4E Strategic Plan encouraged new modes of educational delivery, including mobile learning, with the Philippine Digital Strategy of 2011–2016 promoting this further. Similarly, the Vietnamese Government's 2011–2020 Education Development Strategy includes a focus on ICTs, while the Malaysia Education Blueprint 2013–2025 includes the leveraging of ICTs as one of 11 transformational shifts in education, linked to the 1BestariNet project to provide high-speed Internet access to schools, and the rollout of the Frog LMS. The Thai Government, for its part, has set up a Government Application Center which offers freely downloadable apps, including educational apps, while the Office of the Basic Education Commission (OBEC), part of the Ministry of Education, hosts an OBEC Content Center, which offers K12 educational apps and authoring tools. Meanwhile, the Chinese, Indian, Indonesian, and South Korean governments, though their relevant ministries, have been working on digitizing textbooks, with the first three of these projects referred to as the e-Schoolbag, ePathshala, and e-Sabak initiatives, respectively.

The interwoven roles of the public and private sectors surface in many reports, potentially involving, in varying combinations, different levels of governments and their educational divisions; universities, and research institutes; telecommunications and technology companies; and nongovernmental organizations (NGOs), as seen in contexts as diverse as Cambodia, China, India, Indonesia, Myanmar, the Philippines, Singapore, South Korea, and Taiwan. In Myanmar, for instance, the Connect to Learn project promoting mobile learning is supported by the Ministry of Education, Ericsson, UNESCO and other partners; in the Philippines, the Global Bridge IT program, which spreads digital resources through mobile technologies, has been supported by the Department of Education, Ayala Foundation, Nokia, Globe Telecom, Pearson Foundation, Toshiba, and Microsoft; and in Thailand, the Mobile Literacy for Out-of-School Children project is supported by the Ministry of Education, Microsoft and True Corporation. In countries where there is less direct government support, as in Japan, private companies may take on a correspondingly larger role. And while one-to-one initiatives are sometimes promoted at country level, as in the government-driven e-textbook projects mentioned above, in other locations it is up to individual educational institutions – which may initially mean private schools – to implement one-to-one computing or tablet initiatives, as noted in Macau, Malaysia, and the Philippines.

In developing countries in particular, social justice initiatives seek to overcome regional disparities and urban-rural divides (cf. Pegrum 2014). In some countries, school enrolment falls far below the targeted 100%, even at primary level; thus, in a location like Myanmar, a first priority is increasing primary school enrolment, in line with the United Nations Millennium Development Goals (and the post-2015 Sustainable Development Goals). Digital technologies are widely seen as having a role to play in expanding access to quality education. The Laos Ministry of Education and Sports, for instance, has set up a project to pilot the establishment of ICT centers in provincial schools, though this project faces challenges in terms of limited digital content and limited Internet bandwidth. In part due to a lack of fixed infrastructure outside the cities in large developing countries like China and Indonesia, there has been a focus on the use of mobile devices. The broad reach of mobile approaches can also be seen in the aforementioned Connect to Learn project in Myanmar and the Mobile Literacy for Out-of-School Children project in Thailand, while in Cambodia the Smart Books software helps to compensate for a lack of hard-copy textbooks, and in the Philippines there are co-operative partnerships providing informal mobile learning for those with limited access to the educational system. There is also scope for on-demand learning through apps which may supplement students' formal learning. It is reported that in India and Vietnam exam preparation platforms are popular, while in China there is great demand for English language learning apps. In India, digital technologies are viewed as a way of managing "diversity challenges" in a nation where students may be subject to varying state policies and learning in different languages.

Internationally, as reported in Churchill and Pegrum (2017), some key areas of educational exploration have included multimodal materials delivery, interactions, representations, and creations (e.g., Churchill 2017; Eisenlauer 2014; Kukulska-Hulme and Pegrum in press). In Asia, large-scale textbook digitization initiatives in countries like China and South Korea are likely to promote both multimodality and personalization of learning. Yet it would seem from the country reports that much multimodal online learning content, whether delivered via e-textbooks or apps or a combination of both, primarily involves information delivery accompanied by quizzes. Multimodal games and gamified apps can be highly engaging, and these are used with students, for example, in China, Hong Kong, Malaysia, and the Philippines. Going further, the concept of students becoming involved in multimodal creation and production with digital technologies is mentioned in reports from Malaysia, the Philippines, and Singapore, with a focus on app development in the first of these, and augmented reality app deployment in the last.

Internationally, there is a strong focus on digital collaboration and networking (e.g., Alhinty 2015; Ilic 2015; Pachler et al. 2012), something which is facilitated by the kinds of web 2.0 or social media platforms which are widely mentioned in the

Asian country reports. In Malaysia, for example, school students are introduced to Web 2.0 tools ranging from Kahoot! to Padlet, and it is indicated that similar kinds of tools are being used in at least some schools in the Philippines.

Internationally, there is also a focus on seamless learning inside and outside the classroom (e.g., Wong et al. 2012; Wong and Looi 2011). It is notable that two Asian country reports make explicit mention of seamless learning, namely Hong Kong and Singapore, with this idea being implicit in many other reports which highlight the use of mobile apps as a complement or even alternative to formal educational structures.

Finally, there is also a major international focus on the development of new literacies essential for twenty-first-century life (e.g., Frawley and Dyson 2014; Pegrum 2016b). There is an acknowledgment of the importance of so-called twenty-first-century skills, which include communication, collaboration, critical thinking, and creativity, in the Hong Kong and Taiwan reports. The development of digital literacies is essential to support such skills (e.g., Dudeney et al. 2013), and it is interesting to see that in some contexts, like Malaysia, the Philippines, and Singapore, students are being introduced to coding and creating with digital technologies, while students in Brunei (at least at tertiary level) are developing learning apps.

It is evident from the reports from developed and developing countries alike that digital and mobile technologies are seen as having potential value across a whole range of subject areas, from literacy and numeracy through to Science, Technology, Engineering and Maths (STEM); indeed, the STEM area, which has recently become a major focus in education systems worldwide, is mentioned explicitly in the reports from Cambodia, the Philippines, and Vietnam. Nevertheless, despite all of the apparent potential, in some developed contexts, integration of digital technologies in schools is still limited, as in Macau, and in some developing contexts there is little use of digital technologies at all, as in Laos. In some locations, like Macau, many schools may ban phones, while in others, like Malaysia, the Ministry of Education has banned phones. In various reports, challenges with digital technologies have been identified as arising around practical issues like a lack of electricity (Indonesia), limited and/or unstable Internet connectivity (Indonesia, Laos, Malaysia, Philippines), cost (China, Laos, Macau, Philippines), time (Macau), limited IT support (Macau), and sustainability (Singapore). There are concerns over students being distracted or disturbed in class (China, Indonesia, Malaysia); this arises against a background of broader societal concern over technology addiction (South Korea) and mental health issues for students (Indonesia). There are fears over physical health problems like poor eyesight (China), and potentially ethical issues too (Indonesia). There are also policy restrictions designed to protect student privacy (Japan). In addition, parents, families, and other stakeholders may need to be convinced of the value of digital, and especially mobile, learning, as noted in China, Indonesia, and Macau.

Pedagogical Approaches to Mobile Technologies

It has been argued that today's mobile hardware and software present opportunities for pedagogical transformation (e.g., Cochrane 2013; Kearney et al. 2015; Lindsay 2016).

Certainly, some of the Asian reports explicitly mention the notion of transforming pedagogy, shifting it away from didactic modes and towards collaborative, constructivist modes, as discussed, for example, in Macau.

It has become evident in international studies that there are at least three levels, or paradigms, of mobile learning (e.g., Churchill et al. 2014; Pegrum 2014, 2016c). At the first level, the devices are mobile, but the learners and the learning experience are not. Here, mobile devices are essentially treated as a replacement for, rather than a complement to, computers (Burston 2016). Typically, the pedagogy largely involves information transmission or behaviorist drills, with some scope for personalization but usually less scope for collaboration or authenticity (cf. Burden and Kearney 2017). E-textbook initiatives would generally fall into this category, as do many social justice or access initiatives in developing countries.

At the second level, the devices and the learners are mobile, but the learning experience is still not; here there is usually scope for both personalization and collaboration. Learners might be mobile in the classroom, collaborating around the technologies, or they might be mobile in their everyday lives, engaging in (probably distance) learning in moments of downtime in varying locations. However, in neither case does the context influence the learning. A key related concept is anytime, anywhere learning, often app-based in nature, as referenced in the Hong Kong and South Korea reports, and implied in many other country reports.

At the third level, the devices, the learners, and the learning experience are all mobile, opening up possibilities for education which is personalized, collaborative, and authentic. This is currently a major focus internationally in studies that in varying degrees emphasize contextual learning (e.g., Churchill and Lam 2017; Reinders and Pegrum 2016; Sharples 2016) and seamless learning across contexts (e.g., Song 2014; Wong and Looi 2011). While seamless learning may involve learning that bears no relation to its surroundings, the most promising kinds of seamless learning have a contextual element where students can at least sometimes apply their learning in varying environments and/or can create and share multimedia records of their learning captured in those varying environments. The use of mobile devices' location awareness functionality to design contextual learning activities is evident in Hong Kong, for example, and augmented reality learning trails are discussed in the Singapore report. In the process of engaging in and recording contextual learning activities, students are also very likely to develop a range of digital literacies.

Worldwide, there has been a great deal of commentary on the need for educators, faced with expanding possibilities for pedagogical transformation, to act as designers of learning materials, learning environments, and learning experiences for their students; they might do so independently or in collaboration with programmers and instructional designers (Churchill and Pegrum 2017). This point has been made in the general literature about digital learning (e.g., Garcia 2014; Gee 2015; Laurillard 2012) as well as the literature that focuses more specifically on mobile learning (e.g., Hockly 2016; Milrad et al. 2013; Sharples 2016). It is widely appreciated, as noted in the China and Taiwan reports, that technology by itself does not lead to pedagogical changes. Instead, the importance of appropriate learning designs is recognized, as highlighted in the reports from Hong Kong and Taiwan. It is striking that in China's e-Schoolbag initiative, there is increasing scope for "grassroots, teacher-designed learning materials." In the Philippines, some teachers are creating their own iTunes U courses. In Hong Kong, teachers are encouraged to design customized mobile learning activities with the Beyond Campus app. In Singapore, teachers and students are creating their own augmented reality learning trails.

Some reports, from locations that stretch from Macau to the Philippines, mention the importance of appropriate teacher education or training. Hong Kong's Education Bureau supports a community of practice where teachers can share digital teaching experiences, while Taiwan's Ministry of Education provides teachers with a platform to share innovative mobile learning practices. In Myanmar, the Ministry of Education has partnered with UNESCO to support the integration of ICTs into preservice teacher education by qualified teacher educators.

Research on Mobile Technologies for Learning

In this rapidly evolving area, there is clearly a need for research to develop theoretical frameworks of mobile learning, linked to rigorous empirical studies (Churchill and Pegrum 2017). Internationally, there is a growing number of books and special journal issues devoted to mobile learning, each taking its own perspective on the issues at hand (e.g., Berge and Muilenburg 2013; Churchill et al. 2016; Churchill and Pegrum 2017; Lim and Churchill 2016; Palalas and Ally 2016; Parsons 2013; Traxler and Kukulska-Hulme 2016). This research is essential to better inform learning designs.

Some reports, both from developed countries like Brunei and Singapore, and developing countries like Indonesia and the Philippines, indicate that research has been conducted on learning with digital, including mobile, technologies. In Singapore's case in particular, such research often comes under the umbrella of research and development, or R&D. However, many reports indicate that academic research on the learning impact of digital technologies has been inadequate to date and that more research is needed; this point surfaces both in developed country reports, like Brunei and South Korea, and developing country reports, like India and Thailand. It would seem that there is considerable scope for more research which relates global themes to the particular teaching and learning contexts in each location, so as to inform and improve learning designs.

Conclusion

As noted at the outset of this chapter, the country reports do not necessarily represent a complete picture of mobile learning developments in each context, but they do give us a glimpse of each context from the perspective of well-informed educators. And indeed, despite differences between these locations, it is striking to note the similarities in the themes that emerge.

It is apparent that with the continuing regional rollout of smart mobile hardware and fast mobile Internet access, there will be increased opportunities to leverage mobile learning in the future. While governmental support appears to be crucial to large-scale technological implementation, many other organizations – universities and research institutes, commercial entities, and NGOs – also have collaborative roles to play. In developing countries, such partnerships often target social justice agendas, where the pedagogy may be somewhat traditional but the emphasis is on access. In more developed locations, public-private collaborations are likely to involve integrating cutting-edge technologies into education in pedagogically sophisticated ways, with some of today's greatest promise appearing to lie in augmented reality interfaces used to support collaborative, creative learning situated in real-world settings.

Introducing new technologies, in and of itself, is no guarantee of pedagogical transformation, and it is essential that new tools are embedded in appropriate learning designs and that the challenges raised by mobile and other devices are faced squarely. This makes it all the more essential that further research is conducted to establish solid theoretical frameworks whose validity is demonstrated in empirical studies, in order to develop best practice principles that can guide governments, institutions, educators, and students on how best to capitalize on the teaching and learning potential of the mobile devices which are rapidly spreading throughout the region.

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Mobile Learning in K-12: Roadblocks to Adoption

57

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Abstract

Mobile learning and mobile technologies have garnered a significant amount of attention in K-12. As we define it, mobile learning is about 24/7, all-the-time, everywhere learning that is supported by mobile technologies. And, as we argue that mobile learning is increasingly a dominant form of learning, we look to better understand the roadblocks that are holding back its adoption in K-12. To that end, then, we look back in time and we look forward in time to identify the issues involved in mobile learning adoption in K-12. Rooted then in that analysis, we are optimistic that mobile learning can and will be adopted in K-12 over the next 5 years.

Keywords

1-to-1 · Mobile learning · Chromebook · iPad · Tablet · Smartphone · Android tablet · Pocket PC · Palm Pilot · iPhone · Digital curriculum · BYOD · Bring Your Own Device · BYOT · Bring Your Own Technology · HTML5 · NGSS · Next Generation Science Standards · Project-based learning · PBL

Introduction

The notion of "mobile *learning*" (Sharples et al. 2005; Traxler 2007; ▶ Chap. 55, "Barriers to Mobile Learning Advancements in the United Kingdom" by Whyley) has not changed substantively since the term entered into the education lexicon (about 1997) on the heels of the release and proliferation of mobile *technologies* such as the Palm Pilot. In the past, in the now, and, most likely, in the future, mobile *learning* is about support for *24/7*, *all-the-time, everywhere* learning. Learning inside K-12 schools accounts for some opportunities to learn, but children spend much more time outside of school than inside. And, as Evans (▶ Chap. 54, "From Engagement to Empowerment: The Evolution of Mobile Learning in the United States") points out, data from the Speak Up Survey shows that students are in fact using their smartphones to support their learning outside of the classroom.

Technology tools can facilitate learning in general and *mobile* learning in particular (Cole and Engeström 2007). Indeed, tools are important supporters of "the doing" – enacting, reflecting, remembering, and sharing. Pen and paper, a technology that has been most popular in K-12 schools, *can* be pressed into service to support all-the-time, everywhere learning, but pen and paper technology is, first and foremost, a technology to support some-of-the-time, in-place learning. However, mobile technology in the form of a featherweight, playing cards-sized package, that can record voice and record images, is connected to the Internet and can be manipulated literally with the fingers on just one hand – or now, via voice, promises to support *all*-the-time, *everywhere* learning!

Mobile learning – with support from mobile technology – is important: *mobile learning is the predominate type of learning,* since the type of learning done while sitting at a desk in school, increasingly, is occupying less and less of a student's technology-based learning time (▶ Chap. 54, "From Engagement to Empowerment: The Evolution of Mobile Learning in the United States" by Evans). Yes, it is relatively easy to provide tools that support a learner who is sitting at a desk, reading, and reflecting on that reading. However, supporting a *mobile* learner can be much more challenging. For example, consider the following scenario – a scenario that is representative of what learners experience when outside of school:

- A young learner, on a blustery spring day, is hurriedly walking to school, not wanting to be late. As she passes a Banyan Tree, she is struck by the tree's elaborate root system. In school, the class was studying plants, and this young learner happened to be the "root expert" on her three-person study team. Of course, she was excited to take the "Banyan roots experience" to her team. So, with minimal fuss, as her school-provided smartphone was ready at hand, she withdrew it from the left-hand pocket of her jacket and, barely breaking stride, snapped several pictures of the root system! Back into school – our learner was indeed on time – she used the school network to send her root pictures to her team. Ultimately, the team, using their smartphones and the Mobile Learning Environment (Mifsud and Smørdal 2006), created a multimedia report (Fig. 1) on plants, as required by the classroom teacher who incorporated one of the young learner's pictures.

In our opinion, the above scenario is a type of "litmus test" for technology that purports to support mobile *learning* – learning that takes place inside and outside of school. In what follows, then, we apply this litmus test to other purported *mobile* technologies, e.g., 10-in. tablets, to see if those technologies do truly support mobile *learning*.

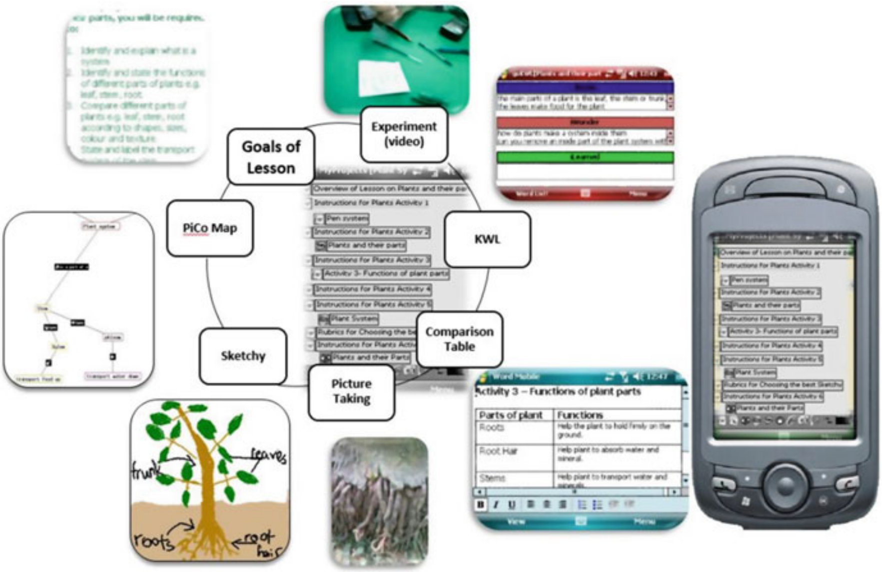

Fig. 1 A lesson on the plant cycle represented inside the Handheld Learning Environment (HLE)

What is the future of *mobile learning*? What are the roadblocks to its widespread adoption in K-12? That latter question is the focus of this chapter. To identify those roadblocks, our strategy is to look at the history of the adoption of mobile learning and identify those elements that have been key to successful adoption. As mobile learning and mobile technology are tightly connected, we can use Moore's "Crossing the Chasm" (Moore 1999) model of technology adoption to understand the three phases that mobile *learning* adoption has gone and is going through.

- Phase 1, 1997–2009: Given the early stage of mobile technology availability, it was only a small number of "early-adopting" teachers that jumped on board and made use of those initial mobile devices, e.g., the Palm and the Pocket PC.
- Phase 2, 2010–2017: During this second stage, *technology,* labeled as "mobile" – tablets, laptops, and Chromebooks – became more available, and the majority (the "early majority" and the "late majority," in Moore's terminology) of teachers accepted these devices into their classrooms. However, as we and others (e.g., Mageau 2012) argue, mobile *learning* was not necessarily being promoted.
- Phase 3, 2018–Onward: In 2018, *mobile* technologies are turning a corner – greater than 50% of upper elementary school students were using a smartphone (American Academy of Pediatrics 2017). In what follows, then, we explore the remaining roadblocks to mobile *learning* adoption.

Phase 1, 1997–2009: Early Mobile Devices for the Early Adopters

During Phase 1, the technology industry produced a broad range of handheld and mobile computing devices.

- **Palms**: Following his own, prescient, 1991 observation (Butter and Pogue 2002): "It is inevitable that all computing will be mobile" (p. 12). Jeff Hawkins co-founded Palm, Inc. in 1992 (Company Overview of Palm Inc. 2018). But, it wasn't until 1997, with the production of the Palm III series – black/white and color – that Palm devices became a very visible technology. The price point was acceptable ($300–450), they were easy to use (the Palm OS sported a finger-touch, icon-based interface – much like the one on the iPhone), and there was a range of apps available (e.g., from calendaring to journaling, using pen input).
- **Newton**: For a short period of time, Apple had an entrant in the handheld device space: the Apple Newton debuted in 1993 with a great deal of fanfare and high expectations. Unfortunately, the Newton did not live up to the hype (Beschizza 2007), and it was one of first projects that was canceled by Steve Jobs when he returned to run Apple in 1998 (Beschizza 2007).
- **Pocket PCs**: Running a version of Microsoft's Windows Mobile operating system, Pocket PCs were introduced in 2000 and produced by a number of manufacturers, e.g., Dell and HP (Pocket PC n.d.). Typically, Pocket PCs were more expensive than Palms ($500–$700) and were more complicated to use.

Interestingly, the term "PDA" – personal digital assistant – arose (Bayus et al. 1997) to characterize all of these types of devices. While the Palms excelled at providing a calendar and a contact list, the functionality of these devices didn't even come close to serving as an "assistant." For example, attempts to do recognition of a user's handwriting were not effective (Honan 2013; Plamondon and Srihari 2000). And, if Palms represented limited functionality and received kudos for their ease of use, Microsoft packed a great deal of functionality into their Windows Phone 6x/7x OS – functionality that was challenging to access on a limited-power, 3.5-in. screened device (Bayus et al. 1997).

Like all new technologies, these early mobile devices had "issues" especially for K-12: the devices tended to be fragile – even drops from 3rd grader heights were enough to shatter the screens; styluses resembled pencils and thus posed numerous issues for elementary and even middle school students. However, what we and the early-adopting educators – that 10% in Moore's model – saw in the PDA was the realization of our dream. Finally, with availability of a low-cost computing device, purchasing one for each and every child was conceivable. While the business and adult world saw laptops as the way to achieve 1-to-1, we saw handhelds as the way K-12 would achieve 1-to-1. In what follows, then, we describe how the Hi-CE Project, which was representative of mobile learning projects, sought to help teachers more effectively adopt these newly emerging mobile technologies.

Hi-CE and Mobile Learning: For the Early Adopters

During the late 1990s, the Center for Highly Interactive Computing in Education (Hi-CE) had been developing educational software for desktop/laptop computers (e.g., Model-It, a learner-centered systems dynamics modeling tool (Metcalf et al. 2000); Artemis, a learner-centered interface to the UMDL (University of Michigan Digital Library) (Wallace et al. 1998)). But because the PDA, as an educational device, was most compelling, Hi-CE stopped developing for desktop/laptop computers and focused exclusively on developing educational software for PDAs.

In 1999, Hi-CE produced the "Cool Dozen" educational apps (Soloway et al. 2001), e.g., Sketchy, a drawing and animating app; PiCoMap, a concept mapping app; and Fling-It, an Internet tool, and made the apps free for download and use. Hi-CE then integrated the apps into an "educational operating system" initially called HLE (Handheld Learning Environment). In 2004, HLE became MLE – the name for the tool changed from Handheld Learning Environment to Mobile Learning Environment (Mifsud and Smørdal 2006). The term "handheld" was disappearing as handheld devices increasingly gained Internet connectivity.

A critical aspect of the HLE was an app called LessonLauncher; it "glued" all the Cool Dozen apps together. Using LessonLauncher, a teacher could create a lesson, a series of learning activities that employed the Cool Dozen apps and that would engage the students in a holistic learning activity. A teacher would then send the lesson, encapsulated in a LessonLauncher file, to each student. In addition, teachers could create different lessons for different students to support differentiated instruction.

In Fig. 1, a lesson about the Plant Cycle that the children worked on is displayed on the Pocket PC screen. (The Plant Cycle lesson was developed by 5th grade science teachers at Nan Chiau Primary School in Singapore in 2005 (Norris et al. 2016).) Each rectangle is an app-based learning activity; click on the learning activity/rectangle and the LessonLauncher opens that app in which the student will do her/his work. Arrayed around the lesson screen are the artifacts created in the various apps. While the HLE/Pocket PC supported learning-while-sitting, e.g., a concept map showing the relationship of the parts in a plant, an animation for what happens when a plant is watered, the HLE/Pocket PC also supported mobile learning, e.g., capturing on video three 5th grade students discussing the classic celery/osmosis experiment and capturing a picture of a plant's interesting roots.

Roadblocks to Mobile Learning: What We Learned During Phase 1

Phase 1 was an exciting time for K-12 and mobile learning. Conferences dedicated to mobile learning sprung up literally all over the world, e.g., International Conference on Mobile Learning (http://www.iadisportal.org/pastevents) and mLearn Conferences (Naismith and Corlett 2006). But Moore's Chasm model was spot-on: during Phase 1 only the early-adopting teachers – the visionaries and the innovators who were technology "aficionados," who were looking for *major* changes in teaching and learning, and who were willing to put in major amounts of effort (e.g., creating curricular activities that exploited the mobile devices) – joined in adopting mobile learning.

Hi-CE's experience in K-12 classrooms was most telling:

- **Start-up**: The early-adopting teachers, about 10% on the left-side tail of the Bell Curve, stepped forward while school principals made funds available for software and professional development. GoKnow, Inc., the distribution arm of Hi-CE, had licensed approximately 40,000 units of the Mobile Learning Environment to schools in the USA, the UK, and Singapore, from 2002 to 2009.
- **Scale-up**: After a successful pilot in year 1, one school principal planned a scale-up. She/he instructed the teachers who watched during year 1 to get onboard. In Moore's Chasm model, this next group on the Bell Curve, about 30% the "early majority" teachers, are teachers who are not technology aficionados but who are only interested in what technology can do with respect to teaching and learning and who are not willing to work like the early adopters at making the technology effective. Indeed, the early majority teachers look with suspicion on recommendations from the early-adopting teachers. And, before the end of year 2, the project ended for the reasons identified below.

Why did scale-up fail?

- **Technology**:
  - **Devices**: The mobile devices kept changing; a model would be available for 1–2 years, and it would be replaced. In conversations with school information

technology (IT) administrators, they reported they were afraid to make the leap into mobile devices; maintaining the existing devices was a challenge, and supporting mixed-device classrooms was problematic for understaffed IT departments.

  – **Network**: During Phase 1, for schools, it was still the "early days" for the Internet. Bandwidth, access points, etc. were all new elements for the IT staff. Wi-Fi was so unreliable in some schools that they used cellular connectivity to link the students' mobile devices to the Internet – at significant cost. (Filtering – a requirement for schools – was a challenge to support on cellularly provided Internet.)
  – **Software**: As the mobile devices were changing constantly, it was virtually impossible to keep the educational applications on the devices updated. There was no central repository for apps during Phase 1. Mobile device management (MDM) was a new and relatively expensive idea, at the time.

- **Curriculum and Pedagogy**:
  Even if all the technological issues could have been overcome, there was a major hole as far as "early majority" teachers were concerned: curriculum – or the lack thereof. The curriculum created by the early majority the year before was idiosyncratic and worked because the early-adopting teachers made it work. The early majority teachers didn't have the time nor the expertise to do what the early-adopting teachers had done.

  Without curriculum that supports inquiry, early majority teachers found drill-and-practice software that they had their students install. Mobile devices could be pressed into serving direction instruction pedagogy without much effort.

Bottom line: during Phase 1, as we argued above, there were many roadblocks to the widespread adoption of mobile learning. However during Phase 2, as we argue below, some of those roadblocks were addressed.

The iPhone and the Age of Mobilism

Brynjolfsson and McAfee (2014) in their recent book, *The Second Machine Age*, argue that technology has had a bigger impact on civilization, on humankind, than "... Animals and farms, wars and empires, philosophies and religions..." (p. 7). In particular, in 1776, they observed that the steam engine, in fact, Watson's version of the steam engine, "More than anything else ... allowed us to overcome the limitations of muscle power, human and animal, and generate massive amounts of useful energy at will. This led to factories and mass production, to railways and mass transportation. It led, in other words, to modern life" (p. 7).

Brynjolfsson and McAfee (2014) go on to argue that "Computers and other digital advances are doing for mental power—the ability to use our brains to understand and shape our environments—what the steam engine and its descendants did for muscle power. They're allowing us to blow past previous limitations and taking us into new territory" (p. 8).

But, consistent with Brynjolfsson and McAfee's thesis, in 2007 technology again changed the world, (Wei 2012). The introduction of the iPhone by Apple, a device that fit in the palm of one's hand supported instantaneous communications, worldwide, and supported supercomputer-level computation – computation which in turn supported all forms of media viewing, creating, and sharing. And, all that functionality was easy to access and it was affordable. The "Age of Mobilism" was underway (Norris and Soloway 2011)! Against the backdrop of that event and that technology, we pick up the history of mobile learning – Phase 2.

Phase 2, 2010–2017: Mobile Technology Goes Mainstream in K-12

During Phase 2, K-12 experienced a dramatic uptick in technology access. According to a Pearson Student Mobile Device Survey (2015), about 60% of K-12 teachers adopted computing technology. In Moore's Chasm model of technology adoption, this 60% is composed of the "early majority" and the "late majority." (It is important to note, however, that in the Chasm model there is still a healthy percentage of individuals – Moore calls the "laggards" – that still have not joined in and adopted computer technology in their classrooms. It is beyond the scope of the chapter to explore how K-12 is addressing this sizable group of non-technology-using educators.) We have identified four technology trends that supported this wave of adoption during Phase 2:

- Tablet computing devices became popular, starting in 2010 (Wainwright 2013).
- Laptop computers increased in popularity due in large measure to a decrease in their cost (Conway and Amberson 2011).
- Bring Your Own Device (BYOD) became popular, beginning in about 2011 (Halpin and Collier 2012).
- Chromebooks became popular starting in 2013 (Singer 2017).

Interestingly, the term "mobile" technology came to include a broad range of computing devices: smartphones, of course, were mobile learning devices, but tablets and even laptops were considered to be mobile devices. However, as we argue below, tablets are not really *mobile* devices.

iPads in K-12

Building on the iPhone, Apple released the iPad in 2010. With its 10-in. screen, in contrast to the 3.5-in. screen of the iPhone, the iPad was a "transportable" device, not a "mobile" device. Consider the story of the young learner described earlier.

- What is the likelihood of the youngster, walking hurriedly to school, snapping a picture of the roots of the Banyan Tree with a 10-in. screened iPad? The iPad would not have been in her pocket; rather, the iPad would have been protected inside her backpack. Taking a picture of the roots of the Banyan Tree would have required that the youngster stop walking, take off her backpack, take out the iPad, take the picture, put the iPad back into the backpack, put the backpack on again, and now walk quickly so as not to be late to school.

But, in the classroom, the term “transportable” and the term “mobile” are, in effect, interchangeable; a student can move about the classroom holding an iPad, so an iPad is effectively a mobile computing device *inside* the classroom.

The above argument notwithstanding, schools, like consumers, became enamored with the iPad (Hu 2011; Wainwright 2012). The finger-touch interface made the iPad easy to use for elementary school children. Its ability to handle media came just when K-12 was finding the value of video for learning (Khan Academy n.d.). The iPad app store provided easily downloadable, supplemental resources (e.g., quiz apps, podcasts, and simulations) for classrooms. In 2013, Apple reported having sold 4.5 million iPads into K-12 (Etherington 2013).

BYOD in K-12

Starting in about 2011 (Halpin and Collier 2012), with the proliferation of student-owned computing devices, some IT staff began pushing for BYOD – Bring Your Own Device. From an administrative perspective, BYOD *appeared* to be a boon; here was a way to use technology in the classroom without the school having to pay for the devices.

But, from a teacher’s perspective, BYOD was a serious challenge. BYOD resulted in a heterogeneity of devices being brought into the classroom. Device-independent software (see Phase 3) was not available then, and thus a teacher couldn’t count on all the different devices having access to the same software (McCrea 2012). Essentially the only tool that a teacher could assume was available was a web browser. It is no surprise that web quests (Dodge 1995; March 2003), a form of digital scavenger hunt, became popular. Students would explore websites and take notes in whatever text editor was available on his or her BYOD computing device. While BYOD classrooms could well be 1-to-1 classrooms where every student had a computing device, given the heterogeneity of BYOD, technology could still only play a supplemental role in the curriculum (Mao 2017). And, from the school’s point of view, BYOD might well promote inequity just as schools were trying to address the growing digital divide (Office of Educational Technology 2016).

Laptops in K-12

George Moore (50 Years of Moore’s Law n.d.) has been credited with observing that the power (or the cost) of the CPU – the heart of the computer – doubled (or halved) every 18–24 months. This exponential growth greatly benefited K-12 schools during

Phase 2. Indeed, the availability of computing devices (so-called mobile technologies) in K-12 increased continually from 2010 to 2017, as documented by surveys of school technology (e.g., Pearson Student Mobile Device Survey 2015). Included below are some representative facts from that survey; in general, the numbers in 2015 increased from those in 2014 by about 15% (Pearson Student Mobile Device Survey 2015).

- "Laptops remain the most commonly used mobile device for school work. Eight in ten students (83%) report using a laptop to do school work during the school year" (p. 10).
- "At the elementary school level, tablets have replaced laptops as the mobile device that students use most often (78% for tablets vs. 66% for laptops)" (p. 10).
- ". . . 78% of elementary school students report that they regularly use a tablet. . ." (p. 11).
- Two in three middle school students (69%) report using tablets.
- Nearly half of high school students (49%) report using tablets.

Chromebook Up: iPads Down

While in 2013, Apple claimed that it had 94% tablet market share for [the] iPad (Cheng 2013), Apple began to see a reversal in 2014:

- "Around 715,000 Chromebooks have been shipped to U.S. schools in the third quarter, while Apple shipped 702,000 iPads to schools" (Tyrsina 2014, para. 2).

  Why?

- "Chromebooks start at $199, while last year's iPad Air . . . costs $379. . . . Another reason is that many school corporations seem to prefer the full keyboard found on Chromebooks instead of the touchscreen found on iPads. . . . while the touch panel is quite versatile, they keyboard is still associated with productivity" (Tyrsina 2014, para. 3).

Besides their cost, Google provided administrative software that made the management of Chromebooks relatively easy (Tyrsina 2014). Since 2014, the market share of Chromebooks has only increased – and increased dramatically (Global K-12 Mobile PC Market 2018) – while sales of iPads have continued to plummet (Singer 2017).

Roadblocks to Mobile Learning: What We Learned During Phase 2

Whereas we have been careful in this chapter to distinguish between mobile *technology* and mobile *learning*, K-12, in its public pronouncements (e.g., Kukulska-

Hulme 2007; Martin and Ertzberger 2013), has not been nearly as careful. Indeed, for all intents and purposes, during Phase 2, mobile learning and mobile technology were synonymous – and recall, mobile technology included laptops! But, we were not alone in calling for the untangling of these two notions – and for providing educators with curriculum and pedagogical models to realize mobile *learning*:

- "For [mobile] computing to achieve its promise, it has to be accompanied by some pretty seismic shifts in how instruction is delivered, the kind of curriculum being deployed (and a group of apps do not count as a curriculum), the role of students in directing their own learning, and how systems and structures support school change... But [schools are] not talking about these reforms; they're talking about their iPad initiatives" (Mageau 2012, para. 5).
- "So, no more 'iPad initiatives,' please... Let's create and publicize initiatives in teaching and learning..." (Mageau 2012, para. 8).
- "Although most educators would agree that mobile technologies have the potential to transform teaching and learning practices in schools . . . models to support this provision continue to be debated" (McLean 2016, para. 2).

Phase 3: 2018–Onwards!

By nature, techies are optimists! Thus, while mobile learning made little actual progress during Phase 2, we feel there are trends, as we describe below, in Phase 3 that might well break the logjam.

Technology

Phase 3 begins in 2018 for a particular reason – a technology trend that will have a major impact on bringing mobile learning into the classroom:

- **Many-to-1 is the New Normal**: As 1-to-1 became the "new normal" during Phase 2, many-to-1 is the new normal for Phase 3. Smartphones, Internet-connection supercomputers that fit comfortably into the hands of children, have now finally reached down into elementary school: in 2018, "...59.8 percent of fifth graders, 50.6 percent of fourth graders, and 39.5 percent of third graders" in the USA are estimated to have a smartphone (American Academy of Pediatrics 2017, para. 4). While discussions about what is a healthy amount of screen time abound (e.g., American Academy of Pediatrics 2013; Middlebrook 2016), the trend is clear: smartphones will be as ubiquitous in upper elementary school as they are in the general population!

Recall the litmus test for mobile technology: taking a picture, hardly breaking stride, while walking hurriedly to school. During Phase 1, and the limited deployment of handhelds, only a very small number of 5th graders could take such a picture. But, in Phase 3 with the increasing deployment of smartphones, virtually all 5th graders will be able to snap a picture while walking and then integrate that picture into their reports, using a Chromebook, while sitting at their school desks. *That* is mobile learning; finally, one piece of the puzzle is essentially in place. Unfortunately, the technology is the “easy” piece.

Curriculum

In 2018, there are three trends relevant to providing appropriate curriculum to support teachers in employing mobile learning in their classrooms:

- **Textbook use is decreasing** (Preville n.d.): Paper-based books, the mainstay of K-12 education, are decreasing in use. But textbooks, and their accompanying guides, have provided teachers with scope-and-sequenced, standards-aligned, curriculum that has been used day in and day out.
- **Digital curricula use is increasing** (Cortez 2017): From applications to content, teachers are increasingly using the Internet as their source for resources. For example, there are literally millions of open education resources (OER) freely available on a multitude of OER marketplaces.
- **Device-independent resources are increasing** (Kleinfeld 2013; Norris and Soloway 2016a): Initially, the iPad store was a wonderful source of resources *for the iPad*. But, in 2014, the World Wide Web Consortium approved the HTML5 standard (Bright 2014). Coding applications (e.g., a concept mapping tool) or interactive content (e.g., a simulation) in HTML5 enables those resources to run inside web browsers. (As it turns out, only some web browsers adhere strictly to the standards as specified by the World Wide Web Consortium, e.g., Safari, Firefox, Chrome.) And, as virtually all devices run web browsers, content coded in HTML5 is device-independent, i.e., content coded in HTML5 can run on a laptop, on a Chromebook, or on the smartphone that elementary school children are now, increasingly, coming to own.

The new, new in the K-12 classroom is still the old, old: curriculum, curriculum. Curriculum is still the heartbeat of the classroom (Alvior 2014). Research shows (Kane et al. 2016) that high-quality curriculum materials, like the tide, raises all the boats – help struggling teachers to be more effective and help master teachers to excel still further. Toward providing curriculum that supports mobile learning, then, the above three trends bode well:

- While K-12 textbook publishers provide digitized versions of their paper textbooks, reading such material on a computer or a small handheld is not particularly appealing nor do paper-based materials take advantage of the interactive capabilities of the computing device in the hands of the students.
- But, finding relevant, appropriate materials online is a challenge: a study by Wywrot (2018) shows that teachers are spending 6–10 h per week searching the

Internet for digital resources, with only moderate success (Norris and Soloway 2016b). Thus, for now at least, it appears that digital resources are being used more as a supplement than as essential curriculum.

- There is a need for core, digital, curriculum, not just isolated digital elements used as supplements. The arrival of HTML5 may well be important for curriculum development in general and for curriculum development for mobile learning in particular. Specifically, as smartphones are a key to mobile learning – to 24/7, all-time-time, everywhere learning – and as smartphones run web browsers just like desktops and laptops, creating curricular resources for mobile learning and mobile learners using HTML5 does not require a special process. That is, in the past, curricular resources for mobile learning needed to be crafted specifically for the different types of mobile devices, e.g., Palm OS devices, Pocket PC devices, Apple OS devices, Android devices, and Windows Phone OS devices. Now, since all smartphones run web browsers, the same curricular materials can work across all types of smartphones.

As the curricular materials created in HTML5 can work on all devices, simplifying curriculum creation, HTML5 availability potentially removes a roadblock for the advancement of mobile learning.

Pedagogy

Mobile learning is all about inquiry learning – about being aware of one's surroundings and wondering why: Why does thunder precede lightning? How does an ATM machine work? The Next Generation Science Standards (Improving Science Education Through Three-Dimensional Learning n.d.), with its focus not on the facts of science, but on the processes of science, and on supporting children in "figuring things out" (Norris et al. 2018) – explaining the phenomena that surrounds them – meshes well with an inquiry pedagogy.

Mobile learning is also all about synchronous collaborations: using computing devices, especially handheld computing devices, while working with others engaged in the inquiry. Collaboration is one of the twenty-first-century skills promoted by a broad range of standards, e.g., Partnership for twenty-first Century Learning (Framework for 21st Century Learning n.d.). For example, in our observations of 3rd grade classrooms in an elementary school in Singapore, we repeatedly overheard the children comment, when they had a disagreement or when they had a question, "let's ask the phone," which meant: let's do some online research.

There is, however, a real tension in K-12: scoring well on standardized tests is a key element in many K-12 classrooms. And, while there is some evidence that inquiry-style pedagogies (e.g., project-based learning) can lead to enhanced student achievement (Geier et al. 2008) on standardized tests, direct instruction is a reliable test-preparation pedagogy (Reis et al. 2007). And frankly, evidence that mobile learning leads to enhanced student achievement on standardized tests is lacking. Thus, while mobile learning resonates with inquiry pedagogies, the need to guarantee high test scores on standardized tests remains a roadblock to widespread adoption of mobile learning.

Conclusion

Learning is 24/7, all the time, and everywhere. Learning, like many other human endeavors, can be more effective when supported by tools. Fortunately, in this "Age of Mobilism," the smartphone and its supporting ecological infrastructure (e.g., Internet connection) have become increasingly more sophisticated and more functional. In 2018, more than 50% of upper elementary school children, in the USA, have a smartphone – simply a "phone" to the millennials (American Academy of Pediatrics 2017). Given this context, we stand by the statement made at the outset of this chapter: *mobile learning really will be the predominate type of technology-based learning in the future.*

And, while K-12 may well be on to other technological pursuits, e.g., personalized learning (Feldstein and Hill 2016), the reality is this: outside of school, smartphones are used for mobile learning. What's the evidence? Just look around. But, there is a disconnect between what individuals are doing with their handheld, Internet-connected, supercomputers and what K-12 feels is an appropriate use of mobile phones. There is indeed considerable debate among educators about the appropriateness of cell phone use in the K-12 classroom with data that suggest that test scores go up when mobile phones are banned from the classroom (Doward 2015).

Now, as we have argued in this chapter, there are specific issues with technology, curriculum, and pedagogy that must be addressed in order for teachers to feel comfortable and be effective in supporting mobile learning in their classroom. And, as we have argued in this chapter, we see indications that those issues will be addressed – and that mobile learning may well be advanced during Phase 3.

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Section X

Game and Simulation-Based Learning and Teaching

Section Introduction: Games, Simulations, and Emerging Technologies

58

David Gibson and Hiroaki Ogata

Contents

Abstract

This introduction to a section of the International Handbook of Information Technology in Primary and Secondary Education introduces concepts from educational data science that are central to researching and understanding games, simulations and emerging technologies. It then outlines briefly each of the chapters in the section.

Keywords

Educational technology games · Digital simulations · Emerging educational technologies · Educational data science · Digital media learning · Evidence-centered design · Game-based learning · Virtual reality · Augmented reality · Makerspace · MOOCs · Online learning · Cloud-based tools

This section of the *International Handbook of Information Technology in Primary and Secondary Education* faces two challenges. The first is to define and scope the

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wide-ranging topics implied by the title and the second is to provide a research-based overview. These are challenges particularly when "emerging digital learning technologies" are in early stages of discovery and implementation. We have limited the scope of emerging technologies as those that provide "digital learning experiences" and then to only a selection of those with significant research foundations. Otherwise, the entire scope of educational technology would be open for consideration. We have thus selected only a handful of emerging topics, leaving it to future updates of the handbook to include things such as robotics, wearables, artificial intelligence, and social media innovations. These newest technologies have the potential to transform learning by accelerating ubiquitous use of technology at scale, promoting the personalization of learning and introducing peer-based interactions into the data stream for continuous computation-led improvements.

To introduce this section, we briefly focus on a broad topic that underpins research on the knowledge base of games, simulations, and emerging digital learning technologies that are increasingly producing big data and the potential for learning analytics. This foundational field – educational data science – shares techniques and research concerns with emerging practices in assessment that utilize big data from digital learning experiences.

Larger flows of data available today about what the learner is doing while making decisions and interacting with digital learning materials is expected to continuously drive research into games, simulations, and other highly interactive technologies into the future (Behrens et al. 2011; Gibson 2012; Gibson et al. 2011; Quellmalz et al. 2012). For example, as artificial intelligence becomes integrated into a common cloud-based toolset and gives rise to a new group of practices in learning technologies, many of the same underpinnings of big data: gathering and cleaning massive amounts of data, pattern discovery, analysis and meaning making will continue to drive knowledge, classroom practice, and the continuous improvement of learning designs. The focus on big data provides an opportunity to point out that as the fields of games, simulations, and emerging technologies mature, educational data science (EDS) and learning analytics are keys to the future of research and the improvement of practice. Understanding EDS and learning analytics are thus two critical starting points for educational leaders, practitioners, and researchers.

Educational Data Science

The terms "educational data science" and "educational data scientist" have recently emerged within learning analytics and educational data mining communities, fields which themselves emerged as communities in the early 2000s (Baker and Yacef 2009; Romero and Ventura 2007). Naomi Jeffrey, contributing to a 2013 panel discussion at a "Learning Analytics and Knowledge" conference (Buckingham Shum et al. 2013) noted:

> The educational data scientist must dive from Learning Analytics (LA) into Educational Data Mining (EDM) and resurface: exploring the real world, proposing meaningful measures, modeling the data, visualizing the output, sharing the technique and automating the process.

We can see in this formulation that there are *processes* (e.g., diving and resurfacing) as well as *techniques* (exploring, proposing measures, modeling, visualizing, sharing) being used to understand learning via big data derived from digital learning experiences.

Educational data science (EDS) is perhaps best viewed as a complex multifaceted collection of sciences aimed at understanding learning and teaching in the digital age. We can characterize the field as scientific inquiry based on data in an educational cloud framework that seamlessly supports formal and informal learning through a layered set of services that supply infrastructure, platforms, and software as services. Key to the EDS processes is the learner log, a trail of information about learning actions in their contexts. EDS also sits at the intersection of three foundational sciences of educational theory in the digital age – cognitive neuroscience, individual and social psychology of learning, and computational science, including data engineering. Aspects of the field of learning sciences, for example, emerge in the connection of cognitive science to the psychology of learning. Educational technology research often sits in the junction of educational psychology and computational science; and in the intersection of cognitive and computational science sits ergonomics (i.e., human-computer interfaces) and artificial intelligence.

A digital media learning framework has been proposed for understanding and assessing learning in the era of big data and cloud resource learning environments (Gibson 2010; Gibson and Webb 2013) founded in three research pillars: (1) evidence-centered design (Mislevy 2011; Mislevy et al. 1999); (2) theories of performance assessment (e.g., Clarke-Midura et al. 2012; Gibson and Webb 2015; Westera 2014); and (3) Unique affordances of immersive digital media learning environments (e.g., Gibson 2013; Ifenthaler 2010).

As noted in (Webb et al. 2013) concerning evidence-centered design (ECD):

> The ECD framework (Mislevy et al. 2003) was developed by members of the National Center for Research on Evaluation, Standards, and Student Testing in the USA and has been applied to the design of a range of different types of computerized assessments including adaptive assessments, games, simulations (Rupp et al. 2010; Shute 2011), and portfolios (Gibson 2010). ECD is a four-staged assessment development framework that includes domain analysis, domain modelling, operational processes and the delivery system. The ECD framework makes explicit the interrelations among substantive arguments concerning domain models, validity, assessment designs and operational processes (Mislevy et al. 2003). The framework has diagnostic capabilities and provides for opportunities for stakeholders to view estimated competency levels, examine the evidence on which these judgements were based and to use this information for educative, formative purposes if appropriate

The ECD framework can be used in the planning and development processes of digital media learning experiences to guide ideation, construction, and then later, the EDS analysis of learner behaviors within a designed learning experience. The framework captures the foresight and intentions of designers and helps a team to embed data collection of evidence that can be used to characterize what a user knows and can do within that planned environment. It provides a road map for analysis of behavioral logs, for example, where the computer documents the actions and contexts of learner behavior. The ECD framework is made operational through three interacting models – the student, task, and evidence models, which have been extensively discussed in the literature (Mislevy et al. 2004, 1999; Rupp et al. 2010).

Reflecting on educational data science from the standpoint of performance assessment and the aforementioned ECD evidence framework, a critical issue is the intention of the learner as actor in the setting – not only what knowledge and capability he or she is exhibiting but what was the understanding of the context, prompt and urgency of acting in a particular way which produced that evidence (Kopainsky et al. 2010). Documenting and supporting the learner's intention is a critical challenge for the future study of impacts of emerging technologies.

The chapters of this section of the Handbook present an introduction to some of the breadth of the fields of games, simulations, and emerging technologies and underlying ideas just introduced. Perhaps easiest to implement are serious games and simulations, whether constructed for specific teaching purposes or not; so three chapters provide frameworks for thinking, raising key questions, and understanding their potential for learning and teaching. Rising quickly in educational research now are emerging practices with makerspaces and MOOCs and these each have a devoted chapter.

Introduction to the Chapters

In ▶ Chap. 59, "Guiding Questions for Game-Based Learning" by Karen Schrier, the capability of games to simulate intricate systems, invite collaboration and cooperation, and show people how to think through problems in new ways, uncover new truths and consider new perspectives is supported by a set of guiding questions for classroom teachers. The narrative provides a brief overview of game-based learning, shares approaches to using games for education, and identifies six characteristics or elements that should be considered when deciding whether and how to use and create games for learning. The chapter also reviews the key questions and challenges that need to be weighed when deciding whether and which game to use in educational settings.

To promote teachers ▶ Chap. 60, "Evaluating Games for Classroom Use," author Katrin Becker focuses on three needs. First, educators need confidence that games embody or support sound pedagogy. Second, educators need to be able to evaluate games for their potential as learning objects. Finally, educators need concrete models of classroom use of games. The chapter provides an evaluation model that can guide a structured analysis of a game for potential classroom use and a sampling of instructional strategies adapted for teaching with games.

In ▶ Chap. 63, "Educational Opportunities for Immersive Virtual Reality," Rick Ferdig, Enrico Gandolfi, and Zachary Immel examine existing recent research on the promise and the pitfalls of immersive virtual and augmented reality tools for educational outcomes. After providing concise definitions, the chapter then summarizes existing educational research on immersive virtual simulations. The chapter ends with a call for future research looking at key areas like special needs, potential negative long-term effects, training for teachers and students, and exploration of key concepts like embodied cognition, computational thinking, self-tracking, spatial reasoning, and situational/individual interests within immersive virtual reality.

In a companion chapter, ▶ Chap. 64, "Educational Opportunities for Augmented Reality," Gandolfi, Ferdig and Immel collaborated again to review research that highlights the current and potential impact of augmented reality in PreK-12, higher education, and professional development settings. While initial findings suggest use of the emerging technology can lead to increased engagement, the research synthesis offers a primarily theoretical argumentation for its PreK-12 implementation.

In ▶ Chap. 61, "Toward Creator-Based Learning: Designs That Help Student Makers Learn," Chen-Chung Liu argues that contemporary educators have been advocating that teaching and learning in schools should go beyond knowledge acquisition. A critical challenge is how to help students learn like expert creators who constantly display active engagement and personal autonomy, and who are keen to collaborate with others. Recently, construction-to-learn activities have received even more attention than before. The maker movement has been seen in many educational settings. However, the setup of makerspaces does not necessarily guarantee a positive impact on students' learning. Too much emphasis on the hardware tools may blur the educational focus and the merits of maker activities. The chapter summarizes and presents studies related to construction-to-learn activities which support students in their learning as creators. It revisits the key design principles of learning systems based on the needs of student makers: "supporting students to express their imagination," "facilitating endless remixing," and "low-threshold/high-ceiling." Design examples and research findings are presented to hopefully shed light on the design of maker activities which can continuously engage students in construction-to-learn activities.

Vanessa Chang, Christian Gutl, and Martin Ebner discuss, in ▶ Chap. 62, "Trends and Opportunities in Online Learning, MOOCs, and Cloud-Based Tools" for primary and secondary education. The narrative begins by discussing the evolution of traditional classroom to online learning, followed by background on MOOCs and related research including those that are directed at K-12 teachers and students. The chapter discusses learning at scale with the MOOCs experience and the use of cloud-based tools (CBT) to create content for learning purposes and to provide teachers with increased flexibility to select their preferred learning tools and media to meet their own classroom needs and objectives. The chapter summarizes experiences, case studies, and examples that illustrate where these forms of technology-enhanced learning are heading.

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Guiding Questions for Game-Based Learning

59

Karen Schrier

Contents

Abstract

The primary goal of this chapter is to identify the main questions and tensions for researchers, practitioners, and policymakers to navigate when considering why, how, when, who and whether to use and design games for learning. The chapter

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reviews elements related to using games for learning, such as motivation, problem-solving, and story, as well as guiding questions such as "what are the goals?" and "who is the audience?" Finally, future trends in games and learning are considered.

Keywords
Games · Game design · Educational games · Game-based learning · Serious games · Digital games

Introduction

In the free online game, *Spent*, players make choices as an unemployed single parent who needs to make it to the end of the month without running out of money (Roussos and Dovidio 2016). For instance, players may be asked to decide whether to give their child lunch money rather than pack a lunch or pay for the treatment of their pet's illness, put it to sleep, or let their pet suffer, each of which have varying financial and social consequences. The educational goal of the game is to reduce prejudice against the poor and to enable players to "walk in the shoes" of someone who is poor, helping to enhance empathy and care (Roussos and Dovidio 2016).

However, when Roussos and Dovidio tested *Spent*, they found that not only did empathy and positive attitudes *not increase* after playing the game but, for some players, *negative attitudes* toward the poor actually increased after playing *Spent*. People who were already more likely to feel like poverty was a result of choices that are personally controllable had even greater negative attitudes toward the poor after playing *Spent*. Roussos and Dovidio suggest that these results were due partly to how *Spent* was designed as a game, in that the players could control their choices and its consequences and make the right choices to survive a month. Thus, players believed that likewise people who face real-life financial struggles should just make better choices. For those players, playing *Spent* decreased empathy for the poor; however, watching a video of the game being played did not have the same effect, because agency over one's choices was removed (Roussos and Dovidio 2016). On the other hand, the game raised $7,000 for a homeless shelter and enhanced awareness of financial inequities for some players (Farber and Schrier 2017).

Spent failed to meet its educational goals for some of its target audience members. Just as with any instructional experience or activity, whether a conventional lecture or textbook, website, or game, there are strengths and weaknesses, unintended consequences, and serendipitous possibilities inherent in the design of the learning experience. The design of an experience, for example, may even matter more than the medium, in that a specific game (e.g., *Mission US*) may work for a specific educational need (e.g., developing historical empathy for middle school students), while other games would not, just like some textbooks are written appropriately for an audience or topic and some are not (Clark et al. 2016; Schrier 2016c).

Ke (2016) explains that there are typically two areas of learning that are supported by games: (1) skills, such as systems thinking, argumentation, literacy, and computational thinking, and (2) domains of knowledge, such as health information or history (Ke 2016). In addition, games may support changes in attitude or affect, such as interest or curiosity for a topic or perspective (Squire 2011). Even for those skills and domain areas that games teach well, the same experience may not work for every student or set of conditions. Digital games are never one-size-fits-all solutions, and a successful activity in one classroom may not necessarily be transferrable or scalable.

The primary goal of this chapter is to identify the main questions and tensions for researchers, practitioners, and policymakers to navigate when considering *why*, *how*, *when*, *who*, and *whether* to use and design digital games. What factors should be considered when designing, using, and assessing a game for learning? How do game designers balance fun and accuracy, immersion and transfer, facts and skills, and innovation and tradition in a game? Would a game be the most appropriate way to teach a particular skill, attitude, or topic?

First, the narrative provides a brief overview of game-based learning, shares approaches to using games for education, and identifies six characteristics or elements that should be considered when deciding whether and how to use games for learning. Next, the chapter reviews the key questions and challenges that need to be weighed when deciding whether and which game to use in educational settings.

What Is Game-Based Learning?

Game-based learning comes in many different shapes, sizes, genres, and styles and varies tremendously, from learning what it's like to be President of the United States in iCivics' *Executive Command* to understanding what it's like to be the parent of a terminally ill young son in *That Dragon, Cancer*. In general, game-based learning involves using games for some type of educational purpose – such as a non-digital card game that features historical figures, a digital drawing game that supports creativity, or a word puzzle game that teaches Spanish. Sometimes a game is a central part of a classroom lesson, such as a long-term assignment to craft a historical building like the Taj Mahal in *Minecraft* (Weitze 2016). Other times games may be a shorter activity that leads to further deliberation, such as using *The Migrant Trail* to kick off a discussion on immigration or using *Dys4ia* to reflect on gender identity and marginalization (Schrier 2014). Game-based learning could be as simple and straightforward as playing a "name remembering" game at camp or as complex as transforming an entire class module into an alternate reality game (ARG), such as Darvasi did to teach *One Flew over the Cuckoo's Nest* for his English students (Darvasi 2014).

We can formally define games, as Juul has done in *Half Real: Video Games between Real Rules and Fictional Worlds*, as having a "rule-based formal system; with variable and quantifiable outcomes; where different outcomes are assigned different values; where the player exerts effort in order to influence the outcome; the player feels emotionally attached to the outcome; and the consequences of the activity are optional and negotiable" (Juul 2005, p. 13). However, whether an experience is fully “a game,” is gamelike, has some playable aspects, or is inspired by but is not actually a game does not matter as much as whether it is useful, effective, and appropriate for the educational experience, needs, audience, and context. As such, what it means to be “game-based learning” continues to evolve, and the role of information technology in creating, offering, and experiencing games is also varied and evolving. The word “digital” will not be used throughout the chapter, but it should be understood that the chapter will focus on digital game-based learning as key area in educational technology that has emerged since the last edition of the handbook. Despite the focus on digital games, however, many of the guiding questions and research can apply to all types of games, including non-digital ones.

Why Digital Games for Learning?

Over the past two decades, there has been an explosion in the use of, design of, and research on digital games and learning, with people using games in classrooms, museums, libraries, and after-school programs and even at home for educational purposes (Schrier 2016a). For instance, more games are being played in the classroom than ever before, with 74% of K-8 teachers using games and 55% of teachers using games at least once a week in the classroom (Takeuchi and Vaala 2014). The Entertainment Software Association found that 63% of American households have at least one person playing video games at least 3 h per week (ESA 2016).

Moreover, empirical studies have suggested the potential of using digital games for learning (Sitzmann 2011; Wouters et al. 2013), though there is little consistency among the methodologies used to measure effectiveness. (For example, many are case studies, were not randomized properly, or have small sample sizes (Crocco et al. 2016; Brom et al. 2016).) In a study with a large data set that uses quantitative measures, Crocco et al. analyzed the use of game-based lessons in English, Math, and Science courses (2016) against control (nongame lessons) courses. Their findings suggested that games correlated with increased enjoyment of learning and that enjoyment also related to deep learning and higher-order thinking, suggesting that games can support learning through increased enjoyment (Crocco et al. 2016). But seemingly in contrast, in a meta-analysis of the cognitive and motivational aspects of games for learning, Wouters et al. (2013) compared games to conventional instruction methods (skill and drill practice, lectures, reading, and websites). Their results suggested that the games were more effective in learning (from a cognitive perspective) and retention, but not in motivation (Wouters et al. 2013).

Another recent meta-analysis of game-based learning research, supported by a Microsoft/SRI International grant for GlassLab Research and conducted by Clark et al. (2014, 2016), found that digital games can support learning better than nongame conditions in terms of cognitive learning outcomes. The design of the game, rather than the medium of “games” itself, was more important to whether the environment supported learning (Clark et al. 2016). Thus, whether a game is successful and effective is complex and often relies on the design and the context within which it is used.

When rationalizing the use of educational games, proponents often mention the increasingly large number of people playing games and using games in learning. They may point to case studies of using games in the classroom (Farber 2015), books on games and learning (Gee 2003), or evangelists for games (McGonigal 2011). However, games have always been connected to learning. Play has always been a way that people learn about each other, connect, understand and share ideas, and contribute to humanity (Schrier 2016c). That said, games should not be used because they are trendy, popular, or *seem* like more fun than other activities. They should be used because they are the most appropriate design solution and contribute to the best experience for specific educational needs. The next section describes six different characteristics of games for learning that may be useful when deciding whether and how to use or design a particular game.

Game Elements to Consider

Educators and researchers have investigated key aspects of games that can contribute to learning. These include motivation, fun and engagement, social interactions, problem-solving, and story, as well as games as systems and tools, which will be outlined in the next sections.

Motivation

Motivation relates to how people decide what to do and why to do it and is defined as moving someone to do something, like play a game (Ryan and Deci 2000). Games, if well designed, can be motivating for players, which make them potentially useful for activating learning, though the relationship among motivation, engagement, games, and learning is complex (Wouters et al. 2013). Eseryel et al. (2011) investigated McLarin's Adventure, an educational massively multiplayer online game (MMOG) geared toward eighth and ninth graders, and their findings suggested that enhanced engagement in the game resulted in better learning outcomes. They found that providing appropriately timed and balanced challenges throughout the game experience related to more engagement and motivation in the game (Eseryel et al. 2011).

On the other hand, games are not automatically motivating. There are a number of challenges to consider. Game players may be pulled in many directions – school, extracurriculars, and family obligations – in addition to entertainment and other game choices. Educational games may not be as visually appealing, narratively engaging, or dynamically designed as their mainstream counterparts. Different types of motivations – intrinsic and extrinsic (Deci and Ryan 2000) – may have differential results in games and learning (Malone 1981). Ryan and Deci's (2000) self-determination theory explores two motivation types: intrinsic (e.g., driven by something inherently interesting) and extrinsic motivation (e.g., due to external factors or objects). Ryan and Deci's research generally suggested people were more likely to practice skills or acquire knowledge if they felt more connected to others, more competent, and had autonomy over their choices and behaviors (Ryan and Deci 2000).

Moreover, people may be motivated by different aspects of gaming. Yee and Ducheneaut's Quantic Foundry, a company that focuses on surveying game players to understand their motivations, found that men are more likely motivated by competition (e.g., rankings, match wins) and destruction (e.g., explosions, car chases, guns), whereas women are more motivated by fantasy (e.g., acting a role in another world) and completion (e.g., finishing missions, collecting). Younger players are more likely to be driven by competition than older (above 35 years old) players, who are more driven by completion and fantasy (Yee et al. 2016).

Fun and Engagement

Should learning games be fun first and educational second? Researchers are split on whether the pedagogical aspects of the game should be prioritized over fun (Ravyse et al. 2017) or whether games and simulations need to be entertaining to be useful, educational, or effective (Crocco et al. 2016; Ravyse et al. 2017). Some researchers point to the importance of fun in educational game design (Habgood and Ainsworth 2011), and most game designers prioritize fun as the top aim of any game (Koster 2004), although what actually counts as "fun" may not be the same for everyone, and the difficult challenges in a game (e.g. Papert's "hard fun") may be what is actually fun (Bogost 2015). Educators should ensure that the balance of fun and work, and entertainment and learning, is appropriately maintained for each student throughout the experience.

Csikszentmihalyi (1990) describes a type of engagement with games – which he calls "flow" – where the player is immersed deeply in the experience. Achieving flow may be integral to learning. Educators need to ensure that, even if players are deeply immersed in a game, they are also engaged in learning and able to transfer any new knowledge to nongame environments.

Moreover, games are sometimes framed as being fun and frivolous, and this perception matters in whether games are acceptable for educational purposes and whether they are taken as "serious" learning environments. If a game is perceived as too fun, players may not take the content seriously enough. In *Beyond Pleasure and Pain*, E. Tory Higgins (2012) describes a study where some participants were encouraged to have fun while learning the material, and other participants were told that the task would be tedious and serious. Participants were also divided by high and low importance: some received instructions that the task was of high importance, and others were told it was not. Those people in the "high importance and high fun" group actually had a lower performance than those in the "high importance and low fun" one. So, while we may expect fun to be motivating and enhance our performance, because people expect that learning will be serious and not fun, this ended up hurting performance (Higgins 2012). Educators need to set and monitor expectations, frame game playing experiences as learning experiences, and also reflect on the game afterward to ensure that students deem a game as highly important and serious, even if it is also fun.

Social Interactions

Not all learning is best accomplished with other people (or even other devices or tools, such as computers, or nonhumans), but when properly designed, games can be particularly adept at enabling social interaction, helping people connect, and expanding community. Some educational goals may benefit from the ways that games can help to support collaboration through a game or around a game (such as in the case of players actively sharing resources or tasks in forums or social media). "Many in-game and out-of-game practices acculturate users, such as problem solving together on a quest, engaging in debates and other social events, or participating on fan sites and blogs" (Schrier 2016c, p. 105, citing work by Steinkuehler, Jenkins, and Gee). Players (such as those of *World of Warcraft*) may develop shared norms and practices through these communities (Steinkuehler 2007) and may also engage in peer-to-peer mentorship (Steinkuehler and Oh 2012), which all contribute to epistemic learning, a type of learning in which people adapt to the vocabularies, tools, values, and norms of a community by participating in it (such as through games) (Shaffer 2006; Squire 2011). Feeling a sense of belonging and inclusion in a game community may also contribute to learning (McGonigal 2011; Schrier 2016c).

Social interactions can also motivate further game playing, problem-solving, and make each greater than the sum of its parts (Eseryel et al. 2014; Yee 2006). For instance, in a study, players who shared a computer while playing a game were more motivated and had higher learning outcomes, possibly because they had to articulate their ideas and moves collaboratively, helping to reinforce their learning and engage them in the game (Inkpen 1994).

When supporting social interaction, caution is warranted. Certain types of online gaming communities can also be deleterious and discourage or demotivate learning. Particular games and gaming cultures may be rife with bullying, harassment, and toxic communication and may feel exclusionary or demotivating. Competitive social interactions may be welcoming to some but not others. For example, in an exergaming study by Song et al. (2013), players who were already driven by competition were more motivated to play, but those that were not driven by this were less motivated to play (Song et al. 2013).

Not all games are designed to support social interaction, whether informal sharing outside of the game or intense collaboration or competition within the game (Schrier 2016c). To enhance learning, educators and researchers are encouraged to think about how to appropriately add a social dimension, such as using social media, wikis and blogs, or journaling with pair-share groups.

Problem-Solving

Games at their core involve problem-solving or the process of finding solutions to problems (e.g., avoiding enemies in *Super Mario Run* or collecting enough Pokémon creatures in *Pokémon Go*). The game serves as a manifestation of a "problem space" (Jonassen 2000), where the game's rules and boundaries constrain and encourage certain solutions to be created in that space. Games may be particularly effective for practicing problem-solving because they can enable players to experience cause and effect by observing what is rewarded or punished within the game (Schrier 2016c). Players can test out hypotheses about how to solve a particular game's problems (e.g., avoiding enemies in *Super Mario Run*), such as through trial and error (e.g., jumping and seeing what happens), in-game tutorials (e.g., watching an example of jumping over enemies), educated strategies (e.g., trying jumping because it worked in the original *Super Mario Brothers*), or observing other players (e.g., watching videos of other people playing the game). Gee explains how games spur players to go through a cycle of questioning and probing the world, which he calls the "probe, hypothesize, reprobe, rethink cycle" (Gee 2003, p. 90). Games can also serve as microworlds, where players can iteratively push on a game's boundaries and explore causes and effects, which helps players test out solutions to problems (Papert 1993).

Games have been credited in honing players' problem-solving skills, such as by encouraging alternate paths, providing stories or analogies, or encouraging the sharing and deliberation of different perspectives among players. Games can help people move beyond functional fixedness or being fixated on the typical problem and solution. But games are not necessarily appropriately designed for all types of problem-solving, and problem types need to be matched to game play, audience, and contexts (Schrier 2016c).

Story

Not all games have or need an explicit story or narrative, but those that do can be particularly motivating for some players, such as those that are driven by fantasy (Malone 1980; Yee 2006) and immersion. Malone discusses fantasy as a key motivator for games, for instance, and uses Walt Disney World to illustrate how children experience fantasy worlds, see themselves in fantasy roles, or fulfill wishes through play (Malone 1980, 1981).

Story can work in different ways. People may be motivated to experience, complete, or co-create a story or narrative experience (Schrier 2016c). Shum et al. describe how story can help situate data and elements of a problem to provide meaningful context and illustrate its human dimensions (Shum et al. 2012). Providing a story context for a problem can also help by showing new perspectives or reframing the problem so people do not get stuck applying conventional or ineffective problem-solving methods. Story can also help make abstract concepts and problems more personally meaningful and relevant (Schrier 2016c). Teachers can also have students write their own stories about playing the game or even expand on the characters or interactions in the game. However, not all games need to have a significant story, and not all students will be motivated by story elements (Yee et al. 2016).

Games as Systems and Tools

Real-world concepts and topics, whether related to economics, history, ethics, literature, anthropology, or biology, require authentic tools, models, and epistemologies to interact with them. To act like a scientist, for instance, you need to be able to use real-world scientific data and study real-world organisms or physical properties. You need to use tools and processes such as microscopes or mass spectrometry. You need to understand how scientists know and interact with the world, the typical language and terms used, and norms and values of the profession. Biological processes, such as photosynthesis, and social policies, such as immigration, are often not straightforward concepts but complex “living, breathing” social, cultural, economic, political, and scientific systems with many interconnecting parts, which, to be fully understood, need to be embraced holistically and systemically.

Likewise, games themselves are dynamic systems that can help situate meaning and simulate the complexity of various concepts, skills, and issues. “Players enter and explore within a game world, which is a deliberately designed system based on a set of rules, assumptions, and values” and which is further influenced by the addition of human players, their game play, the communities that emerge, and their own unique activities (Schrier 2016c, p. 39). While games cannot possibly simulate or model every corner of a dynamic system, they can realistically reimagine aspects of complex processes, skills, actions, and information within an authentic context, situate learning, and bring people together (Schrier 2016c).

Games can also function as tools by which to authentically explore systems and topics and to practice particular skills, attitudes, and perspectives (Shaffer 2006). For example, participants in *Foldit* can use authentic 3-D models of proteins, just as scientists would, and players in *Reverse The Odds* use real images of cancerous tumor cells to make judgments and classifications. Furthermore, players can design and co-create games as tools to help construct their own understanding of various topics, such as by making a game that models healthy interpersonal behaviors or designing one that authentically reflects gravity on the moon.

Guiding Questions for Studying and Using Game-Based Learning

This section explores various tensions, challenges, and questions to consider when studying the impacts of, or implementing, games for learning.

What Are the Goals?

A primary challenge in designing, using, and assessing games for learning is establishing goals and ensuring that both educational goals and game goals are appropriately matched. Weitze (2014) describes game goals as “objectives . . . what we strive for . . . [and are] fundamental to games” (p. 226). In a game, there are immediate, pragmatic goals (e.g., finish a level) and sub-goals (e.g., jump over an obstacle). There is also an ultimate game goal, ultimate outcome (Fullerton 2014), or end result needed to complete, accomplish, or reach to win the game. In a well-designed game, players know that they have reached game goal(s) through in-game feedback, such as points, rewards, trophies, badges, unlocked levels, or progression of some kind (Weitze 2014).

Learning or educational goals, on the other hand, relate to a measurable change in skills, knowledge, abilities, information, attitude, feeling, and/or connection (Weitze 2014). In particular, curricular goals concerning knowledge, skills, and attitudes relate to those aspects of a curriculum that need to be covered or taught in a given activity, module, and/or time frame (Weitze 2014). Students and teachers may determine when learning goals have been reached through a combination of assessments, such as exams, completion of assignments, reflection exercises, observation of behavior, progression to more complex activities, or the successful application of learning to real-world processes (Weitze 2014).

As may be apparent, game goals, educational and curricular goals, are not necessarily the same and may diverge significantly. When designing games for learning, all relevant goals should work together appropriately and be "concrete. . .challenging but achievable. . .rewarding. . . balance[d] in the short- and long-term" (Weitze 2014, p. 231; Whitton 2009). Weitze describes a number of methods for orchestrating goals, such as the Q Design Pack for Games and Learning (Salen et al. 2011) and Smiley-Model (Weitze and Ørngreen 2012). For instance, in the Smiley-Model, designers can use the game goal, rules, choices, challenges, and feedback to intertwine with the learning goal (Weitze 2014).

Who Is the Audience?

Another key consideration is understanding the audience: who are the learners, what is their current skill level and expertise, what is their prior experience with games and gaming, and what do they enjoy learning, playing, and doing?

First, consider what motivates learners in terms of the games they want to play. Bartle (1996) describes four different player types (killers, achievers, socializers, and explorers). Achievers care about meeting goals and rising above challenges (similar to achievement in learning). Explorers want to discover the virtual world and push boundaries; socializers want to interact with others; and killers want to compete, show off, and wield power (Richard 2014; Bartle 1996). Building on this model, Quantic Foundry identified distinct player motivations for digital games, such as competition, destruction, challenge, story, and design, and four clusters of motivations for board games (e.g., conflict, strategy, immersion, and social fun) (Yee et al. 2016). Likewise, Radoff (2011) considers how different types of feedback may motivate a player. Quantitative feedback may be points, badges, monetary rewards, or leaderboard statistics; qualitative feedback may be stories, smiley faces, strengthened bonds, jokes, gifts, or character development (Richard 2014; Radoff 2011). Vandenberghe (2012) began to match the "Big Five" personality types to elements of play, such as novelty (openness), challenge (conscientiousness), stimulation (extroversion), harmony (agreeableness), and threat (neuroticism) (Richard 2014).

Thus, knowing what drives and motivates a learner can help with matching that individual to the correct type of game or learning experience. Beyond considering player motivation types, players can also be matched based on hobbies, interests, or personality and just as with any learning experience, their "reading ability, learning curve, cognitive ability, learning style, and physical ability, as well as tactile desires" (Richard 2014, p. 209) – though all factors do not need to be simultaneously considered to make an appropriate match.

Other audience factors to consider include the accessibility of the game, the game's technology, and the culture that emerges from and around the game (Richard 2014). Gaming cultures emerge from or around a game and may include political or cultural views expressed in the game; or implicit biases or values may be negotiated through the game. For instance, does the game support an inclusive learning environment or will players feel marginalized by a game's genre: representations of race, sexuality, or gender? Does each player and player type have an equitable chance of engaging in the experience and attaining its goals?

What Is the Context for the Game?

The context of the game – how it is played, where it is played, with whom it is played, and how the game is framed – all affects its success, efficacy, and acceptance as an educational experience. Gee distinguishes between the little "g" game and big "G" Game. "Everything in-game is the game, with a small 'g.' The context around play is part of the Game, with a big 'G.' That is, it is not only the physical environment around the game but also the virtual environment," as well as the learning context (Simkins 2014, p. 268, citing Gee 2012). Rarely should a game be viewed as a stand-alone activity (just the "g"); rather, it should be considered as part of a larger learning experience alongside other types of interactions, activities, lessons, topics, exercises, and assessments, as well as in relation to the broader environment and communities surrounding it (the big "G").

Factors related to the educator can affect the success of a game in a classroom, such as a teacher's beliefs and attitudes about games, their professional development and training, and the teacher's prior experience with games and game-based learning (Groff et al. 2016). Teachers, for instance, may have trouble deciding whether a game is appropriate for a particular educational need or whether the content within the game is accurate and design effective (Kirriemuir and McFarlane 2004; Groff et al. 2016). Moreover, educators may not have the necessary game literacy (Zimmerman 2008) or design understanding to look more deeply into of the game and understand how it works; what values, misconceptions, or biases it may express or magnify; or how students may cheat, hack, bully, or otherwise transgress in the game (Consalvo 2007). They may not know how to question or interrogate the game with students even if they have a lot of experience with a particular game.

Another important consideration is the physical place where a game is played. Playing a game in a dinosaur museum, where students are able to also see bones, preserved tails and features, or teeth up close, is different than playing a game about virtual dinosaurs in a classroom or at home. Playing a location-based mobile game as a pair while walking around the site of the Battle of Lexington (as with

Schrier's *Reliving the Revolution* (Schrier 2014)) is different than sitting at a computer, virtually walking around a historic site (as with *Mission US* or *Past/Present*).

Moreover, the type of support that is provided also matters. A busy after-school program, with only one teacher to support many individual student needs of different ages, is a different environment than a small preschool classroom with three teachers who can collaboratively guide a game. An outdoor camp game for high school students that involves physically exploring a large forest may need different types of support than an improv game for college theater students. A game needs to be shaped to the context and needs different types of facilitation to enforce any boundaries, rules, and norms.

The communities that emerge around and within games also affect the context through which a game is played (Kafai and Fields 2009; Steinkuehler 2007; Shaffer 2006). Jenkins et al. describe "participatory cultures," where people are actively creating, reconfiguring, revising, and reconstituting media and collectively participating in worlds such as games, where they are creating new avatars, story lines, or fan materials (Jenkins et al. 2006). The spaces where participants, players, and fans interact may be sanctioned by the game designers or even unsanctioned, and this affects the context of the game.

Thus, just as with any educational activity or experience, educators and designers must consider the dynamic and evolving interaction among students, place, expertise, educator, community, and other factors. Continuing to evaluate and reevaluate the context, and adjusting the experience, is part of the new role of the teacher-as-designer of learning experiences with games.

Practical and Technological Considerations

Practical and technological factors such as cost of the game, length of setup, time of game play, platform and technology used to create and play the game, length of class period or educational experience, and technology available to the students all make a game more or less feasible for learning. These pragmatic considerations need to be fixed or acted upon before moving to other considerations, such as curricular fit or audience's needs. If the technology itself does not work or cannot be accessed, we cannot even consider how to include it for educational use.

Certain platforms may be better at teaching and encouraging particular skills or interactions. For instance, a networked game (such as a console or browser-based game that has multiplayer options) may support certain social interactions in a virtual world, whereas a mobile or non-digital game may encourage real-world social interactions. On the other hand, a single-player computer game may be better at investigating individual performance on a skill or concept, depending on its design.

The platform used also has implications for accessibility, inclusion, context, equity, design, and learning in general. *Minecraft* accessed from an in-class private server may provide a safer "walled off" environment than playing on an open server with virtual strangers. Students with different sensory needs, neurotypes, or abilities may be affected negatively by an intense virtual reality game, one with too many players, one that requires rapid hand or physical movements, or one that does not involve tactile interactions, depending on needs.

The length of time for completing a game can vary widely. Although longer games may be difficult to incorporate into classroom or more structured learning environments, the payoff for an extended experience with the game may be valuable. Groff et al. note that "Although more work may be involved to leverage these games successfully, they also offer the potential of developing 21st century skills, such as problem solving, decision-making, planning, strategy, and collaboration" (2016, p. 23, citing Klopfer et al. 2009).

Students may also be able to work with teachers, researchers, or designers to create games. For instance, younger students may use programs such as *Scratch*, *GameStar Mechanic*, or *Minecraft* to create or modify games as part of an assignment (Nolin 2016). Older and adult students may use Construct 2, GameSalad, Unity, Unreal, Twine, Metaverse AR, or ARIS to create games (see Nolin 2016; Chen 2016 for more details on each platform).

Curricular Considerations

The curricular objectives and domains of knowledge covered by a game can also affect its design and use. For instance, the educational objectives of a game, and any curricular needs of the learning experience, affect the need for accuracy in the game, the capability for authentic practice, level of literacy needed to play or learn from playing, skill development possibilities, support for creative and critical thinking, as well as the way domain knowledge can be applied within and beyond the game.

The extent to which game accuracy and precision matters, for example, depends on the game and learning goals and the types of skills, facts, topics, themes, approaches, or attitudes you aim to teach. When teaching students how to manage resources or to consider broader history themes, such as the balancing of resources toward religion, culture, military, and economic growth, then the COTS game *Civilization* may be appropriate and would not necessarily need to maintain a high accuracy to real historic events (Squire and Barab 2004; Squire and Durga 2006). Too much detail or connection to the real world in certain contexts may stifle the flexibility, creativity, and experimentation needed to learn a particular concept. What works well in real life or even in a book or video may not perfectly translate to a virtual space or non-digital gaming environment.

For instance, in *Mission US*, students can explore different moments and events from history, such as the Revolutionary War or the Underground Railroad (Schrier 2014; Farber and Schrier 2017). Enabling an authentic practice of relevant skills, such as argumentation or perspective-taking, may be more important than providing historically accurate or overly realistic scenarios (Schrier 2014).

Likewise, games can enable interaction with authentic scientific tools and models to help teach computational and technical skills (including "problem solving, algorithms, modeling, and abstraction" (Werner et al. 2014, p. 38a). Other games may provide opportunities for dialogue or discourse or even musical, artistic, and physical interactions to learn relevant skills and behaviors. For instance, Kognito creates dialogue-based games, where players work through practice conversations (such as about a family member suffering from PTSD or about a doctor working with a family on healthy eating behaviors).

Assessment and Evaluation

One of the most important and challenging aspects of using and designing a game for learning is understanding whether it is effective, accessible, and useful for students, meets educational needs and goals, and teaches the appropriate skills, concepts, attitudes, or topics. Simkins (2014) recommends three questions that need to be considered to help in shaping any assessment plan: what are the learning goals of the game, how is the game played (mechanics, elements, game goals, game play), and what is the context of play? Assessment of games in learning is similar to other types of educational assessment, with pros and cons for different methodologies. Gibson and Webb (2013) argue that assessment should move from summative types to assessments that are "continual, diagnostic, and formative" and consider the "personal growth of the student, impact on social issues, and cultural importance" (p. 17).

Quantitative methodologies focus on measuring with a goal of replicating, verifying, and comparing results across and between students (Simkins 2014). Simkins describes some possible quantitative methodologies such as pre- and post-game examinations or eye tracking of what students are doing in a game. Qualitative methodologies "involve collecting data on what people are doing within their context. . .[could] involve a very close read of the actions, speech, practices, and behaviors. . .[and the] environment, social, cultural, and physical" context (Simkins 2014, p. 279). The Department of Education (DoE) also suggests the benefit of collecting and making use of student-learning data in real time so that educators and schools can make more effective, data-driven decisions and can better support differentiated learning, accessibility and greater feedback, inclusion, and transparency (USDOE 2010).

There are different aspects of games that can be assessed, such as whether in-game goals were completed, whether learning goals were reached, whether game play was effective in supporting goal completion, and how the in-game and out-of-game context encouraged learning. Any assessment is affected not only by the learning attained but also the context of the game and assessment(s) given, the students/people being assessed, the person providing the assessment, and other factors (Simkins 2014). Assessment does not need to take place outside of the game (such as through an exam or paper written using concepts or skills used in a game). The game itself can incorporate assessment through its play. For instance, the DoE describes how a virtual world, River City, assessed student scientific inquiry and communication skills in situ (USDOE 2010; Dede 2009).

Assessment and reassessment are part of any well-designed game because players need feedback to know if goals and tasks are complete. The fact that the player has reached particular goals in a game could be in itself a useful assessment of the player's status and learning needs. For instance, Gibson and Webb (2013) identify specific types of assessment that may be relevant to games, such as investigating students' decisions in a game, commenting on peer students' game creations, and/or responding to a prompt through the creation of a game or interactive project. In other words, the act of playing and/or interrogating the game is a form of assessment.

Balancing Needs and Perspectives

Game design is a series of trade-offs and mini-solutions to an enormous number of questions that need to be weighed, such as designing flexible game play versus maintaining strict accuracy or enabling deep immersion in the game versus ensuring the ability to transfer learning to outside contexts. The decision about what type of game to use – for example, whether commercial-off-the-shelf (COTS) entertainment games or those focused on educational purposes – may also be rife with further questions and consequences. When representing an event from history or a physics property in a game for additional examples, there are a seemingly infinite number of ways to simulate something, with give-and-take decisions among many different constraints, such as accuracy, resources, expertise, time, platform needs, audience needs, game play desires, etc.

Choosing whom to include on a decision-making or design team may also involve trade-offs in budgets, technological limitations, resources, and expertise. For instance, educational games often include educators and researchers on their teams alongside game designers such as *Mission US: For Crown or Colony* (Schrier 2014; Farber and Schrier 2017). Many big-budget entertainment-focused games use large teams of people such as designers, developers, artists, musicians, and storytellers, whereas games specifically made for education often have smaller budgets, less resources, and fewer people (Schrier 2016c). Strong teams for educational game development combine expertise in game development, storytelling, art, and design, as well as in education, curriculum development, subject-area expertise, and assessment. Different stakeholders and perspectives need to work together to collaboratively decide how to navigate practical, creative, and educational tensions and questions while also meeting goals, standards, and metrics.

The Future of Games and Learning

This chapter brings up a number of questions relevant to game-based learning. Yet, the answers are not always obvious and will continue to evolve alongside technological, cultural, social, and economic changes. For example, expensive, immersive technologies such as those related to virtual reality are growing in use alongside cheaper and DIY (do it yourself) technologies, such as *Arduino*, *Raspberry Pi*, and *littleBits*, which will increase the types of digital and highly interactive educational experiences educators can create, as well as alter who has access to these types of experiences (Schrier 2016b). Likewise, robots and robotics, as well as wearable technologies, interactive displays, context-aware technologies, and connected objects ("the Internet of Things") are starting to be used within or alongside games to teach and support learning. For instance, students are learning how to program using robots and other interactive objects and technologies, which could also be used to create and support game play (McGill 2012).

Mobile and tablet usage is becoming more widespread, though inequities still exist, and knowing which educational apps and games to access and how best to use them in educational settings will require additional research and experience. Large data sets (big data and learning analytics) are also being used more frequently for predicting behavior and assessing learning – both in games and in other types of educational activities. The increased usage of data will affect the types of questions that will get asked as well as the types of methodologies and approaches available for considering, using, and studying games and learning. A new divide – the data divide – has been emerging (Boyd and Crawford 2012) between those who can use, analyze, and maintain the data culled from educational games and those who cannot. Ethical questions (such as those related to data use, privacy, transparency, equity, accessibility, and algorithm creation) need to be considered alongside pedagogical and design questions.

In addition to teaching content areas and topic-related skills (e.g., math facts and literacy), other types of skills have also become vital, such as computational thinking, twenty-first century and civic-minded skills such as argumentation, perspective-taking, media literacy and media fluency, and identifying biases. Game-based learning may be another way to show students how to separate fact from fiction, understand and evaluate viewpoints, and analyze information (Schrier 2014).

Finally, educators need to find innovative ways to engage students in solving real-world problems and creating new knowledge. Educators can use games also to help uncover solutions to real-world complex issues, such as poverty, war, or climate change. Games, and their ability to simulate intricate systems, invite collaboration and cooperation and show people how to think through problems in new ways, may help people uncover new truths, and consider new perspectives. Game-based learning has the potential to not only help people acquire knowledge but also to reveal new understandings of humanity, our world, and our past, present, and future.

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Evaluating Games for Classroom Use 60

Katrin Becker

If we teach today's students as we did yesterday's, we are robbing them of tomorrow.
John Dewey

Contents

Abstract

To promote teachers choosing and using games in the classroom, educational leaders, researchers, and practitioners must address three needs. First, educators need confidence that games embody or support sound pedagogy. Second, educators need to be able to evaluate games for their potential as learning objects. Finally, educators can benefit from concrete models of classroom use of games.

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This chapter provides a brief introduction to game-based learning pedagogy, an evaluation model that can guide a structured analysis of a game for potential classroom use and a sampling of instructional strategies adapted for teaching with games.

Keywords
Digital game-based learning · Game-based pedagogy · Learning with games

Introduction

Digital games are being used more and more often as teaching resources in the classroom (Habgood and Ainsworth 2011). One way to build confidence that games do indeed embody sound pedagogy is by connecting the technology and design with "classical" learning and pedagogical theories that predate games. When a game has been chosen as a potential candidate for use in the classroom, it should then be evaluated with respect to how well this particular game embodies relevant learning theories, as well as more practical concerns such as the game's connection to the curriculum and whether or not there is adequate teacher support. The criteria that make a game suitable for use in the classroom are varied. Jim Gee states that games for education must be re-playable and immersive, that they must build expertise and identity, be transdisciplinary, allow for different trajectories of expertise, and more (Gee 2012). These are worthy goals, but it is unclear that they are always necessary, and some argue that they aren't even always desirable. An educational game can also be "an elegant experience that encourages and enables the target player to achieve the intended learning goal(s)" (Heeter 2013). Ultimately, a lesson must be built around the game to be used, and providing strategies for that can determine whether a game is more or less likely to be used than some other technology in any given context.

Games and Learning Theories

What theories and models underpin educational game design and use? Wu and colleagues performed a meta-analysis of studies on the learning theories foundational to digital game-based learning and found a variety of learning theories (Wu et al. 2012). They grouped them into four categories: behaviorist, cognitivist, humanist, and constructivist approaches to which social learning can be added as a fifth.

1. **Behaviorism** holds that behavior can be shaped by associating a desired response with a specific stimulus (Watson 1925). This category includes Skinner's operant conditioning (Skinner 1938), Thorndike's connectionism (Thorndike 1910), and Gagné's conditions of learning (Gagné 1965).
2. **Cognitivism** holds that learning is affected by the workings of the brain and how people think. This group encompasses Bartlett's schemata (Bartlett and Bartlett 1995); Piaget's cognitive development (Piaget 1951); Weiner's attribution theory

(Weiner 1974); Collins, Brown, and Newman's cognitive apprenticeship (Collins et al. 1987); and Sweller's cognitive load theory (Sweller 1988).

3. **Constructivism**, which holds that learning is actively constructed and linked to existing knowledge by the learner (Bruner 1960). This group consists of Latour's actor-network theory (Latour 1996), Bruner's discovery learning theory (Bruner 1961), Leont'ev (1978) and Luria's activity theory (Luriëìa 1976), and Papert's constructionism (1980).
4. **Humanism**, which claims that learning must involve the whole learner and their environment. Finally, this category includes Kolb's experiential learning (Kolb and Fry 1975), Maslow's hierarchy of needs (Maslow 1943), Deci and Ryan's self-determination theory (2000), and Csikszentmihalyi's flow theory (Csikszentmihalyi 1991).
5. **Social learning**, which is said to occur in social contexts, such as those including the physical presence of other people, but it can also be mediated by technology. See Bandura's social learning theory (1977), Vygotsky's social development theory (1934), Vygotsky and Cole's social constructivism (1977), and Lave's situated learning theory (Lave and Wenger 1991).

Choosing Games

Information from the scholarly connection between theories of teaching and learning and the design of learning games can be used to help choose games for use in the classroom, but there remain some key questions that also need to be addressed, such as whether to use a game specifically designed for learning or to adapt a commercial off-the-shelf (COTS) game.

Commercial off-the-Shelf (COTS) or Serious Games?

A serious game is one designed for purposes other than or in addition to pure entertainment (Sawyer 2003). This includes but is not limited to educational games. While there is growing acceptance of the use of educational games, COTS games are not as well accepted, often with good reason. Using a COTS game in a formal learning context is, in most cases, analogous to an "off-label" use. Teachers use commercial off-the-shelf games knowing that this is not what the games were designed for, and so it is important to recognize that the efficacy of these games will inevitably come from a well-matched pairing of learning design outside of the game and directed or goal-oriented play within the game. In other words teachers need to make sure that the games they choose and use are going to meet teaching needs.

Assuming the content of the game matches with the learning objectives, COTS games can have some advantages that educational games don't. COTS games are often richer in terms of the worlds and environments; they are made with substantially larger budgets, so they are bigger, often with celebrity voices and music. This can have a positive impact on both motivation and acceptance. Some of the smaller casual games can be useful in supporting the learning of a single concept or skill. They often have many levels with short rounds, making it possible to incorporate them as a supplement to a lesson without having to be the "feature attraction."

On the other hand, it can be difficult to identify COTS games that map onto the curriculum well enough to justify the time spent using them. Assessment, while it is something many COTS games are very good at, tends not to be the kind of assessment teachers can readily apply to formal educational contexts. Finally, many commercial games are not free, and though they may be less expensive than a textbook, they do often assume that players will have access to the latest hardware and that is often not possible in a formal educational environment.

Serious games, especially those designed specifically for use in formal educational environments, often have learning objective-based assessments, classroom or other group licensing arrangements, and clear ties to known curricula. On the other hand, many educational games still lack those qualities that make COTS games "good." For example, they often look good but fail to hold the players' interests. This phenomenon relates to the decorative media trap, which is the mistaken notion that a game that looks good must also be good (Becker 2012a). The analytical model outlined in the next section provides a way to analyze games, both COTS and serious, that allows teachers to see where the game excels and where it is lacking. It also provides a way for games to be compared against each other.

The 4PEG Game Evaluation Model

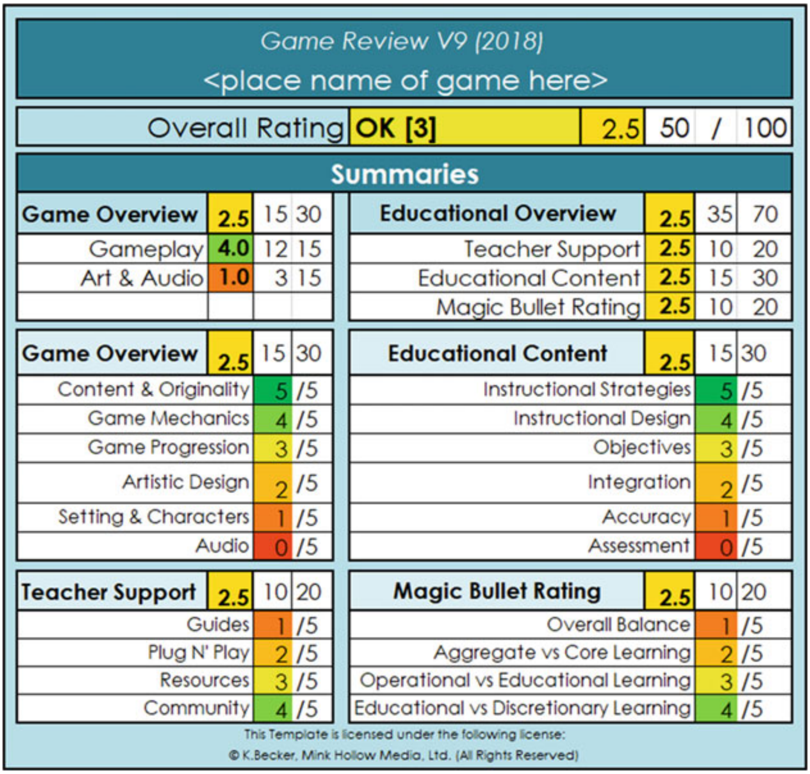
The 4PEG (four pillars of educational games) evaluation model (Becker 2016) allows teachers and others to perform a structured analysis of games to assess potential classroom use. The pillars are:

Gameplay – there's really no point in using an educational game unless it also works as a game. This pillar assesses the game *as a game*. It attempts to answer the following questions: How does the example measure up as a game? Is it fun? Is it Interesting? Is it aesthetically pleasing?

Educational content – whether this game has been created specifically for learning or purely for entertainment, this pillar addresses the requirement that the game have identifiable educational content. It attempts to answer the following questions: How are there one or more recognizable educational objectives to be found in this game that are discernible either from the game itself or from the accompanying support materials?

Teacher support – in order to be truly useful in the classroom, games must have sufficient teacher support so that teachers are not always required to build lessons from scratch. There must be adequate teacher support to make it viable for use in a formal setting.

Balance of categories – the final pillar is based on the "magic bullet" model (Becker 2012b) to determine how well are the various learning elements balanced in the game.



Game Review V9 (2018)

<place name of game here>

Overall Rating	OK [3]	2.5	50	/	100

Summaries

Game Overview	2.5	15	30
Gameplay	4.0	12	15
Art & Audio	1.0	3	15

Educational Overview	2.5	35	70
Teacher Support	2.5	10	20
Educational Content	2.5	15	30
Magic Bullet Rating	2.5	10	20

Game Overview	2.5	15	30
Content & Originality		5	/5
Game Mechanics		4	/5
Game Progression		3	/5
Artistic Design		2	/5
Setting & Characters		1	/5
Audio		0	/5

Educational Content	2.5	15	30
Instructional Strategies		5	/5
Instructional Design		4	/5
Objectives		3	/5
Integration		2	/5
Accuracy		1	/5
Assessment		0	/5

Teacher Support	2.5	10	20
Guides		1	/5
Plug N' Play		2	/5
Resources		3	/5
Community		4	/5

Magic Bullet Rating	2.5	10	20
Overall Balance		1	/5
Aggregate vs Core Learning		2	/5
Operational vs Educational Learning		3	/5
Educational vs Discretionary Learning		4	/5

Fig. 1 4PEG rating sheet

A rating sheet for the 4PEG model (Fig. 1) consists of 20 elements that can be graded on a scale of 0 (missing) to 5 (excellent). The scores for these individual elements are then summed to give a number between 0 and 100 as well as an average score for each pillar. In the following sections, the 4PEG model is discussed in detail.

Gameplay

Gameplay ratings are intended to assess the quality of the example as a game independent of its potential as an educational object. Gameplay is rated according to six criteria intended to provide information that will indicate whether it is likely to be a good fit for learning purposes:

Content and originality: Overall, is the game appealing?

Game mechanics: What can the players do in the game? A high score represents that the game mechanics complement the intended use of the game.

Game progression: The transitions between levels or progression from start to end should go from simple to challenging and should be smooth and appropriate for the game.

Artistic design: Is the visual design appropriate for the game? Is it a good fit for the kind of game it is and for its intended purpose?

Set, settings, characters, and costumes: Do the surrounding environment and the characters in the game work in harmony with each other to create a coherent experience?

Audio: Is the audio track appropriate for the game? Is the music necessary to the game? Can it be easily switched off?

Educational Content

This pillar addresses the quality and extent of the educational potential in the game considering 11 aspects.

Instructional strategies: An instructional strategy is a plan for what will happen during the course or lesson. What kind of strategy is being used in the game to help people achieve the educational learning objectives? For example, a guessing game or drill and practice may be appropriate for learning anatomy, but not for understanding the dynamics of Mendelian genetics.

Instructional design: Instructional design is the process of creating instruction through the analysis of learning needs and the systematic development of learning materials. Merrill's *First Principles of Instruction* (2002) is used as the benchmark against which the instructional design component of the game is measured.

Problem: Does the game engage learners in solving real-world problems, or if not, are the problems ones that can be applied to real-life problems?

Activation: Does the game activate existing knowledge as a foundation for new knowledge?

Demonstration: Does the game demonstrate new knowledge to the learner?

Application: When the player learns something new in the game, is the learner provided with opportunities to use it within the game?

Integration: Does the game help learners integrate new knowledge into the learner's world?

Objectives: This category rates the extent to which the game supports the objectives as determined someone doing the rating, who, prior to testing the game in the classroom, is making a reasoned judgment. The goal is to assess whether or not the game provides the necessary "raw materials" to address valued educational learning objectives.

Integration: In a serious game, it is essential that the educational learning outcomes be part of the required interactions of the game. It should not be possible to get through the game while ignoring the learning objectives.

Accuracy: Does the game contain accurate information? The facts associated with the educational learning objectives should be correct, and the needed concepts and principles should be clear.

Assessment: Is the in-game assessment relevant to the educational learning objectives? In some games a losing score can sometimes be just as valuable for meeting educational objectives as a winning one; on the other hand, the actions required to achieve a positive score may have little to do with what players are supposed to be learning (Gopin 2014).

Teacher Support

The level and quality of easily accessible teacher support is assessed considering four elements.

Teacher's guide: Teacher's guides should be clear, well-organized, and easy to locate. Support materials should include such things as: a description of gameplay, content description, any special permissions or skills required to install or run, and installation and execution processes.

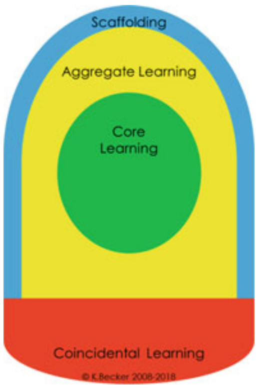
Plug n′ play: Do the support materials include lesson plans with thorough instructions for using the game in the classroom or other target environment? It should not require a large time investment to make it "teacher-ready."

Supplementary resources: Additional information specifically for teachers, such as background on the game and the topics it addresses, ways to use the game, and where to get help, should be complete and readable.

Community: Is there a community where teachers can go for help, support, to share ideas and experiences, and explore ways to use the game?

Balance of Categories

Learning with games can be classified as a balance of four categories of learning, termed here as the "magic bullet" aspects of a game for learning (Becker 2008a). The categories include the learning that is required in order to win the game, other designed content, and unintended learning both external to and coincidental to the game.



Aggregate learning: Aggregate learning includes all that CAN be learned, as deliberately designed by those who created the game.

Core learning: Core learning is that which MUST be learned in order to achieve a given goal. It will almost always be a subset of the first category and includes only those items that are necessary in order to win or get to the end.

Scaffolding: This category includes learning that happens outside of the game: in fan sites and other social venues. This category also includes "cheats."

Coincidental learning: The final category includes all other things we can learn. These are not necessarily designed into the game, although sometimes designers may hope that players choose to take these up.

The model includes an additional layer of contexts that are specific to educational contexts, so each kind of learning mentioned above becomes a subcategory of one of the following components:

Operational: Game controls, game mechanics, and other overhead depending on how the game will be used.
Educational: How does the teacher plan to use the game?
Elective: Any elements of the game that don't fit into one of the other two categories.

The balance pillar contains four key perspectives in which each rating is determined by how well the balance of the elements fits the type of game it is and its intended use and audience.

Overall balance: How well do the four magic bullet categories of learning match the game's intended use?
Aggregate vs core: Is the balance of things students can learn versus things they must learn appropriate for the intended use of the game?
Operational vs educational: Is the time spent learning to play the game appropriate for the game's intended purpose?
Educational vs discretionary: Is there an appropriate balance of learning and engagement?

The variety of categories in each of the pillars provides a detailed analysis of the game's strengths and weaknesses. A low game score may be tolerable if it has a high content and support rating. Alternately, a low support rating may not be important if the teacher has the experience and the time to develop custom materials.

Designing Game-Based Lessons

While there are a growing number of people who talk about using games in the classroom as an instructional strategy (Salen 2008), it can still be hard to find information on instructional strategies that use games. This can be a significant barrier as insufficient time, lack of tech resources, difficulties finding games that fit the curriculum, and not being sure how to integrate games in a teacher's teaching can all contribute to a teacher's reluctance to use games in the classroom (Molin 2017). Support in the form of strategies such as those in the following sections can help encourage some teachers to try using digital games that might otherwise avoid them.

Beyond Content: Games as Prompts for Thinking

Although we have largely focused on games as content, there are other ways to use games in the classroom. The author has outlined 15 different ways to use games in the classroom in some detail elsewhere (Becker 2016). The following is a brief summary of seven of them:

1. Content – the content of the game directly addresses some curricular need.
2. Example – the game is an example of or an artefact that supports what is being taught.
3. Inspiration – games can be used as inspiration for creative writing, for construction, as examples of scenarios, as role models, and counter-role models.
4. Art – some games have a unique artistic style that is worth studying.
5. Medium – the constructionist approach to learning focuses on making a game about the topic or concept being taught.
6. Literature – games can offer unique perspectives on narrative, and some can be studied as literature.
7. Environment – a game can provide an environment for an activity or part of a lesson.

Instructional Strategies

Instructional strategies shape the actual things teachers do in the classroom to bring planning to fruition. The following six ideas are a few examples of strategies that can incorporate games:

CROWN Closure Technique

CROWN is a closure technique that encourages students to reflect on the completed lesson (Jacks 2005), which can be applied to the entire lesson that uses the game, only the game, or to one part of the lesson or game.

C = communicate what you learned.
R = reaction.
O = offer one sentence that sums up what the whole lesson was about.
W = Where are some different places you could use what you have learned?
N = note how well you did today.

Collections

Many games allow players to collect items of various sorts. This strategy uses those collections as the source of projects, presentations, or writings related to the learning objectives. Players can be directed to gather collections of items that fit specifically with some concept or topic they've been given.

Data Analysis

Students can use games to gather data for analysis and graphing. In a multiplayer game, students can create and design surveys to conduct within the game. For example, in a game where players can choose human or animal avatars, players could record how many characters of each type they have come across in a certain period of time and then ask those characters why they chose the characters they did. In a single player game, other data can be collected. For example, when you plant flowers in Animal Crossing, they turn brown after a time and need to be watered. Players could record plantings and when the flowers turn brown along with the locations and then analyze the data to see if any patterns emerge.

Field Logs

Field notes or logs typically include written notes, comments, and reflections as well as sketches and maps. When gaming, players can imagine themselves as observers or researchers in the field and make notes about their "time in the field" for later analysis, reflection, and comparison.

Find the Fib

Groups of students write two true statements and one false statement and then challenge other groups or even the teacher to "Find the Fib" (Rowan 2013). As a game-based learning strategy, the statements will come from the game. Many games take liberties with various aspects of reality in order to make the game more playable, intuitive, or entertaining. Players can find two things within the game that are true and one that is false. For example, the relative sizes of some of the characters may not be to scale, or time might pass differently. There may be facts in the game that are incorrect. "Find the fib" is a way to get students to think critically about what they are seeing and experiencing in the game, and it can also provide a way to highlight specific learning goals.

Through the Eyes of the Enemy

Students consider alternate perspectives and gain empathy by trying to view the situation through the eyes of the antagonist in the story (Rowan 2013). Games are especially good at facilitating this kind of strategy as it is often possible to play "as the bad guy" in a game, and this can lead to interesting insights. Even when that is not possible, in a game that has an antagonist, it is possible to explore how the interaction might look from the perspective of the antagonist.

Lesson Plans

Along with assurances that good games embody sound pedagogy and suggestions for how to use games in the classroom, lesson plans for teaching with games can be adapted to contain distinct elements such as the following:

Game Description and Objectives

Identify how the game connects with learning outcomes and instructional objectives. List all topic and content-related materials and resources that you and the students will need in this section. Are there things that need to happen before the lesson begins? What do the students need to do?

Other Materials and Resources

List the resources necessary to use the game. If the students will need anything in addition to what the teacher needs, include that to make sure it is available on their devices. The resources that are specific to the game should be listed separately from other resources for the lesson and might include such things as a 4PEG review of the game (see above discussion) and any community websites, instructional manuals, teacher guides, or other documents related to the game. If the game gets used in another teaching context, the operation information need not be duplicated.

Lesson Activities

Describe what students will do before playing the game (pregame), during the game (in-game), and after the game (debriefing or post-game).

Pregame

How will students' interest in the topic be fostered? It's unwise to assume that they will automatically be interested, simply because they are using a game.
How will students' prior knowledge of the topic be revealed?
Do they need time to learn how to play the game before beginning the activity?
What about students who already know how to play the game or those who have never played video games?
How will they be prepared to attend to the objectives during play?

In-Game

What sequence of activities will the student experience?
What will the teacher do?
What will the students do?
What will students do who finish early?
How much time will each activity take?
What about clean up?
Will the teacher guide them through their play session, or are they playing on their own?

Debriefing

How will the play session be ended?
Where will students "reconvene" for the debriefing? The debriefing should help students reflect on or summarize what they have learned.
How will the lesson be ended? The closing should be linked to the instructional objectives.

Here are some additional questions to ask:

- What specific content is covered in the game and what is missing?
- Does it provide an overview of the topic (breadth), or does it focus on a particular aspect of it (depth)?
- Will the game be a single play for one lesson or be used across multiple lessons?
- Are there factual or conceptual errors or misleading information in the game? How are those going to be addressed?
- Are there alternate viewpoints in or around the game that can be used?
- How will gameplay be managed?
- Does the game allow saving at a particular point and then sharing the progress?

Conclusion

Choosing and using games in the classroom can make use of many techniques already recognized as sound pedagogy grounded in learning theory. Connecting teaching with games to good instructional practice, while not necessarily easy, brings a potential payoff that includes highly engaged students who are excited to learn. Furthermore, assessing games and sharing insights as well as support materials can move practitioners toward game-based learning pedagogy as a positive new teaching tool in their educational toolset.

The three-pronged approach to helping teachers evaluate and incorporate digital games as described in this chapter addresses a variety of needs and concerns that teachers often have when considering the use of digital games in the classroom. However, like every other new technology that has been applied to formal education, it will take time for games to gain acceptance and be seen in the same light as more traditional methods (Salen 2008). The body of research continues to grow rapidly (Chung-Yuan et al. 2017), and the field is still a young one, but with more specific studies of game use in the classroom as well as research on best practices for design and development, this incarnation of game-based learning in formal education looks to be more successful and lasting than the "edutainment era" of the 1980s and 1990s.

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Toward Creator-Based Learning: Designs That Help Student Makers Learn

61

Chen-Chung Liu

Contents

Abstract

Contemporary educators have been advocating that teaching and learning in schools should go beyond knowledge acquisition. A critical challenge is how to help students learn like expert creators who constantly display active engagement and personal autonomy and who are keen to collaborate with others. Recently, construction-to-learn activities have received even more attention than before. The maker movement is occurring in many educational settings. However, the setup of makerspaces does not necessarily guarantee a positive impact on students' learning. Too much emphasis on the hardware tools may blur the educational focus and the merits of maker activities. This article summarizes and presents studies related to construction-to-learn activities that support students in their learning as creators. It revisits the key design principles of learning systems based on the needs of student makers: "supporting students to express

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their imagination," "facilitating endless remixing," and "low-threshold/high-ceiling." Design examples and research findings will be presented based on a series of studies in the field. These can shed light on the design of maker activities that can continuously engage students in construction-to-learn activities.

Keywords
Maker space · Creator-Based learning · Imagination · Remix · Constructionism

Maker Movement and Pitfalls

In recent years, the development of various DIY production tools has made it possible for users to fabricate their own objects based on their own needs. As envisioned by Hod Lipson, our life will become science fiction as many imaginary parts such as coffee cups and houses can be printed out with 3D printers (Lipson and Kurman 2013). Due to the availability of such DIY production tools, construction-to-learn activities have received even more attention than before. The maker movement began with Neil Gershenfeld's fabrication stations where individuals were empowered to use diverse types of tools to fabricate objects based on personal needs (Gershenfeld 2005). Since then, different types of "fab labs" have been installed at different educational institutions. The maker movement has been seen in many educational settings. It represents a phenomenon whereby people enthusiastically are engaged in maker activities to develop creative products with kits such as 3D printers or laser cutters (Halverson and Sheridan 2014). It has been advocated that such maker activities may be reinventing our schools as they transform learning into an active process. Maker activities fulfill several important pedagogical principles. Firstly, students are creators rather than consumers, and thus the engagement in such activities is generally based on enthusiasm. Furthermore, the activities are self-directed because makers have to solve unexpected problems in the process of making products. The products they create are a demonstration of what they have learnt to do (Dougherty 2012).

To facilitate construction-to-learn activities, many makerspaces have been set up in different places such as universities and libraries. The makerspace is a physical location where construction tools such as 3D printers, laser cutters and saws are made available. Students can gather there to work on projects together (EDUCAUSE Learning Initiative 2013). They can also share resources and knowledge in the makerspace. The makerspace is even more important for novice makers than for proficient makers as they can get help from others. Therefore, many K-12 schools and universities have been setting up makerspaces to implement maker activities on campus.

The maker movement may shed light on how learning activities should be designed to engage students in active learning. For instance, students can be engaged in practices in which they must apply tools/technology to build objects, showcase their creativity, and learn with others. Recent enthusiasm for the maker movement is the result of the availability of DIY tools on the market, and thus many schools are now equipped with 3D printers in the makerspace for diverse educational purposes. However, schools and educators should be aware of the potential pitfalls of simplifying the implementation of maker activities as the installation of makerspaces. First, the setup of makerspaces does not necessarily guarantee a positive impact on students' learning. Too much emphasis on the hardware tools may blur the educational focus and the merits of maker activities. Maker activities risk becoming mere skills training for the DIY tools while failing to fulfill any educational merits. Second, educators may see the maker activities simply as assembling tangible objects according to existing menus, without considering the creativity principles embedded in them. Third, as the making process is usually conducted in the physical makerspace, the social practice may be constrained at a certain level without the possibility of stretching students' creativity to a higher level.

In this vein, this chapter aims to clarify the implementation considerations of maker activities based on a series of studies related to construction-to-learn activities (Burton et al. 1984; Harel and Papert 1991; Kiili 2005; Knobel and Lankshear 2008; Liu et al. 2011, 2014, 2016). Such creator-based learning aims to foster creator mentality in classroom learning practice and features three significant creativity principles during the learning practice: supporting students to express their imagination, facilitating the remix process, and low-threshold/high-ceiling. These three principles are particularly important for the design of maker activities as they could be helpful in avoiding the three pitfalls of the current maker movement and in extending the maker activities to become a creativity development process.

Supporting Students to Express Their Imagination

The first principle for implementing maker activities is to support students to express their imagination while engaged in the activities. Imagination is considered as the core of creativity and one of the elements of students' engagement in the learning process. Imagination, according to the Oxford dictionary, is "the faculty or action of forming new ideas, or images or concepts of external objects not present to the senses." It is the key component of human creativity based on Finke's Geneplore model of creativity (Finke et al. 1992). The Geneplore model asserts that creativity involves the generation of new ideas followed by the exploration of the detail of the new ideas. However, current teaching practice does not put much focus on how students' imagination can be integrated into learning.

To overcome the constraints of the current maker activities, the study by Liu et al. (2011) proposed the notion of an imaginative construction game to motivate students to learn by supporting them to build a product based on their imagination. This construction game relies on the basis of constructionism which posits that students construct knowledge most effectively in a context where the learner is participating in constructing a product that is visible to the audience (Harel and Papert 1991). Construction is the basis of maker activities as it motivates students to learn by engaging them in constructing an object visible to the audience. With the help of

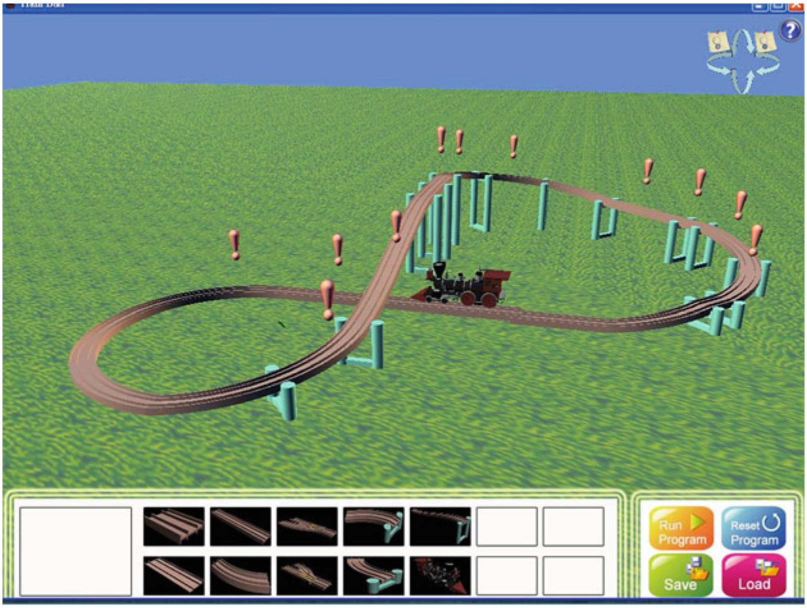

Fig. 1 An imaginative construction game supporting students to build and program rail systems

various kinds of production technologies such as Logo or Scratch, students must discover and analyze information as well as build knowledge in order to construct an entity.

The imaginative construction game illustrates two design considerations that may be helpful in implementing maker activities: production tools supporting students to express their imagination and simulation of students' imaginative ideas. Examples of such imaginative construction games include SimCity wherein the players must imagine, build, and manage a city. Such games may facilitate the achievement of educational objectives because they enable the players to exercise their imagination and analyze ideas. Therefore, the study by Liu et al. (2011) developed an imaginative construction game, namely, Train B&P (Train Build and Program it, see Fig. 1) based on the constructionism framework. Students can construct a railway model with the simulation in the same way they can with real toy trains such as Tomica trains. However, they can design imaginative rail systems that overcome the physical constraints of the real toys with such an imaginative construction game.

The imaginative construction game highlights the design consideration of enabling students to simulate their imaginative ideas before building them. It has been extensively advocated by researchers that computer simulations can facilitate discovery learning as they model complex system in the real world and allow students to explore, experiment, and exercise their ideas (de Jong and van Joolingen 1998). The constructionist approach to learning also highlights such computer simulation as one important means of enhancing in-depth learning while constructing or analyzing a product (Shneiderman 2000). If students can interactively initiate and test their ideas while constructing a product, they are more likely to be engaged in the learning activity.

Train B&P enables students to write computer programs to build the railway model as a means of learning to code. Train B&P provides two simulation functions to help students simulate the rail models they built in the 3D environment. The first simulation is the physics engine embedded in the game. The engine simulates the movement of a train in a physical environment considering gravity, speed, acceleration, and friction. The second simulation is the program compiler that simulates the behavior of the programs students built. The program compiler allows the students to visualize the behavior of railway models in a virtual environment. In this way, students' imaginative ideas can be tested in order to improve their designs.

The results of the study suggested several implementation considerations for maker activities. It was found that the imagining-and-constructing activity significantly promoted students' intrinsic motivation to learn. Furthermore, the visualization and simulation tools also balanced the students' challenge and skills perceptions, thus significantly improving their flow perception during the learning process. The students were motivated to apply multiple problem-solving strategies including trial-and-error, learning-by-example, and analytical reasoning strategies while constructing products. Therefore, embedding students' imagination and helping them to simulate their imagination with proper tools may be necessary to go beyond the reproduction of existing products and to promote the maker activities to a level of creativity.

Facilitating Endless Remixing

The term "remix" originally referred to the audio-editing techniques used to create a new mix of an existing song. It has now been expanded to the generation of various types of artefacts such as articles and images (Knobel and Lankshear 2008). It is believed that remixing is the basis of human creativity. Creativity through remixing is a process of creative synthesis through which innovative ideas are obtained through a series of synthesis of existing ideas (Harvey 2014). Creativity is shaped from using the existing ideas or artefacts in three forms: making unfamiliar combinations of familiar ideas (combinational creativity), noticing new things in old spaces (exploratory creativity), and making new thoughts possible by altering the rules of the old spaces (transformative creativity) (Boden 2015). The core principle of the remix process is the endless hybridization process, whereby individuals create new entities using existing artefacts (Lessing 2008); remixing is therefore a pathway to creativity. Figure 2 displays how the remix process takes place in social contexts. Students may donate their products to a social platform, while others may retrieve and rework them to generate new products. They can work together to combine their ideas to generate new, innovative products. As they retrieve, understand, and amend existing artefacts, they can not only improve their understanding of the artefacts but also improve their quality (Liu et al. 2014). Such a process is helpful to implement the socio-constructivist viewpoint of learning which suggests that individuals' ideas

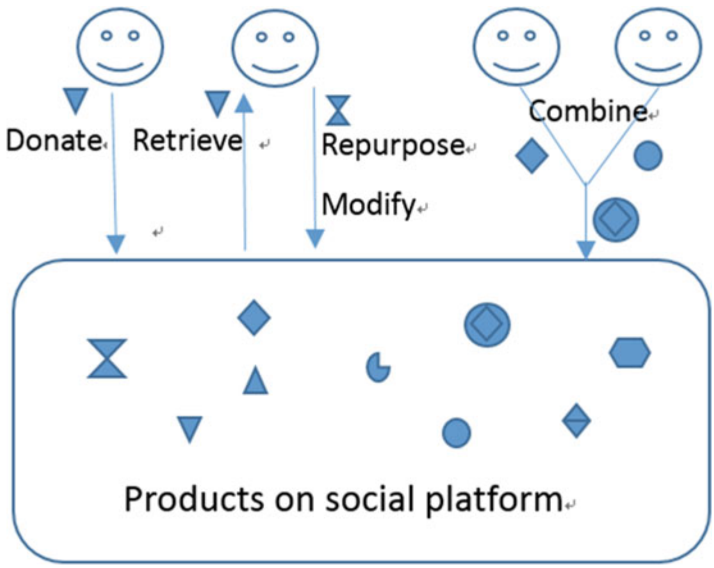

Fig. 2 The remix process in the construction-to-learn activities

are improved through social interactions (Roschelle et al. 2005; Shaw 1995). Therefore, individual capacity can be enhanced by the remix process.

However, remixing is not valued in schools. For instance, using material on the Web or others' work in assignments is regarded as plagiarism (Norman 2001). The main reason is that students do not understand the social value and manners of the remix process. Students often simply copy others' work without attributing credit to the original contributors when doing value-added remixing. Having acknowledged its potential downside, researchers have been increasingly applying the principle of the remix process to promote creativity in various construction activities. Some of the activities are closely related to maker activities. For instance, the remix process has been utilized to improve the learning of programming (Kafai 2016; Vasudevan et al. 2015; Liu et al. 2014). In the remix process, students do not learn to code from scratch. Instead, they learn to code by reworking the code generated by others. The analysis of exiting codes is an integral process of the learning of coding. Therefore, such a remixing is the core process of open-source development in which students join together to understand and pursue productive integration of code written by others (Kafai 2016). The remix process is also used by educators to develop students' storytelling ability (Liu et al. 2017), and artworks (Knochel and Patton 2015). During the remix process, students create new artefacts through modifying, repurposing, or combining available materials, instead of starting from scratch. Since students do not need to do everything by themselves, these materials therefore act as important scaffolds to help novice students participate in creativity activities (Liu et al. 2014; Vasudevan et al. 2015).

The remix process may therefore be helpful in terms of improving creativity in maker activities as it provides a mechanism of endless hybridization to make new artefacts from using existing ones. The study by Liu et al. (2017) has demonstrated how the remix process facilitated the creation process of digital storytelling. The remix process in the study became an imaginative re-creation activity in which students integrated or interpreted existing intellectual works with their imagination to create new works. Such an imaginative re-creation activity is deemed as an essential function of novel reading to imaginatively re-create the perspective about the novel for oneself (Bruni 2016). Liu and his colleagues' study (2017) found that students applied various approaches to add value to the existing model stories such as scene enrichment, character enrichment, and emotional expression enrichment, which are also important quality drama and story features. Their survey of students' perceptual feedback also supported the argument that the remix process is effective in terms of maintaining students' sense of interest and curiosity as well as enhancing their confidence in developing creative products.

Such a remix process may also enhance social creativity in the maker activities. It strengthens the "transactivity" of the social activities, denoting the degree to which students reciprocally build their works or argumentation based on those of their peers (Weinberger 2011). In the study by Liu et al. (2014)), they experimented with how students developed code through modifying peers' code work as a means of learning to program. Through the remix process, individuals' coding works were enhanced, as several remixes could be derived from a single original work. Such a remix process has been applied in the programming community in Scratch (Monroy-Hernández and Resnick 2008).

However, the remix process in social settings may encounter the social dilemma of knowledge sharing. This dilemma denotes the phenomenon that individuals simply try to maximize individual payoff (Cabrera and Cabrera 2002). To implement the remix process, students need to share their work with peers, and then value-added hybridization can possibly occur. However, the sharing of individual work may decrease the sense of ownership of the work, and thus refusal to share becomes the most beneficial strategy (Dawes 1980). As the initial condition of remixing is to share individual work, there arises a need to resolve this dilemma in order to encourage work sharing in the maker activities (Liu et al. 2014).

In this regard, the study by Liu et al. (2014) suggested that, with proper mediation, the remix process can significantly improve participants' attitudes regarding the derivative works, the satisfaction level of the remix outcomes, perceptions of peer interaction, and the sense of work ownership. They recommended that the Creative Commons (CCs) (http://creativecommons.org/) mechanism may be a potential approach to increasing individuals' responsibilities and motivating them to participate in the remix process. Traditionally, individuals cannot copy, use, modify, or distribute a work developed by others unless the author of the work give permission. Such a constraint on intellectual properties significantly limits the creative use of these properties. The CCs was thus proposed to work as a flexible mechanism that accelerates the remix process as it makes it possible to use others' intellectual property in a more flexible form. For instance, under the share alike license of CCs, individuals allow others to modify their work and then to distribute the derivative works, also under the share alike license. The study by Liu et al. (2014)

suggested that the CCs mechanism provides students with a reliable tool for mediating the remix process as it increases the willingness to share individual works as a source of remix. The CCs can significantly improve participants' attitudes toward the derivative works, the level of satisfaction with the remix outcomes, perceptions of the peer interaction, and the sense of work ownership. One of the objectives of the maker activities is to develop students' creativity literacy. Therefore, educators may consider the CCs mechanism as useful for students to experience, understand and model the social creativity process to prepare them for future creativity.

Low-Threshold and High-Ceiling

The English poet Samuel Taylor Coleridge coined the phrase "suspension of disbelief," indicating that the audience tends to overlook the limitations of a medium. This notion pointed out that readers tend to suspend their judgement about the quality of a literature creation. Due to such a tendency, a writer can use such "suspension of disbelief" to make an illusion that people like his/her creation (Böcking 2008). This notion has been referred to as the novelty effect (Clark 1983) in the use of technology in education. The current enthusiasm of the maker activities may have been the result of the effect of suspension of disbelief. Educators and students tend to overlook the challenges and limitation of maker activities in schools. According to the literature (Clark 1983; Hur and Oh 2012), very soon the enthusiasm will decrease when the novelty effect of the maker movement wears off.

Educators and researchers should ask the question during the implementation of maker activities: Do the technologies we are using in the maker activities really engage students in learning, or are we using students' ignorance or lack of knowledge to promote suspension of disbelief? The question should also be applied to all researchers using technologies to support other learning scenarios. The DIY tools such as 3D printers and other hardware devices may trigger students' curiosity during their initial encounter with them. However, their curiosity may soon fade if the maker activities do not sustain their interest in persistently participating in the activities. It is suggested in the literature that students' enthusiasm in learning activities is not a static process (Herrington et al. 2003) but that it changes according to the challenge and skill levels (Kiili 2005; Liu et al. 2016). The game design principle may shed light on the ways to address this temporal issue. Game design principles suggest that game systems need to be tuned to persistently engage students in a flow state from a lower to a higher level of challenge throughout the whole game process (Kiili 2005). Therefore, one of the principles to persistently engage students in maker activities is the low-threshold but high-ceiling principle (Myers et al. 2000). More specifically, the low-threshold feature of the technologies or maker activities should enable novice students to easily participate in the activities. At the same time, the high-ceiling feature has to allow students to work on increasingly sophisticated products. This is similar to the choice of Lego for children of different ages. For children under 3, they need large Lego blocks because they are easier to manipulate, thus making it easy for them to participate in Lego building activities. However, children over 7 will not be interested in such big blocks. They need more complex building blocks to work on complex products.

The low-threshold/high-ceiling principle was initially coined to address the pedagogical guidelines for developing complex abilities (Burton et al. 1984). The principle is critical to sustaining students' engagement as it helps to achieve a sense of balance in students' challenge and skills perception in the maker activities. Such a balance is an essential condition of flow (Csikszentmihalyi 1975). In other words, to sustain students in a prolonged maker activity, the activity should afford students a high level of freedom so that they can exercise their imagination and regulate their activity to achieve the imaginative and challenging goal.

The low-threshold principle is critical to enabling novices to participate and to build their confidence in the maker activities. Through proper design, the threshold of the technologies can be lowered to support novice students to participate in maker activities. Tangible programming blocks such as AlgoBlock (McNerney 2004), for example, provide facilities for children to learn to code computer program. Such an easy-to-manipulate programming blocks are a potential approach to addressing the low-threshold principle. In programming activities, children may encounter cognitive barriers that significantly hinder young children's participation in the programming activities. The programming blocks provide tangible interfaces between the children and computer to support them in the creation of codes without needing complicated computer skills. In addition to the technology approaches, educators need to be aware of the pattern of students' engagement in using a certain technology and to take appropriate pedagogical approaches in order to address important temporal pedagogical considerations to achieve the high-ceiling principle.

Regarding the pedagogical approaches, the study by Liu et al. (2016) identified several types of disengagement that hindered their long-term engagement in the maker activity and derived pedagogical approaches to solve the disengagement. In their study, a making-my-digital-book activity was implemented to help third graders learn English from model stories. This was a self-directed learning activity in which the students freely created their digital stories based on the model stories with drawings and their own oral narrations without direct teaching (Fig. 3). The activity lasted for 2 years, from 2013 to 2015, and thus sustaining student engagement became a critical issue.

Liu and his colleagues (2016) identified that students' engagement dynamically changed over time. When triangulating students' engagement perceptions with their creation activity, Liu and his colleagues found mainly two reasons for disengagement: wearing off of the novelty effect and repetition. Regarding the wearing off of the novelty effect, during the students' first encounter with the creation activity, they showed a high level of engagement. However, they soon showed the first disengagement as they had no prior experience of similar creation activities and encountered difficulties creating digital stories. The novelty effect faded off soon. Liu and his colleagues also discovered that this disengagement could be easily reversed by the teacher's guidance that helped them accomplish their first story. Such a reverse of disengagement echoes the importance of the low-threshold principle. Educators need to arrange activities to enable the novice students to participate and shorten the period of disengagement due to the wearing off of the novelty effect.

Fig. 3 Students learn to create multimedia stories with drawing and oral narrations

The other reason for the students' disengagement in the creation activity was the repetitive nature of the activity. Such repetition is necessary for the long-term learning process of certain subjects such as language learning. In the study by Liu et al. (2016), the students experienced disengagement again over a longer period of participation in the creation activity. As they kept repeatedly creating and publishing stories during this phase, such repetition caused disengagement. Regarding such disengagement, Liu and his colleagues suggested that social activities that promote the awareness of the higher standard of stories were necessary to reverse the disengagement. When the students noticed the high-quality stories that some others published in the class sharing activity, their awareness of a higher standard of multimedia stories motivated them to improve the quality of their stories. Such a result suggests that educators should have a mechanism to keep students aware of the increasing standard that they should achieve to fulfill the high-ceiling principle. With this standard in mind, students are more likely to work on increasingly complex products to avoid repetition disengagement.

The studies above shed light on the implementation of low-threshold/high-ceiling maker activities. Scaffolding for novice students can shorten the disengagement due to the novelty effect. Setting up increasingly higher standards for maker activities is also a necessary pedagogical approach to continuously engage students in the maker activities in a long-term program.

Conclusions and Future Directions

Maker activities may fulfill the notion of creator-based learning. This is a way of learning by creating something new and meaningful. In contrast to instruction-based learning, creator-based learning is open-ended, rather than fixed scope, therefore requiring students to explore a domain by themselves to pursue long-term learning goals. Students have to expand their creativity, curiosity, and imagination and collaborate with others in order to create. The creator-based learning needs to integrate multiple competencies such as technology, science, art, and language. We believe that such creator-based learning is helpful for cultivating the minds of makers and preparing students to become lifelong learners.

Maker activities have great potential to transform current education practices into creator-based learning. Learning can become a construction process rather than a knowledge acquisition process. However, to avoid their pitfalls, the implementation of the maker activities should consider the educational principles and promote the educational values of the activities. We have conducted a series of studies to investigate the ways to implement such creator-based learning.

This chapter summarizes our studies regarding creator-based learning and illustrates how the three principles may be used to implement maker activities. Firstly, integrating students' imagination in the maker activities promotes students' intrinsic interest in learning and persistently motivates them to apply multiple problem-solving strategies. Secondly, the remix process improves social creativity in maker activities as it provides a mechanism of endless hybridization which strengthens the "transactivity" of the social activities. During the remix process, students reciprocally build their works or argumentation based on those of their peers. Thirdly, the low-threshold/high-ceiling principle is necessary to enable novices to participate and build their confidence in the maker activities and to build increasingly high standards to improve the quality of the products they make.

We have deliberated three design principles to implement creator-based learning. However, there are still many open issues that need to be addressed in the implementation of maker activities in schools. Firstly, how maker activities can be leveraged in the school curriculum. As maker activities often involve multiple disciplines including science, technology, engineering, art, and mathematics (STEAM) and require a long period of implementation time, how creator-based learning can be aligned with the school course schedule needs further exploration. In particular, pedagogical approaches that leverage the contrast between the openness of creator-based learning and the structured learning format in schools should be necessary to help teachers implement maker activities in schools. The second issue is the assessment of learning performance in creator-based learning. Learning assessment is normally conducted within a constrained and rigid framework. Such a framework contradicts the open and creative nature of creator-based learning. How assessment schemes can be implemented in creator-based learning to assess students' learning and creativity performance needs further investigation. In particular, how the assessment and creativity and learning can be synergized to support the development of both creativity and knowledge in certain domains is a critical issue.

Other future works that should be addressed include how curiosity may play a role in creator-based learning and how curiosity can be triggered and measured in maker activities. Regarding the remix process, it is necessary to resolve the social dilemma of knowledge sharing to promote social learning in the maker activities. Gathering information on these issues through further studies can help obtain a thorough understanding of creator-based learning, which would inform educators and researchers in their design and pedagogical decisions on the implementation of maker activities in schools.

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Trends and Opportunities in Online Learning, MOOCs, and Cloud-Based Tools

62

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Contents

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Abstract

Online learning, in particular massive open online courses (MOOCs) and cloud-based tools, is on the move. This chapter takes a deeper look at opportunities and possibilities that might be provided to K-12 education through these emerging tools. The chapter summarizes experiences, case studies, and examples that illustrate where technology-enhanced learning is heading.

Keywords

Online Learning · MOOCs · Cloud-Based Tools · K-12 learning and teaching · Cloud services · Technology-enhanced learning

Introduction

Technology is everywhere and it is intertwined in learning and teaching. At the start of the new millennium, Prensky (2001) stated that there are radical changes in the way students learn and how teachers would teach in the twenty-first century. Public schools in the United States provide at least one computer for every five students (Herold 2017). In Australia, every three students have access to one computer (Fogarty 2015). As evident in today's digital era, the use of enabling technologies has increased exponentially, and all educators – K-12 teachers, college professors, and administrators – must be well-equipped to follow the growth. Today's students are technology-driven (Nagler et al. 2014, 2016; Oblinger and Oblinger 2005) with many growing up with mobile devices, smartphones, laptops, tablets, and fast internet access; and they are more inquisitive while aspiring to learn in a formal, collaborative, and social setting (Conole et al. 2006; Margaryan et al. 2011; Bullen et al. 2008). In this regard, K-12 teachers and administrators must embrace new teaching and digital strategies taking into account aspects to incorporate both formal and informal learning. It is becoming clear that teaching and learning in the twenty-first century are vastly different to teaching and learning in previous centuries. In this context, the experts polled in the NMC Horizon Report 2016 K-12 agreed on the long-term trend of "redesigning learning spaces to accommodate more immersive, hands-on activities" which indicates that online learning and virtual reality are important emerging educational technologies (Adams Becker et al. 2016).

As educational technology permeates our society, teachers and administrators must now be aware of and learn to take advantage of enabling learning technologies and tools that influence the learning environment ecosystem and can be used to drive student engagement and motivation to learn. In addition, this global transformation has demanded that teachers learn new teaching skills and administrators adopt new operating models in response to technological changes.

Learning and teaching technologies have evolved from chalkboards, correspondence or on-air classes, overhead projectors, photocopiers, calculators, films, and videos to portable computers, microcomputers, whiteboards, personal digital assistants, learning management systems (LMS), the Internet, iPads, tablets, social media, wikis, and blogs – and the list of innovations has continued into the twenty-first century. In particular, the introduction of LMS and the arrival of the World Wide Web in the 1990s changed the dissemination of learning experiences. Coupled with the use of Web-based applications, collaborative and constructivist learning emerged with the first use of bulletin boards (Maurer and Scerbakov 1996). The advent of Web 2.0 technologies introduced e-Learning 2.0 (Downes 2005), and this saw the rise of collaborative online learning, followed by the integration of mobile technologies (Ally et al. 2014) and cloud computing. With mobile computing devices and networked technologies and the mass consumerization of smart devices, some schools have implemented bring your own devices (BYOD) initiatives, and others have implemented one-to-one (1:1) computing programs. Today, online learning such as massive open online courses (MOOCs) includes teaching and learning for mass audiences (e.g., several MOOCs have more than 25,000 students learning together). Currently, there are research studies that are investigating the use of wearable technologies and sensors (Wong et al. 2015) and virtual reality technologies for learning and teaching (Spitzer and Ebner 2016). One of the newest emerging trends is the availability of a makerspace where creative thinking skills are exercised in a collaborative work space infused with computational imaging and other new capabilities (Schön et al. 2014; Adams Becker et al. 2016). Some of the new skills needed in the makerspace include how to use 3D printing, laser cutting, 3D modeling, and robotics. More recently, cognitive computing (e.g., IBM Watson) has introduced the concept that technology can understand, personalize, interact, and emulate or think like a human (IBM, 2017) and may be used to support online learning.

As important developments in educational technologies continue to emerge, K-12 teachers and administrators need to embrace the use of enabling technologies in *the world of connected instruction* (Smith 2014) to improve learning and teaching in schools. New teaching models utilizing technology-enhanced learning encourage students to be active learners allowing them to be both consumer and co-creator of contents. The future trends and opportunities in learning for K-12 point to new potential in the field of MOOCs and online learning. Although some work has been published on MOOCs and K-12 (e.g., Canessa and Pisani 2013; Ferdig and Pytash 2013; Ebner et al. 2016), many K-12 teachers and administrators may not have yet encountered the practical and pedagogical benefits of MOOCs in the K-12 domain (Ferdig and Pytash 2013). Adams Becker et al. (2016) identified difficult challenges in adopting teaching innovations into mainstream practice due to financial and organizational issues.

The aim of this chapter is to raise awareness about the emerging potential within primary and secondary education for the use of cloud-based tools in MOOCs and online learning. The chapter begins by discussing the evolution of traditional classroom to online learning, followed by background on MOOCs and related research including those that are directed at K-12 teachers and students. More specifically, this chapter will focus on learning at scale with the MOOCs experience and the use of cloud-based tools (CBT) to create content for learning purposes. The aim of introducing CBT is to provide teachers with increased flexibility to select their preferred learning tools and media to meet their own classroom needs and objectives.

Evolution of Online Learning

The evolution of online learning can be seen as following a five-stage process (Ebner et al. 2013). Stage 1 includes traditional teaching in lecture halls or classroom without the use of any technology. In today's most common stage 2, teaching is supported with technology; for example, with the use of overhead projectors or simple online services. Stage 3 includes the assistance of a LMS or similar online-based information systems, where teachers provide learning contents and learning tools such as discussion forums. Stage 4 adds blended learning approaches (e.g., using both face-to-face and online learning interactions) where some teaching shifts to the online setting as an activity to be engaged by the student prior to or after the classroom. Stage 5 is a mature stage where all teaching and learning takes place entirely through interactive student engagement in the online setting. In this stage, access to learning can be open access and unrestricted.

The concept of online learning at stage 5 prospers with the advancement of Internet capabilities. Subject content for online learning can be developed and presented using videos, audios, and graphic elements. To encourage student engagement in an online setting, courses can be taken synchronously in real time using webcams or chat rooms and asynchronously through discussion boards and peer-to-peer learning.

As the learning reaches stages 4 and 5, teachers may incorporate the use of mobile technologies to increase student motivation and engagement in the classroom. Incorporating bring your own devices (BYOD) into the learning activities can help teachers transform and enrich their teaching methods into project- or enquiry-based activities (Sharples et al. 2014). Teachers may create online activities such as voting and polls or ask questions via clickers on their smart devices. Students like to use and have control over their smart and personal devices, and they may be engaged to do a learning task and complete the classroom task.

In recent years, MOOCs have paved the way for personalizing learning at scale. MOOCs are primarily free, interactive online courses available to anyone who has Internet access and wants to take the course. MOOCs have already made their mark in higher education at a global scale, with many top universities offering MOOCs on well-known platforms such as edX, Coursera, FutureLearn, Udacity, and others. More recently, cloud-based services are incorporated into MOOCs as these services have a selection of engaging activities such as simulations and graphic programming environments (MOOCMAKER 2016a).

MOOCs are also making their way into K-12 education and there are immediate benefits of doing this. With the use of interactive digital tools and other services, MOOCs may be used as an effective strategy to disseminate knowledge and basic literacy to masses of people; conduct outreach to primary education students; supplement existing content to make it more interesting, engaging, and informative; and engage students in diverse peer-based learning outside the walls and other barriers of the classroom and community. Moreover, MOOCs can foster self-regulated learning skills (Neuböck et al. 2015). With these potential use-cases in mind, K-12 teachers and school administrators must be well-prepared to understand

and utilize the Internet, cloud services, social media, and visualization technologies. To be able to create effective and engaging courses at scale, teachers must explore and engage in the use of various learning technologies and tools to address varying learning challenges to gain maximum educational outcomes.

Massive Open Online Courses (MOOCs)

Overview

Over the last two decades, technological inventions and changing attitudes of society have resulted in new forms of open and massification of education. Open source and cloud-based tools as well as open education resources have provided freely available courses to anyone without restrictions. Although open education resources such as the MIT OpenCourseWare program can be tracked back to 2002 (see https://ocw.mit.edu/), George Siemens and Stephen Downes raised the awareness in 2008 by offering an online course called "Connectivism and Connective Knowledge" which was open to the public and attracted more than 2000 participants. The new concept of involving a large number of learners without any restrictions became known as massive open online courses or MOOCs. Since then, MOOCs have become increasingly popular. MOOC research has grown, and top educational institutions now offer hundreds of MOOCs to millions of people. In 2011, Stanford University offered the MOOC "Introduction to Artificial Intelligence" and reported some 160,000 enrolled users. For 2016, some 6800 courses from more than 700 universities and some 58 million users have been reported (Class Central 2016; MOOCMAKER 2016b) which shows how open education has scaled up since the first introduction of MOOCs.

Types of MOOCs

The first MOOC offered by Siemens and Downes (n.d.) followed the connectivist theory known as cMOOC. The role of a cMOOC is used to refer to a MOOC that is designed to connect learners, to share and learn from one another. Another type of MOOC is called xMOOC which is normally offered by university-based platforms and is modeled on traditional "stand, deliver, and test" higher education teaching methods. Rosselle et al. (2014) classified three types of MOOCs based on five dimensions: (1) learning goals, 2) choice of resources, (3) organization of learning activities, (4) organization of individual and group work, and (5) collaborative co-production.

- ***cMOOC.*** This type of MOOC is designed based on the connectivist approach and provides learners with the flexibility and openness for all the above dimensions.
- ***xMOOC.*** This type of MOOC is based on the idea of using a centralized learning management system, and the courses are designed by a set of defined activities incorporating some or all five dimensions listed above.

- ***iMOOC.*** These types of MOOCs follow an investigative approach in the instructional design. iMOOCs are restricted in terms of learning goals and the organization of the learning activities. However, such MOOCs give learners freedom to select learning resources and organize group work for collaborative co-production.

In the last few years, another type of MOOC builds on the same open infrastructure and technologies but with restricted access is called a Small Private Online Course or SPOC (Fox 2013).

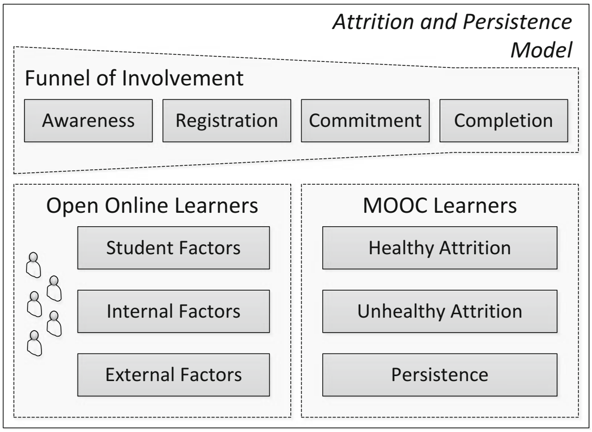
Characteristics of MOOCs

MOOCs are most often associated with open-access courses accessible to anyone, anywhere in the world. Learners have the opportunities to advance their knowledge and skills through formal learning as well as in lifelong learning settings. This setting allows learners from around the world with diverse social and cultural background to collaborate, interact, communicate, and work with one another. The MOOC environment also provides opportunities to those who cannot access traditional and formal learning due to financial constraints, geographical barriers, time, and other factors.

A successful MOOC course is typically highly engaging with lots of activities with contents that are presented in videos and rich media sources such as the use of graphics, images, games, infographics, slide deck, and course handouts. Quizzes and assignments are generally used to test the learners' mastery of the course. In order to motivate and engage with learners, gamification and simulation approaches may be considered as innovative features. MOOCs can be designed as self-paced, instructor-led, or a mixture of both methods. Where possible, a self-paced course is attractive in that it allows learners the freedom to work through activities at their own pace. Related to this, MOOC courses with succinct activities and shorter duration can also help to keep the learners motivated and committed to complete the course. With instructor-led courses, resources must be carefully planned, and sufficient facilitators or tutors need to be assigned to participate in discussion forums and respond to learners' questions. Learning activities should also be designed in a way that encourages learning in groups. A good mix of self-assessment, peer assessment, and automated assessment that provides useful feedback can guide the learners throughout the learning activities. The MOOC must also be designed in such a way that will allow learners to track their progress, and there is also the ability to take notes in the MOOC itself.

Since most MOOCs allow for global reach and are scalable, learners can come from all over the globe with different levels of education, varying technical and computer literacy, and diverse metacognitive skills. Depending on the way the MOOCs are designed, there can be a mismatch of the level of difficulty of the course and expectations of the learners. This generally leads to issues of high dropout rates. Detailed insights of learners' behavior and intentions when they are enrolled and of

Fig. 1 MOOC learners attrition and persistence model



those who are committed to finish the course must be considered. Most MOOC learners reached thus far have tended to be lifelong learners whose primary motivation is to learn about topics that interest them. Thus, many may only complete the learning content without completing any assessments. While educators in a traditional setting treat high attrition rates as a failure, this may not be true for MOOC completion (Gütl et al. 2014b). Research on attrition in MOOCs by Gütl et al. (2014a) reveals that learners who generally enrolled in MOOCs fall into three main categories. There are those who may only access the learning content without completing all the activities. There are other learners categorized as "completers," and finally, there are others characterized as "persistence" learners who intend to complete all five dimensions as listed in Rosselle et al. (2014). Depending on the learners' goals, course completion is not necessarily a measure of success. Figure 1 depicts a holistic model for learner attrition and retention in a MOOC (Gütl et al. 2014a).

MOOCs: Applications in Primary and Secondary Practice

MOOCs can be used for different purposes in K-12 education. Currently, teachers have successfully integrated online experiences such as MOOCs into the classroom by supplementing their teaching. Teachers may use part of the learning activities in the MOOCs to supplement their teaching. Students themselves can also enroll in the MOOCs independently. In some schools, educators have used MOOCs to discover career opportunities (Ferdig and Pytash 2013). Teachers have also enrolled in MOOCs for their own professional development, and some countries have requirements for continued professional development for teachers. One such example of a MOOC that is developed to help teachers continue professional education is the "Analytics for the Classroom Teacher" (see https://www.edx.org/course/analytics-classroom-teacher-curtinx-edu1x-0) MOOC offered by Curtin University on edX platform.

There are ample opportunities for both teachers and students with K-12 learning with MOOCs. As learning in MOOCs is primarily self-regulated learning, teachers may need to guide students of how to use the MOOCs (Neuböck et al. 2015). Schoolchildren tend to "learn by doing," and with a greater focus on science, technology, engineering, and mathematics (STEM) education, there are a number of examples that show motivated students watching videos to learn about physics or mathematics. Some students also follow videos to learn how to program small applications, a common practice among young people using YouTube videos to learn almost anything at anytime. Some MOOCs are built with gamification features that further motivate students to complete certain tasks. Some interesting development and successful applications are listed below:

- As part of the STEM education, STEM-MOOCs exist for students with the age range of 13–15. The conceptual and practical experiments of STEM are conducted via videos. Early research with the tracking of students' performance showed students can benefit by having guided online learning (Khalil and Ebner 2015). Teachers can certainly supplement part or all of the STEM education into the classroom.
- To increase interest in programming especially for young learners age 10 and above, there are MOOCs that will teach both teachers and students to code. For example, a MOOC on Pocket Code was implemented offering step-by-step "How-To Program" videos to program a first mobile application. The core concept of the MOOC follows the principle of open learning outside the classroom to attract students to learn basic computer science knowledge.
- In partnership with Google Australia, the Computer Science Education Research Group at the University of Adelaide developed a series of K-10 MOOCs on Digital Technologies for STEM curriculum (see http://csermoocs.adelaide.edu.au/moocs).These resources are freely available for teacher's education and professional learning (Falkner et al. 2015).
- In 2014 another MOOC for schoolchildren has also been offered, called the "the circle." Over 40 videos were produced embedded in a special didactical approach. Keeping in mind the seamless learning approach, students get a master plan of how the videos can be used to learn the topics. This MOOC uses elements of gamification, and at the conclusion of each topic, students can collect stars to signal their completion and achievement (Fößl et al. 2016).
- In 2016, Microsoft created a series of MOOCs to guide K-12 school and education leaders to develop teachers, enhance classroom teaching, and improve student engagement and learning outcomes. The aim of the MOOCs is to improve leadership in K-12 education and to drive transformational changes in the innovative digital schools.
- There exist a number of MOOCs on calculus, biology, statistics, and computer science, and teachers can certainly integrate the course materials as a "flipped classroom" concept and to augment their curriculum.
- Finally, teachers who may learn new skills about upcoming MOOC topics will benefit from this form of professional development. For example, there are MOOCs about incorporating 3D printing, vinyl cutting, and programming robots that teachers can use in the classroom (Ebner et al. 2016).

Cloud-Based Tools and Services

Overview

At the beginning of the new millennium, the Web, which was originally designed mainly for the consumption of information, has transformed into a participatory Web. Information consumers have become more actively involved in creating and remixing and repurposing existing contents in their role as information "prosumer." The second period of the Web, called Web 2.0, has introduced new paradigms of Web development and browser capabilities for interactive and dynamic content management. These concepts have further evolved and combined with early distributed computing into cloud-based services and tools.

Generally, *cloud computing* is defined as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources [. . .]" (Mell and Grance 2011). Most common cloud services are Infrastructure as a Service (IaaS) providing computational infrastructure such as storage and processing power, Platform as a Service (PaaS) offering platforms hosting software, Software as a Service (SaaS) offering the actual applications and services, and Backend as a Service (BaaS) allowing the outsourcing of the server components for Web and mobile applications (Armbrust et al. 2010).

Cloud Services in Education

Cloud services can provide great value and impacts in various learning and teaching settings, from individual self-directed learning scenarios to group learning activities in MOOC environments. In particular SaaS, for cloud-based tools (CBTs) or cloud-based Web applications and services, can offer attractive opportunities for institutions, teachers, and students. Internet users who grew up with modern media consume and apply such tools and services for most activities in their daily life.

CBTs provide several opportunities in modern learning settings and are scalable at individual and massive online learning levels. There are four distinct types of scenarios which can be concluded from the above:

- ***Outsourcing of resources.*** Applications with high resources on computational power, memory load, and storage capacity can be accessed outside the learning environment, such as video streaming, simulations, and virtual worlds.
- ***Scaling up resources.*** In the case of massive online learning experiences, it is difficult to predict when learners will access the online materials. Cloud services can guarantee scalability and elasticity by "on-demand" provisioning of resources.
- ***Accessibility.*** CBTs can provide tailored access to services, e.g., to mobile devices, which might vary from responsive design to streaming services for simulations and game-based environments.
- ***Alternative learning experiences.*** A variety of existing CBTs and Web-based services may provide alternative and engaging learning experiences for learners and instructors.

Types of Cloud-Based Tools and Services

A rigorous literature study and review of existing CBTs and Web services has been conducted as part of the *MOOC Maker* project (MOOCMAKER 2016a). The project has revealed a wide range of tools and services. The classification of cloud-based applications discussed in the remainder of this section is an adapted version of the original structure of the *MOOC Maker* project (MOOCMAKER 2016a).

- ***Course design and authoring tools.*** This class of tools can support instructional designers, content authors, and teachers in creating and maintaining learning content. Examples of the online tools included Udutu (http://www.udutu.com), EasyGenerator (https://www.easygenerator.com), and Elucidat (https://www.elucidat.com).
- ***Content creation tools.*** Unlike the above group of tools, this class of tools supports both teachers and students in the creative process. A number of tools exist to support media, such as text, images, diagrams and charts, videos, animations, and presentations. Illustrative examples include Google Docs (https://docs.google.com), Gliffy (https://www.gliffy.com), and Emaze (https://www.emaze.com).
- ***Collaboration tools.*** This group of applications enables students to work together with their peers and communicate and share information with their peers and instructors. Cloud-based services for synchronous and asynchronous communication include WhatsApp (https://www.whatsapp.com) and Facebook (https://www.facebook.com). Examples for collaborative content creation cover a broad range of application scenarios, such as mind map creation and sharing by MindMeister (https://www.mindmeister.com) or storytelling by Storybird (http://storybird.com). Illustrative examples for content sharing include social bookmarking such as Delicious (https://del.icio.us) and for scientific papers and citations Mendeley (https://www.mendeley.com/).
- ***Hands-on tools.*** The focus of "hands-on tools" is for activities for active engagement that can be administered individually or in a team. This includes 3D simulations and virtual reality, such as in physics TEALSim (http://web.mit.edu/viz/soft/visualizations/tealsim/) or in medicine BodyViz (http://www.bodyviz.com/), or supportive programming environments like REPL.IT (https://repl.it/) or Blockly (https://developers.google.com/blockly/).
- ***Assessment and feedback tools.*** This group of tools comprises assessment of knowledge and skills as well as provision of feedback and guidance. This might be as simple as quizzes like Quizlet (https://quizlet.com/) and Automatic Question Creator (AQC) (Höfler et al. 2012) or managing the marking process using ClassMarker (https://www.classmarker.com/). Related to assignments are tools to check for plagiarism and services such as PlagTracker (http://www.plagtracker.com/) can be used.
- ***Knowledge and auxiliary services.*** For background information and knowledge related to the learning content, a number of services are available through the use of open content repositories and encyclopedias such as Global-Geography

(http://global-geography.org/). In order to work on assignments, document repositories can be used along with spell checkers or dictionaries like LEO (http://www.leo.org).

- ***Learning management and support tools.*** This group of tools helps teachers and students to keep track of the teaching and learning activities which include news and time management tools such as TalentLMS (https://en.talentlms.com/) l. Self-guided learning support may also be included (Nussbaumer et al. 2015), and motivational aspects can be designed using gamification such as GameEffective (http://www.gameffective.com/).

Remixing of Cloud-Based Tools and Services

CBTs enable teachers and students with high flexibility to support learning activities by using a wide range of existing tools. The concept can give learners the freedom to select preferred tools for a particular task. Although this would scale up in terms of the number of users and the variety of tools available, it also introduces a higher complexity in terms of integration of multiple tools. This includes the configuration and management of roles and features according to the learning tasks and ownership of content and archiving of created deliverables.

For modern and engaging learning activities, it is preferable to combine two or more of the CBTs according to pedagogical objectives. Take as an example a task in second language training where collaborative writing tools are enriched with capabilities of spell checking and a thesaurus provided by other CBTs. Generally, learning orchestration identifies the capacity to combine two or several tools and adapt features to support specific learning goals. Such complex functionalities require an orchestration of CBTs on a granular level of tool interaction, data exchange, and intervention. It also calls for unified user interfaces in the integrated learning environment, abilities of assessment, and role management (Hernandez Rizzardini and Gütl 2016).

Seamless integration of CBTs can also support the creation of *cloud education environments (CEE)*, a powerful unified learning environment for enhanced educational experiences. This requires full control over the educational experience by role definitions and corresponding management of those roles, authority over resources created, easy initial steps for the integration of a new tool, and configuration for the use of CBTs to be adapted for specific learning tasks. Ideally, new CBTs should be automatically integrated without any programming effort and be used in the CEEs. (Hernández Rizzardini 2015).

Generally in online education and in the context of CEE, the following technical aspects need to be considered (Hernández Rizzardini 2015):

- ***Authentication.*** This aspect includes user and group management and single sign-on on all platforms and CBTs.
- ***Content packaging.*** The reuse and exchange of learning assets are covered by content packaging mechanism.
- ***Data definition.*** This aspect focused on schema (in XML or any other format) for describing the content structure.

- ***Data transport.*** This covers aspects regarding how data are transferred among systems.
- ***Launch and track.*** This addresses information how content and tools can be launched and tracked.
- ***Metadata.*** This aspect deals with the data attributes and corresponding values to describe, search, and retrieve learning content and services.

Over the years, many standards and specifications for educational interoperability have become available covering one or more aspects listed above and discussed in detail in Aroyo et al. (2006) and Hernández Rizzardini (2015). Learning environments and middleware systems exist to support teachers, administrators, and practitioners to create and manage their own learning experiences on CBTs. Responsive Open Learning Environments (ROLE), a European project in the FP7 program, aims on a personal learning environment (PLE) by utilizing Web-based tools and technologies. ROLE provided technical infrastructure which enables learner groups to assemble widgets and services in PLEs (Hernández Rizzardini 2015). Research has also been conducted, and a middleware has been developed to integrate CBTs without programming effort by adopting recent technologies, such as JSON-LD and Hydra (Hernández Rizzardini 2015; Hernandez Rizzardini and Gütl 2016).

Cloud-Based Tools: Applications in Practice

Cloud-based tools are increasingly adopted in learning experiences, from formal learning in school and at university settings to vocational training and lifelong learning. It can be found in a wide range of learning settings, from individual learner's usage to the scale of MOOC environments (Anshari et al. 2016; MOOCMAKER 2016a). In the remainder of this section, two examples are introduced.

The first example is based on the middleware introduced in the previous section and covers one successful example of how cloud-based tools can be integrated and widely used for open learning settings in a MOOC environment (Hernández Rizzardini 2015). Galileo University built the virtual learning environment Telescope on top of the LRN learning platform (http://dotlrn.org/s) specifically designed for MOOCs. Additionally, the middleware for CBT integration has been used to offer various types of tools for learning purposes. The cloud learning activities orchestration (CLAO) system as reported in Hernández Rizzardini and Gütl (2016) enables teachers and MOOC coordinators to select specific CBTs, manages features on fine-grained levels, and configures graphical appearance within the virtual learning environment Telescope. In a pilot study, the setup has been used to offer the "cloud-based tools for learning" MOOC. Learning activities have been designed as xMOOC and include the following CBTs: Google Docs (https://docs.google.com/) as text editor, Cacoo (https://cacoo.com/) for creating diagrams and flowcharts, MindMeister (https://www.mindmeister.com/) as mind map tool, SlideShare (http://www.slideshare.net/) for sharing presentations, and Educaplay (https://www.educaplay.com/) for assessment and feedback activities.

Two thousand and forty-five users from Latin America enrolled in the course. Findings revealed that the effort of integration of the middleware for CBT integration and CLOA system for CBT orchestration was low compared with the effort on integrating on a tool by tool basis. In terms of performance, middleware and integrated CBTs were able to scale up with more than 2000 students enrolled in the course. The MOOC course designer and teachers are able to set up the learning activities and attach CBTs and configure features and appearance in the virtual learning environment.

In order to gain insides on motivational aspects and cognitive learning strategies of the students, the Motivated Strategies for Learning Questionnaire (MSLQ) was applied (Pintrich and García 1993). Students' attitudes on the value of using CBTs show a high intrinsic and extrinsic goal orientation as well as task value. The findings reveal a high-control self-belief and self-efficacy for learning, and the perceived level of anxiety in using CBTs was on a medium level. The metacognitive self-regulation in the MOOC settings was perceived as high, and elaboration and organization have been identified as the most relevant cognitive strategy in the MOOC setting (Hernández Rizzardini 2015).

The second example illustrates the integration of a hands-on tool into the edX platform used as learning and assessment activity. Physics simulations of electrostatic and electrodynamic phenomena, available in MIT's TEALsim (Dori and Belcher 2005; TEALsim 2017), were integrated in the MOOC platform. This example illustrates the CBT application in a formal learning setting for university students but is also easily adaptable for learning experiences in school education.

Seven simulations have been ported using the Google Web Toolkit (GWT) (Adam et al. 2013) and converted from the stand-alone Java application into a Web-based tool built on HTML and JavaScript to be used as extra activities in a university course in physics. Findings reveal that the hands-on tool was hardly used by the students. In order to improve the situation, it was decided to tightly integrate the tool in the learning activities to increase the application of the tool for assessment activities (Zeleznik 2015).

EdX (https://www.edx.org/) is one of the major MOOC platforms, which provides a variety of features, functions, and tools to create and run courses and analysis of user behavior. It also provides a JavaScript-based interface "jsinput" (edX 2017) to integrate external tools and exchange data between edX and the external tools. The TEALsim simulations have been integrated in such a way that a set of exercises can be personalized and configured for each student. The corresponding set of data controls the initialization of the tool for the hands-on experiences. Any interaction with the simulation is captured and sent back to the edX platform. Data are used for learning analysis and feedback in the learning phase. This setup enables the designer of a MOOC to specify a range of exercises for each of the students and also keep track of their performance. It also defines specific assessment activities which can be used to grade the performance of the students. This simulation and visualization scale up for a high number of participants in a MOOC course (Zeleznik 2015).

Research has indicated that learners are motivated and have positive attitudes toward using CBTs. They expressed excitement when using a variety of tools as they are exposed to interactive ways of learning. With the positive learning experience, learners gained improved performance in the course. A minor drawback is the time to be familiar with several of the CBTs. To overcome this, training and tutorial videos should be provided to guide the learners while they are using the tools.

Embedding Online Learning, MOOCs, and Cloud-Based Tools Infrastructure in Schools

School stakeholders such as teachers and administrators who are embedding the opportunities presented with MOOCs and CBTs must follow three key areas to plan for a seamless implementation. The areas are (1) networked and technological infrastructure, (2) security and privacy, and (3) bring your own devices (BYOD) strategy. With the technology infrastructure, sufficient network bandwidth must be available to support the transfer of a large amount of data from various devices, applications, and data on servers. Robust network infrastructure supporting data movement from access device to data center is crucial in ensuring a seamless learning environment. Internet usage will increase in the school environment from learning and teaching activities, to administration functions. The bandwidth usually will virtually increase in every aspect of K-12 education, and connectivity must be reliable. High-speed connection that supports fast response times is critical to ensure students are connected as and when they need to use any applications via the Internet. Students and teachers alike expect the same rapid response when they connect to MOOCs and CBTs. Likewise, they would require powerful laptops, tablets, or desktops. Single or same sign-on is a capability that facilitates all integration on MOOCs or CBTs. Users will expect ease of access to multiple resources in the cloud without having to use different logins and credentials.

In terms of security and privacy, schools are required to comply with regulations governing the security of private information. As such computer and information security is of particular concern to schools as they maintain confidential information about students ranging from academic records to health information. Schools must derive information communication technologies (ICT) principles and governance. ICT security compliance standards exist to support schools and mitigate risks. Some of the principles include user authentication using proven cryptographic methods; privacy capabilities including data encryption, data anonymization, and mobile location privacy; single sign-on login capability; access protection to prevent third parties from accessing data; access to IT disaster recovery plan and data centers; and secure cloud-based data backup and storage.

BYOD programs will continue to have greater interest for school teachers and administrators. As technology continues to advance, students will increasingly want to use their devices at school. When BYOD are integrated in learning and teaching in the classroom, BYOD can offer many opportunities. BYOD also bring many challenges, in particular the issue of equity, fairness and access. Students may not own a smart device, and if they do, the data usage may be restricted (Sharples et al. 2014). Schools may have to provide more re-charging power stations and consider the school's wireless infrastructure when encouraging the use of BYOD in classrooms. Schools will have to set clear guidelines to manage BYOD in the classroom environment, for careful and appropriate use, security and equity issues (Sharples et al. 2014).

Conclusion

It is clear that the twenty-first-century learning and teaching needs are very different to those of previous centuries. In the twenty-first-century classroom, in addition to imparting knowledge and skills, the advancement of technologies has allowed teachers to be facilitators of student learning. Teachers must supplement their traditional classroom teaching with new teaching strategies to engage their students in learning using a variety of instructional methods following different pedagogical approaches aided with technology. Students can be active participants if the classroom curriculum is designed in such a way that promotes active engagement, and this can be done by incorporating modern technologies in the curriculum.

Teachers and administrators can upskill by enrolling in MOOCs that are relevant and applicable to their role. Teachers also have greater flexibility of selecting CBTs for specific learning activities, and they have the opportunities to embed CBTs in the classroom. Teachers can also design their courses with greater interactive and stimulating learning experiences. From the technical and organizational point of view, online learning, MOOCs, and CBTs are highly scalable and widely accessible. Resources and applications can be accessed and used without a high payload. As discussed in this chapter, technology and software tools play a big role in developing learning activities for students in the modern-day classroom settings. With the effective use of technology and services such as CBTs and MOOCs, students can learn twenty-first-century skills of collaboration, creativity, critical thinking, and problem-solving (Crockett 2016). Advancement of technologies offers teachers with greater teaching methods and opportunities in the classroom. Some of the characteristics and features that teachers play in the twenty-first century with use of the technologies include the following:

- Student-centered: With this, teachers are focused on each student's needs, and with technology, students will play an active role in their learning with teachers facilitating in the classroom (Crockett 2016).
- Computing devices: Computing facilities and BYOD are readily available in the twenty-first-century learning. With the availabilities of cloud-based services and other resources such as MOOCs, teachers are able to create more engaging learning activities.
- Active learning: Students are encouraged to be active learners. With the availability of engaging learning activities, students are able to work independently or work collaboratively in teams. This will give students the ability to master a skill at their own pace or work, enquire, and research together with teammates.

- Collaborative learning: With computing devices, students will be able to work in group projects and solve problems in groups (Rotterham and Willingham 2009). With their smart devices, students are also able to work outside of classroom in synchronous and asynchronous modes.
- Connect: Students are able to connect with those students who would like to work on the same topic and perhaps those who are able to work together given time constraints.
- Adaptive learning: As students are at different stages of learning, teachers may be able to adapt and personalize the learning according to the student's abilities. There exist a variety of software tools that will enhance the learning of their students (Rotterham and Willingham 2009; Palmer 2015).
- Innovate: Teachers can continue to innovate and try new ways to teach and engage their students. In addition to the available tools, services, and resources for formal learning, teachers may also teach using social media and incorporate outside of classroom teaching.

As MOOCs and CBTs are maintained and upgraded automatically by third parties, a major drawback resides with the sustainability of the courses and tools (Rotterham and Willingham 2009). Administrators must have strategies, policies, and guidelines to manage the networked and wireless technologies, the implementation of BYOD, security, privacy, and technology equitable access to all students. Of greater importance is that administrators and school leaders must provide professional development to teachers and to communicate with parents of the expectations with the use of technologies and educational materials.

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Educational Opportunities for Immersive Virtual Reality

63

Richard E. Ferdig, Enrico Gandolfi, and Zachary Immel

Contents

Abstract

This chapter provides an overview of immersive virtual environments (IVE) in education with an emphasis on immersive virtual reality (IVR). A companion chapter in this volume focuses on a second type of IVE called augmented reality (AR). First, definitions are provided, focusing on concepts such as immersion, fidelity, presence, and simulations. Second, a review of research is presented for IVR that highlights the current and potential impact in PreK-12, higher education, and professional development settings. Findings suggest the use of IVR can lead to increased engagement. However, the synthesis also points to a relative dearth of published research for PreK-12 implementation. The chapter ends with a call

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for future research looking at key areas like special needs, potential negative long-term effects, training for teachers and students, and exploration of key concepts like embodied cognition, computational thinking, self-tracking, spatial reasoning, and situational/individual interests within IVE.

Keywords
Immersive virtual reality · Immersive virtual environments · CAVE · Embodied cognition · VR

Introduction

A historical review of the implementation of technologies for education would show a rather slow transition from radio to television to the personal computer. However, once the personal computer reached its tipping point in modern society and in classrooms around the world, the speed of innovation seems to have increased exponentially with seemingly endless possibilities. For example, researchers and educators have recently examined the potential role of games and simulations, mobile devices and applications, haptics and touch devices, coding, and robotics.

Perhaps the most recent, cutting-edge implementation has come from the area of immersive virtual environments (IVE). Notable new and standard names in the educational use of such technologies have included *Second Life*, *Active Worlds EDU*, *Google Glass*, *Microsoft HoloLens*, and *Oculus Rift*. The purpose of this chapter is to examine a specific type of IVE known as immersive virtual reality. The chapter begins by providing concise definitions. It then summarizes existing educational research, focusing on the promise and pitfalls of immersive virtual tools for teaching and learning. The chapter concludes with a call for more research to further explore the value and benefits of VR for PreK-12 teaching and learning.

Defining IVE and IVR

A critical first step in defining virtual reality research is to further define the concepts of *immersive virtual environments* and *immersive virtual reality*. Entire volumes have been written attempting to best describe these concepts; a cursory overview will not give justice to the deserved and lengthy conversation. However, it is critical to set the stage for these terms to focus this review.

People began using the term *virtual reality* consistently in the 1960s (Freina and Ott 2015). Since that time, people have begun to further delineate the concept by describing both non-immersive and immersive VR. "The former is a computer-based environment that can simulate places in the real or imagined worlds; the latter takes the idea even further by giving the perception of being physically present in the non-physical world" (Freina and Ott 2015, p. 1). There has been significant use of immersive VR (IVR) for professional development, entertainment, research, and higher education. Although much of the work of IVR originally happened in cave automatic virtual environments (CAVE; Cruz-Neira et al. 1993) or with full head-mounted displays (Shibata 2002), newer technologies like *Oculus Rift*, *PlayStation VR*, and *HTC Vive* are changing how researchers and educators are thinking about IVR installations.

Immersive virtual environments (IVE). Immersive virtual realities can include newer forms of augmented reality such as *Google Glass* and *Microsoft HoloLens*. As such, the term here is broadened to *immersive virtual environments*. An immersive virtual environment would best be considered as a set of digital tools used to provide an alternative habitation that centralizes the user experience to immerse him or her within its virtual boundaries. IVE also utilize input systems (e.g., motion controllers), artificial intelligence routines (e.g., interactions between the virtual setting and the player's input), mechanics, and aesthetics (Freina and Ott 2015). In theory, IVE could use all five senses to accomplish this task; "most VR environments today do not actually address all of them but usually focus on two: sight and hearing" (Freina and Ott 2015, p. 3).

The concept of immersion is what helps delineate IVE from other simulations. Most of the existing research further depicts this notion of immersion by using the concepts of *fidelity* and *presence*. Fidelity describes the ability of the simulation to mirror what is being simulated (Alexander et al. 2005; Riva et al. 2007). For instance, digital medical scenarios, flight simulators, and virtual driving machines can all be evaluated for fidelity based on how closely they mirror real-world environments. This is often referred to as fidelity of display, which examines vividness or the sensory quality of the virtual setting (McMahan et al. 2012).

Display fidelity is a useful concept, but measuring it becomes more complex when the virtual environment does not easily mirror real-world environments. As such, researchers also examine interaction fidelity or the exactness of real-world interactions being reproduced in the environment (McMahan et al. 2012). Interaction fidelity helps measure how naturally users are able to act in the virtual environment and consequentially perceive an agential incorporation (Calleja 2011).

In addition to fidelity, researchers also examine immersion by measuring presence. At its broadest definition, presence refers to being in the "here and now" (Calleja 2011). Mestre (2005) argues presence was defined as a "psychological state experienced as a consequence of focusing one's energy and attention on a coherent set of stimuli" (p. 2; also see Slater and Wilbur 1997). However, the author pushes the definition to address ecological validity, suggesting that it goes beyond just the interface to include sensory and motor behavior. There is an obvious connection between the two concepts as a high fidelity can improve presence. Both are critical to addressing immersion as a distinctive quality of IVE. There are two types of IVE: the first, addressed in this chapter, is *immersive virtual reality*. The second is *augmented reality*; it is addressed in the augmented reality chapter (▶ Chap. 64, "Educational Opportunities for Augmented Reality" by Gandolfi et al.).

Immersive virtual reality (IVR). Immersive virtual realities attempt to replicate a source reality like a medical examination or a flight path. IVR is typically represented by simulations that go beyond simple sight and sound. This may include empowering sight and sound with 3D or a 360-degree perspective. IVR also uses iconic input systems that help support the correspondence between reality and virtuality. Iconic systems provide opportunities for the user to interact with the environment in natural, gesture-based manners or through tactile augmentation. The degree to which the simulation emulates the source (its fidelity) is related to its effectiveness. The challenge, of course, is using IVR for situations that do not have a well-framed origin or reality (e.g., a fictional reality).

IVR applications often address conditions of severe difficulty or impossibility. These conditions include space (e.g., being in other places or spaces instantly), time (e.g., historical or futuristic), ethics (e.g., creating a reality without ethical and moral implications or consequences), safety (e.g., creating a reality with no or limited risks and dangers that would exist in reality), situation control (e.g., taking untrained or young learners into risky situations), and realism (e.g., being involved in an environment that does not exist or in an environment about which few facts are known). In these environments, designers and educators have the opportunity to create a new reality with their own rules and scripts.

Crecente (2016) provides an important historical perspective on the development of IVR (see Crecente's publication for a detailed explanation of how these advancements contributed to our present perspectives of VR writ large). Milestones include:

- 1958 – Sensorama.
- 1966 – Ultimate Display (first HMD).
- 1975 – Videoplace (precursor of CAVE).
- 1978 – LEEP (extreme wide-angle stereoscopic optics system).
- 1979 – Aspen Movie Map (precursor of Google Street View).
- 1982 – Wired Globe.
- 1980s – Jaron Lanier starts to work on multi-person VR simulators and avatars and invents the concept of "virtual reality."
- 1992 – VR movie Angels – first VR movie (by Nicole Stenger).
- 1992 – Virtual fixtures (see AR).
- 1993–1998 – Osmose/Ephemere (VR controlled with breathing and balance).
- 1995 – first CAVE.
- 1998 – CABIN and COSMOS – similar to CAVE (Michitaka Hirose).
- 2003 – Bravemind/use of VR for rehabilitation and psychological resilience (Albert Rizzo, USC's Institute for Creative Technologies).
- 1997–present – the use of VR for social experiments and tests (Mel Slater, Event Lab).
- 2010 – Kinect.
- 2012 – *Oculus Rift*.
- Today (2018) – Vive, PlayStation VR, Oculus Touch.

There are a number of educational opportunities within IVR. For instance, IVR has been created to share lectures (*LectureVR*, http://immersivevreducation.com/lecture-vr/), to share learning spaces (*AltSpaceVR*, https://altvr.com/; *Frooxius*, http://frooxius.com), to tell stories (*AlchemyVR*, http://www.alchemyvr.com/), to visit national parks (*Google National Parks*, https://artsandculture.withgoogle.com/en-us/national-parks-service/parks), to improve health education (*Embodied Labs*, http://www.embodiedlabs.com), to learn and teach architecture (*ImmersiveVR*, http://www.immersivevr.it/en), and to teach and learn (*VREP*, http://vrep.org; *PublicVR*, http://publicvr.org).

A Review of Research on PreK-12 Immersive Virtual Reality (IVR)

Given its relative infancy, there are not a tremendous amount of published research articles on using IVR in PreK-12. However, there are a plethora of descriptive articles. For instance, Samsung completed a survey (Bolton 2016) asking educators about VR. They suggested that science, social studies, and history are key areas of potential benefit from IVR. A majority of survey respondents said they would be eager to use the tools (93%), thought they could improve learning (83%), stated they would increase student understanding of learning concepts (77%), and indicated VR would improve motivation (84%).

Other descriptive articles depict research or development projects in process both in and out of PreK-12. These contributions focus on new degrees (e.g., Connor et al. 2015), novel projects for robotics (e.g., Crespo et al. 2015), new theories about motion tracking (e.g., Fominykh et al. 2014), the potential of VR for urban planning (e.g., Nguyen et al. 2016), VR for health (e.g., Randall et al. 2016), and various other aspects of VR for teaching and learning (e.g., Häfner et al. 2013; Ip et al. 2016). Finally, there are articles that list IVR tools (e.g., Brown and Green 2016).

The research that does exist on IVR for PreK-12 learning is promising. For instance, Bower et al. (2016) studied the use of virtual worlds for cooperative learning and copresence with preschool teachers. The majority of participants considered the virtual world useful for communication, teamwork, and copresence. Chan et al. (2016) used a CAVE-like system for visual arts education. Students reported an overall positive experience but suggested that viewing other students' work in VR was difficult due to viewing issues and the focus on a single user. The study did provide additional evidence that VR could be useful for comprehension and inspiration. Ip et al. (2016) also used a CAVE while working with children with autism as they transitioned from kindergarten to first grade. Children had successful outcomes related to emotion recognition, affective expression, and social reciprocity (see also Lorenzo et al. 2013, 2016).

Some of the IVE research compares technologies. For instance, Fabola and Miller (2016) deployed various VR devices (e.g., *Oculus Rift*, *Gear VR*, and *Google Cardboard*) in teaching cultural heritage. Their results demonstrated that headset-based virtual reality systems stimulate young pupils' interest in learning history more than screen-based virtual reality systems. Passig et al. (2016) created a teaching intervention for first and second grades in which strategies for solving problems were combined with a variety of technologies including IVE. The authors reported data that suggested teaching in a 3D IVR environment contributed to the children's cognitive modifiability more than in the other groups in the Analogies Subtest of the Cognitive Modifiability Battery (CMB).

Not all of the research compared IVE to non-IVE and not all of the research outcomes were positive. For instance, Ke and Carafano (2016) presented an assessment of *Astronaut Challenge*, an immersive flight-simulation-based learning program. The authors suggested that the higher level of the sensory immersion in a simulation-based learning environment may foster task engagement and procedural practice but not collaborative conceptual processing. Ritz and Buss (2016) noted the potential for cognitive overload that can occur when using CAVEs in education.

A Review of Research on Non-PreK-12 Immersive Virtual Reality (IVR)

There are a number of other studies outside of PreK-12 that provide further evidence of the promise of IVR in PreK-12. Studies have demonstrated:

- VR can be more effective than video training for laparoscopic surgery (Alaker et al. 2016).
- IVR can be a useful tool for exploring and measuring concepts; in one study, it was adopted to understand the relationship between paranoia and self-confidence (Atherton et al. 2016). In a separate study, it was used to examine paranoid ideation, anomalous experiences, self-confidence, self-comparison, physiological activation, and behavioral response (Valmaggia et al. 2016).
- IVR can be exploited to study social interactions by changing variables and creating new situations; however, realism in immersion makes those environments more convincing (Bombari et al. 2015).
- *Oculus Rift* may potentially have a higher degree of immersion compared to *Google Cardboard* and a standard 3D TV when exploring heart rate and simulator sickness (Chessa et al. 2016). *Oculus Rift* was also shown to be engaging and motivating and lead to a greater sense of presence and immersion in virtual operating rooms (Kleven et al. 2014).
- VR training along with visual feedback, tactile feedback, and robot actuators can improve motor control with paraplegic patients (Donati et al. 2016).
- VR applications reduced operating room risks and surgery time by improving planning and organization (Pelargos et al. 2017).
- 3D VR can increase immersion, usability, amazement, and excitability in users; however, it can also lead to increased nausea (Hupont et al. 2015).
- Individuals consider the use of a head-mounted display more socially acceptable if the device is being used to support a person with a disability (Profita et al. 2016).
- VR can lead to higher levels of presence and involvement in the instruction of computer graphics for engineering and architecture courses (Moreira et al. 2016) and with airplane simulations (North and North 2016).

- IVR can be more effective compared to other forms of instruction due to the ability to engage multiple senses (Webster 2016).

In sum, there are research studies that demonstrate positive outcomes of using IVR in PreK-12 education. There are also a variety of studies outside PreK-12 that provide convincing evidence of the need to continue to explore new IVR applications for teaching and learning. However, it is critical to return to the point that simply integrating IVR into PreK-12 experiences does not translate into automatic gains. There are conditions under which these positive outcomes have occurred. Unfortunately, many IVR applications are implemented blindly and without a clear focus (Karutz and Bailenson 2015). Additionally, accessibility and usability are still barriers to successful implementation (Riva and Wiederhold 2015).

IVR Development Tools for K-12 Integration

Due to its relative novelty, IVR development tools are still emerging. There is also a mild danger in listing specific tools as innovations are introduced and/or disappear daily. However, there is value in at least describing some current tools so that educators and developers may begin to explore personal, curricular, and research-based implementations of VR in K-12 teaching and learning. This list includes but is not limited to:

- *StorySpheres* (https://www.storyspheres.com/) facilitates embodied storytelling by allowing users to add audio content to 360° sphere images.
- *InstaVR* (http://www.instavr.co/) supports the creation of IVR content and experiences for the most popular headsets; it includes an intuitive authoring interface.
- *Viar360* (https://www.viar360.com/) is an online platform for editing immersive stories by including interactive hotspots in 360° videos.
- *Wonda VR* (http://www.wondavr.com/) shows similar features as other VR tools with triggering mechanics, multiple paths and timelines, and an accessible drag-and-drop interface.
- EON Reality provides a development suite for educational experiences in IVR (https://www.eonreality.com/applications/augmented-virtual-reality-education/) spanning instructional games and hyper-detailed simulations.

There is also a possibility of using free (for noncommercial use) game engine tools like *Unity3D* and *Unreal Engine*, which embed several add-ons and tutorials for developing IVR environments (e.g., https://unity3d.com/learn/tutorials/s/virtual-reality). These require advanced technical skills; however, their flexibility and potential seem limitless. There are also guidelines, tutorials, and materials available online.

Conclusion

The first goal of this chapter was to further define immersive virtual environments (IVE) and then explicate examples of IVE: immersive virtual reality (IVR). (A companion chapter in this section focuses on augmented reality.) The second goal was to conduct a literature review on the topic to determine what the field knows and what researchers still need to learn – particularly about implementation into K-12 settings.

Most of the research on IVR is in higher education or outside of education with examples like rehabilitation, exposure therapy, and simulation training (e.g., Flores-Arredondo and Assad-Kottner 2015). The consensus among most researchers is that IVR will have more potential pedagogical exploration (and potential value) now that prices of technology are decreasing and the availability of resources is increasing. There is significant research on both fidelity and presence and how they impact the user experience of immersion. From a practitioner's perspective, there are a limited number of articles on how IVR can be successfully implemented into PreK-12 settings. Research is clear that implementation as stand-alone activities has not been as successful as using IVR as a supplement to other learning strategies.

There are several opportunities for future research and practice within IVE for IVR:

1. *Researchers need to explore accessibility in IVR*. Theoretical and empirical articles for IVE related to accessibility are very limited. This form of research should explore accessibility both as a delivery mechanism (e.g., who has access and can use it) and as a topic of exploration (e.g., can IVR serve those with disabilities?). Future applications could explore individualization, integration, and navigation through space and with various interfaces.
2. *Researchers and practitioners need to further explore how to educate teachers and students in the use of IVE for learning*. There has not been a significant amount of research on preparing PreK-12 instructors in the use of IVR or AR. The same is true for students (for an exception, see Wei et al. 2015). The latter is disconcerting; faculty and teachers often assume that because students have access to tools, they automatically know how to use them for learning.
3. *The field needs more pedagogical reflection*. Much research has been devoted to the hardware and software aspects of IVR. From a practitioner's perspective, there needs to be more models of how IVR can be successfully implemented into PreK-12 settings (O'Shea and Elliott 2016; Radu et al. 2016). This is particularly true for content that has yet to be explored (e.g., a majority of the work has been on science or in informal settings like museums and parks).
4. *Researchers should explore further notions of embodied cognition* (Gallagher and Lindgren 2015). At its core and in relation to this context, embedded cognition is the notion that a learner uses body and sensory involvement as a cornerstone to interaction with content (e.g., Shayan et al. 2015). The relationship between cognition and haptics is thus worthy of continued exploration.

5. *Researchers and practitioners should further explore concepts like computational thinking, spatial reasoning, and situational/individual interest*. A significant amount of the existing empirical research in IVR has explored content acquisition or concept change in areas like motivation and perception. Although how students perceive or are motivated because of IVE is interesting, there are deeper psychological and pedagogical concepts worthy of exploration (e.g., computational thinking and spatial reasoning). One of the challenges facing IVE is the novelty effect. Researchers and developer will need to explore how they can capitalize on this situational interest – a "focused attention and the affective reaction that is triggered in the moment by environmental stimuli, which may or may not last over time" (Hidi and Renninger 2006, p. 113). Research could help practitioners and developers understand how to help students move from situational interest to individual interest (Chen et al. 2016) before the novelty wears off.
6. *The field needs a deeper understanding of big data and the relationship to the quantified self (or self-tracking)* (Neff and Nafus 2016). Engagement with IVE tools will undoubtedly create more data. How researchers and practitioners can get access to this data will be critical. Given the relationship between mobile devices and AR, there will likely be new opportunities for users to monitor themselves in real environments. Helping users become aware of the data they are creating (or co-creating) will be an important pedagogical accomplishment.
7. *Researchers need to further explore the negatives of IVE*. No technology is perfect; no educational technology creates perfect learning environments or solely positive outcomes. As with any new innovation, most of the early adopters have focused on the promise and potential of such tools. Although these advocates need to be commended, the field also needs research to understand the short-term and longitudinal positive *and* negative effects of using IVE. Early indicators suggest that physical outcomes (e.g., nausea) and cognitive overload may be risk considerations. There are also concerns about the potential negative instructional aspects that could be exponentially increased by developers and pedagogues who wish to implement IVE simply because it is the latest cool tool.

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Educational Opportunities for Augmented Reality

64

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Contents

Abstract

This chapter provides an overview of immersive virtual environments (IVEs) in education with an emphasis on augmented reality (AR). A related Chap. 63, "Educational Opportunities for Immersive Virtual Reality" focuses on the other main branch of IVE. The chapter begins with an attempt to clarify and define terms. Then, a review of research is presented for AR that highlights the current and potential impact in PreK-12, higher education, and professional development settings. Findings suggest that use of AR can lead to increased engagement. However, the synthesis also points mostly to theoretical argumentation for AR's PreK-12 implementation.

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Augmented reality · Holograms · Immersive virtual environments · Informal learning · Mobile learning

Introduction

The purpose of this chapter is to examine a specific type of immersive virtual environment (IVE) known as augmented reality. A full explanation of IVE as well as a discussion of the other type of IVE – immersive virtual reality – can be found in a companion ▶ Chap. 63, "Educational Opportunities for Immersive Virtual Reality" (Ferdig et al.). The chapter begins by providing concise definitions. It then summarizes existing educational research on augmented reality. The chapter concludes with a call for more research in how AR can be used to support learning in PreK-12 education.

Defining *Augmented Reality*

A critical first step in exploring and discussing augmented reality research is to further define the concept of *augmented reality.*

Augmented reality (AR). One type of immersive virtual environment is called *augmented reality.* AR can be defined as computer-mediated scaffolding of a real environment. Freina and Ott (2015) proposed that AR provides a view of a physical, real-world environment whose elements are integrated with computer-generated sensory input. Persefoni and Tsinakos (2015) suggested that AR lets one experience the world with virtual objects without losing a sense of reality.

AR is often delivered by headsets (e.g., *Microsoft HoloLens*) or through mobile applications (e.g., *Pokemon Go*), although it could also be delivered in situ (see Gallagher and Lindgren 2015). Mobile delivery of AR has gained popularity because of the geolocation abilities of smartphones as well as the ubiquity of cellular devices across socioeconomic status, gender, race, ethnicity, and age.

An interesting question for AR is to further define what is getting augmented. In some situations, this could be a context. For instance, a device can help you learn more information through location tags, images, sounds, videos, and other content over existing landscapes like parks, playgrounds, streets, and classrooms. AR can also be used to augment objects such as books, trees, or even medical equipment. Functions of AR include visualization (e.g., seeing inside the human body), supplementing information (e.g., seeing medical charts next to a person), transformation (e.g., seeing what an object or place looked like historical or will look like in the future), or creation (e.g., adding additional information like trees or houses to existing environments). These additional augmentations can be static, dynamic, or even interactive (Cuendet et al. 2013).

Arth et al. (2015) provided a detailed and evolutionary perspective on the development and implementation of AR. A brief timeline of key historical events includes (see http://www.augment.com/blog/infographic-lengthy-history-augmented-reality/):

- 1990 – The concept of AR was created in 1990 by Tom Caudell, a Boeing researcher.
- 1992 – Virtual fixtures (i.e., an overlaid virtual layer on a real one) were invented by Louis Rosenberg. This technology had a significant impact on AR development.
- 1994 – The first AR theatrical dance, Dancing In Cyberspace, was staged by Julie Martin (real performers danced among virtual objects).
- 1999 – The NASA X-38 spacecraft was developed with the hue-saturation-value (HSV) system, which used the AR Battlefield Augmented Reality System developed by the American Government with the intent to harness AR on the battlefield.
- 2000 – The open source ARToolKit was created (https://artoolkit.org/) allowing the development of AR applications from the bottom.
- 2013 – The Volkswagen Mobile Augmented Reality Technical Assistance (MARTA) app was published highlighting the commercial potential of AR.
- 2014 – Google Glass for consumers was made available, and Magic Leap technology was announced.
- 2016 – Pokémon Go/HoloLens developer licenses were released.

There are a number of educational tools related to AR. For instance, *ARToolKit* (http://artoolkit.org) includes tracking libraries for developing AR applications (further details follow below). *AR Sandbox* (https://www.nps.gov/lavo/learn/news/ar-sandbox.htm) is an augmented sandbox at the Lassen Volcanic National Park that makes visible and interactives concepts related to topography and watersheds. With the app *AR-Calgary Zoo* (https://www.calgaryzoo.com/events-activities/special-events/dinosaurs-alive/prehistoric-park-augmented-reality-experience), the Calgary Zoo allows its visitors to see animated dinosaurs in specific locations through their mobile camera. *Eco Mobile* http://ecolearn.gse.harvard.edu/ecoMOBILE/overview.php) is a mobile experience that supports science teaching outdoor. The Smithsonian National Museum (http://naturalhistory.si.edu/exhibits/bone-hall/) has added an AR layer to some of its collections. *Augthat* (http://augthat.com) facilitates the inclusion of AR content in classroom activities and lesson plans. The *Quiver* suite (http://www.quivervision.com/apps/quiver) targets young learners with AR activities that bring to life real drawings. Finally, *Agents of Discovery* (https://agentsofdiscovery.com) is a mobile educational platform that enriches real environments with science-related contents and missions.

AR vs. VR. There is a resulting question of the relationship between VR and AR and whether they overlap or if there are extreme or ideal conditions of either. Arguably an ideal virtual reality would be an environment that harnessed the empirical senses (e.g., touch, smell, sight, sound, balance, orientation, etc.) to create a situation where the user could not tell the difference between the virtuality and reality. An ideal augmented reality would be one where all senses are also employed but where the user cannot tell whether the object is real or augmented. Both these extremes are utopian, but innovations are increasingly pointing to them by covering more and more senses and patterns. Both point to the same result of delivering an empowered reality by improving normal experiences (according to several parameters and for various goals); both undertake different paths to get to that result (see Shayan et al. 2015; Karutz and Bailenson 2015; Gallagher and Lindgren 2015). Perhaps what separates them (for now) is the reality they are augmenting.

Milgram and Kishino (1994) highlighted this distinction as a continuum between the two extremes of physical environment and virtual environment. When a mediated environment is close to the former, we have an augmented reality; when the latter is in charge, an augmented virtuality takes place. Anything in between would be considered a mixed or blended reality. The reflection begs the question of whether one is augmenting reality or augmenting virtuality. It also asks researchers, educators, and developers to consider if time will eventually make these distinguishable immersive environments indistinguishable – or at least more blurred in their definitions.

A Brief Review of Simulation Research

IVEs (immersive virtual environments) are all simulations of one form or another, but not all simulations are IVEs. Such a distinction suggests that research on IVEs such as AR requires direct empirical research. However, it is worth beginning a review of the research by looking at simulations, as they set the stage for what we already know about using simulations more broadly.

Merchant et al. (2014) defined simulations as "interactive digital learning environments that imitate a real-life process or situation (. . .) [and] allow learners to test their hypotheses of the effects of input variables on the intended outcomes" (p. 30). Sitzmann (2011) further defined educational simulations as "instruction delivered via personal computer that immerses trainees in a decision-making exercise in an artificial environment in order to learn the consequences of their decisions" (p. 492).

Research has been conducted on the use of simulations both in and outside of PreK-12. Within K-12, D'Angelo et al. (2013) found that simulations can be positively used when learners are interacting with models. This is particularly true when those models are difficult to observe in real life. Merchant et al. (2014) completed a meta-analysis and found that simulations were useful when students were assessed immediately after the instruction. Simulations were also found to be more useful when integrated as practice sessions rather than stand-alone activities. Finally, Sitzmann (2011) discovered that gaming simulations increased post-training self-efficacy, declarative knowledge, procedural knowledge, and retention. The most positive outcomes occurred when students were actively involved, when students could access the simulations whenever they wanted, and when they supplemented learning rather than serving as stand-alone activities.

It is critical to note that the findings presented here and throughout this chapter do not set the stage for asking whether simulations or IVEs work or fail to work.

Research has already provided evidence that the more important question is to examine the conditions under whether these tools work (Ferdig 2006). In PreK-12 research, simulations worked under certain conditions; the same is true for the research on simulations outside of PreK-12. For instance, Alaker et al. (2016) found that VR simulations as a part of medical training supported laparoscopic surgery (e.g., shortened operation times). Chan et al. (2013) reviewed the literature for neurosurgery and came to the conclusion that as a curriculum supplement, simulations improved realism and training outcomes. Finally, Kincaid and Westerlund (2009) observed that simulations offered a safe environment for leaners. Simulations not only provided more frequent feedback and assessment, but they also helped instruction by improving cooperative skills and reducing human error. In sum, simulations do not always work, but there is substantial evidence that there can be positive outcomes when implemented carefully and in conjunction with other education efforts because they promote learning by doing, problem-solving activities, and alternative settings to inhabit.

A Review of Research on PreK-12 Augmented Reality (AR)

Similar to the research on IVR, there are a number of articles published that describe practical and empirical research projects on AR in teaching and learning environments (Wei et al. 2015; Clark and Clark 2016). For instance, within PreK-12, projects have been created to teach elementary students about geometry and spatial cognition (Radu et al. 2015). AR projects have also been developed to teach about wildlife conservation (Phipps et al. 2016), to teach science in informal environments (Zimmerman et al. 2015), and to explore the role of multiuser AR environments (Noor and Aras 2015). Outside of K-12, projects have been created to use Kinect to explore cultural heritage (Bostanci et al. 2015; Pacheco et al. 2014), to use AR to guide visitors in museums (Djebbari et al. 2014), to teach about parks and historic places (Gordon et al. 2016; Kelling and Kelling 2014; Martínez-Graña et al. 2016), and to help learners understand anatomy (Jamali et al. 2015).

There are also articles that simply describe the promise of AR in education. Gallagher and Lindgren (2015) stated that AR could be useful because it affords metaphor use and full body movement. Kidd and Crompton (2015) suggested that AR allows educators to create authentic and engaging environments that are rich and student-centered. They are some of the few authors who discuss concerns about accessibility and the potential of AR for disabilities research. Kysela and Štorková (2015) claimed that AR could make history and tourism instruction more engaging and situated. Persefoni and Tsinakos (2015) argued that the potential of this technology is promising due to visualization (what cannot be seen) and discovery (being pushed to explore). Wu et al. (2013) added that location-based AR could address the difference between formal and informal learning and therefore could provide ubiquitous, collaborative, and situated learning.

Finally, there have been several literature reviews completed that are directly related to the use of AR in education. Most recently, Akçayır and Akçayır (2017) found an increase in the number of AR studies in the last 4 years. They provided evidence that the biggest advantage of AR is enhancing learning achievement. However, challenges include usability and technical issues from connectivity problems in outdoor activities to accessibility of the user interface. Antonioli et al. (2014) also found promise for AR but noticed that most of the published work was related to student or teacher reactions and less about actual outcomes and dealing with challenges like cognitive load (see Dunleavy and Dede 2014). Bacca et al. (2014) highlighted AR implications for learning gains, motivation, interaction, and collaboration but raised concerns about superimposed information and users paying too much attention to virtual information.

Although there is value in reviewing these analyses, there is also insight that can be gleaned from looking directly at the studies to learn more about AR in PreK-12 education. For instance, a large percentage of the published research on AR in education has provided evidence of the importance and potential of using AR for science learning. For instance Techakosit and Wannapiroon (2015) directed an heuristic evaluation (n:9 experts) of an AR science laboratory finding that it significantly supported science literacy. Chang et al. (2013) examined socioscientific issues (SSI) and determined that AR could support student learning through presence, immediacy, and immersion; they also suggested that this may lead to more informed decision-making. Cheng and Tsai (2013) also explored science learning and advanced concepts like mental models, spatial cognition, situated cognition, and social constructivist learning which might be used to stage more effective interventions.

Fleck et al. (2015) used AR to support astronomy learning. Their research provided evidence that the combination of both real and virtual objects lowers abstraction levels of young learners. Furio et al. (2015) successfully adopted AR to improve motivation related to learning the water cycle (although learning outcomes were arguably the same). Huang et al. (2016) developed an AR-based botanic garden that successfully improved both learning outcomes and positive emotions related to learning about eco-discovery. This was a similar finding to Kamarainen et al. (2013) who improved learning and peer cooperation related to environmental issues. Echeverría et al. (2016) created an AR collaborative game about electrostatics and found positive outcomes in terms of engagement, usability, and knowledge.

Chiang et al. (2014a) focused on inquiry-based learning activities. Their AR experience was tested with 57 fourth graders, and results showed that the proposed approach is able to improve the students' learning achievements. Attention, confidence, and relevance were also perceived higher in comparison with the control group. Laine et al. (2016) demonstrated increased positive reception of science learning using context-aware games focused on storytelling. Finally, Lindgren et al. (2016) worked with immersive AR and reported significant increase in targeted comprehension due to the whole-body activity affordance of the interactive system.

Content growth wasn't limited to science learning; there were also research studies reporting improved performance in mathematics using AR. For instance, Sommerauer and Müller (2014) found that a mathematics AR exhibition is more effective than a non-AR one in terms of knowledge acquisition and retention tests.

Many of the empirical articles also addressed concept rather than solely content growth (Yilmaz 2016). For instance, Chen et al. (2015) found improved engagement with elementary students when using AR. Chiang et al. (2014) were able to provide evidence of knowledge construction behavior growth when harnessing AR. Cuendet et al. (2013) showed how AR could give teachers opportunities to more dynamically engage and be more flexible with students. Di Serio et al. (2013) used AR with middle-school students and showed increased motivation in comparison with traditional course lectures.

A Review of Research on Non-PreK-12 Augmented Reality (AR)

There are a number of other studies outside of PreK-12 that provide further evidence of the promise of AR in PreK-12. Studies have demonstrated that:

- AR can be used to improve students' laboratory skills while they build positive attitudes toward this type of environment (Akçayır et al. 2016).
- AR applications like *Pokémon Go* can increase physical activity and user health benefits and potentially reduce social withdrawal (Althoff et al. 2016; Tateno et al. 2016).
- AR-based tours can improve visitors' sense of place, their involvement, and their overall learning (Chang et al. 2015; Harley et al. 2016).
- AR experiences can affect user satisfaction and engagement with theme park settings, content, service, and overall quality (Jung et al. 2015).
- Google Glass as an example of an AR implementation can successfully help visitors connect with and learn about art (e.g., paintings; Leue et al. 2015).
- AR can support participation reinterpretation of public spaces (Liao and Humphreys 2015).
- Students positively perceive the use of AR in their learning (Martín-Gutiérrez et al. 2015).
- AR can support collaboration and teamwork while still keeping a strong sense of reality (Majorek and du Vall 2016).
- The use of AR can facilitate immersion and involvement in museum experiences (Mason 2016; Shirai et al. 2015).
- AR was found to increase integration and safety in situations where humans were interacting with robots (Michalos et al. 2016).

To summarize, there are a number of articles directly related to PreK-12 education that provide both theoretical and empirical support for the use of AR in education. As with IVR, access to hardware could be a potential constraint, particularly in lower socioeconomic status schools. There is a growing body of research evidence outside of PreK-12 that could positively impact both the implementation of AR in PreK-12 as well as future research in this area. The caveat to all of this research, however, is that this is not simply a case where implementation equates to learning outcomes. Not all AR experiences are positive. O'Shea and Elliott (2016) summarize:

> There are several causes for the relative lack of 'good' AR technologies for learning. As with most things in education, problems begin with lack of resources. (. . .). Another issue (. . .) is limited infrastructure within educational settings. (...) Also, the technology itself is still at a nascent level. (. . .) Perhaps the most difficult barrier to overcome, though, is the fact that most AR experience designers lack knowledge of learning pedagogies, methodologies and strategies. (pp. 106–107)

AR Development Tools

Despite its brief history, AR development tools are getting more and more popular, allowing educators to create and design their own AR applications and materials. The leading program is the previously mentioned open source *ARToolKit*, which is a software development kit (SDK) of tracking libraries that allow users to build AR applications by supporting different devices and technologies (e.g., real time AR, headsets). Released in 1999 and currently owned by DAQRI, *ARToolKit* is powerful but requires technical skills to be mastered. Other options include:

- *TaleBlazer*, which is a free online development platform (http://taleblazer.org) creating mobile location-based AR experiences. Developed at the Massachusetts Institute of Technology, this program is based on the creation of virtual agents that can be placed in a real environment's spots guiding and interacting with the user by displaying additional content, from videos and pictures to prompts and quizzes.
- *FreshAiR* (http://www.playfreshair.com/) is a mobile-oriented editor for adding an AR layer to real environments, from national parks to university campuses, by harnessing geolocation mechanisms. It is possible to create and include locations, media content, specific triggers, assessment items, and even roles within the augmented space. Therefore, chains of action and conditions can be designed personalizing and enriching the user experience.
- With *HP Aurasma* (https://www.aurasma.com/), users can upload whole assets and augmented elements (the so-called auras – images, videos, 3D creations, websites, animations) in their surroundings in relation with real objects, sharing and personalizing the exposition and collecting resulting data and analytics.

Regardless, it should be noted that given its relative infancy, this type of software constantly changes and evolves; therefore, researchers and educators should continue to monitor creation and development tools in order to maximize their efforts.

Conclusion

The first goal of this chapter was to further define and explore research within IVE: augmented reality (AR). The second goal was to conduct a literature review on the topic to determine what the field knows and what researchers still need to learn – particularly about implementation of AR into K-12 settings.

A majority of the research on AR in PreK-12 education is theoretical in nature (e.g., case studies, position papers, and project presentations). The existing empirical research focuses heavily on science education, "settings" research (e.g., parks, museums, etc.), and on user experience of perceptions and motivation. There has also been a recent surge of interest in how AR can support collaboration and teamwork. The amount of research that does exist may grow due in part to the popularity of mobile-based applications like *Pokémon Go* and tools such as *ARToolKit*.

According to these findings, some highlights can be outlined spanning future directions for research and instructional practice in PreK-12 education:

1. *Current research is significantly descriptive as its core* with an emphasis on validating researchers' products rather than deploying a more objective perspective. Broader, deeper, and more longitudinal studies are needed to expand the educational scope of AR. This could include comparing different applications and learning environments as well as exploring its use in varying subjects or with diverse populations.
2. *AR is not currently usable by everyone.* More efforts are required to inform accessibility and usability issues and concerns within AR experiences in education. Such a dimension may make a difference in instructional scaffolding and supporting students with special needs and specific learning styles and preferences. For instance, customization features may be a key criterion for future development
3. *Lack of pedagogical design.* Pedagogical explorations targeting AR are still somewhat rare; yet we know implementation requires awareness in terms of planning and preparation. Therefore, researchers and experts need to formulate proper professional development strategies for educators and practitioners embracing software selection and reference rubrics. This will support moving beyond the novelty effect of AR to support instruction and cognition (e.g., knowledge retention).
4. *AR content is usually harnessed – and not created – by educators*. This situation could lead to weakened educational potential in terms of learning outcomes and curriculum integration (see Merchant et al. 2014). Therefore, teachers should start to explore development tools (see an example list in this chapter) for shaping their own media experiences aligned with their instructional activities. Understandably, there is a risk in learning something that is constantly evolving and that is still characterized by a narrowed educational focus (several AR programs used in education do not have explicit instructional purposes).
5. *AR is not a perfect technology.* A clear focus on AR weaknesses should be explored and documented in order to help prevent implementation issues and frustrating experiences. For instance, using AR applications outdoor can entail connectivity problems and concrete risks for the learner (e.g., being aware of his/her surroundings). Moreover, AR in the classroom may foster distraction rather than engagement if not implemented properly.
6. *Holograms need to be deepened with a renovated focus on education*. Holograms are an exciting and potential crucial component of AR; their importance will

increase with devices such as *HoloLens* and *Magic Leap*. Therefore, their impact on instruction needs to be analyzed, from cognitive load measurement to engagement effects and emotional reactions. Further explorations can inform their role in collaborative tasks and formal (or informal) learning settings.

7. *The AR context needs to be sufficiently considered*. Despite AR having a broad range of application, the context of use represents a fundamental variable needed to maximize its educational potential (especially in informal learning). Designing effective AR applications depends on the interplay with the context itself, from environment traits (e.g., Where are the augmented objects placed and in relation with what?) to social dynamics (e.g., Is the student/user alone? Is the teacher with him/her? Are group activities planned?) However, it is still an overlooked aspect in several studies about this technology.

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Section XI

Issues and Challenges Related to Digital Equity

Section Introduction: Issues and Challenges Related to Digital Equity

65

Thérèse Laferrière and Paul Resta

Abstract

This section is devoted to digital equity, and its evolving nature. Seven chapters are included in this section. Considering IT as a potential agent to social inclusion, authors devote much attention to the issues, challenges, and strategies involved in moving toward digital equity. Ways in which teachers and teacher educators can pay attention to digital equity when using IT in education are identified.

Keywords

Information and communication technology · Digital divide · Learning environment · Social inclusion · Knowledge divide

The question as to whether the digital divide is decreasing or increasing is a matter of the point of view one takes. It depends on the object and approach of the researcher. For instance, Van Deursen (Communication Science) and Helsper (Economist) (2015) claimed they found a link between Internet usage and widening inequality. Meanwhile, from an educational perspective, Hohlfeld et al. (2017) have results suggesting that Florida schools have improved on several indicators related to the

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digital divide. Dolan (2016) looked at the evolving complexity of the digital divide. Efforts to reduce the digital divide gap are many and cover a large spectrum (e.g., using technology to support at-risk students' learning (Darling-Hammond et al. 2014); smart partnerships to increase equity in education (Leahy et al. 2016)).

In this section of the handbook, there is acknowledgement that digital equity does not escape the long-standing issues and challenges identified by equity research (e.g., gender, racial/ethnic, urban/rural, social class, learning disabilities). But instead of arguing that IT widens the gap between sexes, economic groups, ethnic groups, and countries, the contributing authors consider IT as a potential agent for social inclusion. Therefore, they devote much attention to the issues, challenges, and strategies involved in moving toward digital equity and the ways in which teachers and teacher educators can pay attention to issues of equity when using IT in education.

There is also an acknowledgement that those who contribute toward digital equity face significant issues and challenges at the national, regional, and local levels. Level one issues regard access to the Internet and to digital technologies and resources. Level two issues pertain to the uses of IT in teaching and learning. Knowing that IT is playing an increasingly critical role in preparing a new generation of students with the knowledge and skills needed to be successful in a knowledge-based global society (OECD 2017), the co-editors of this section chose to give more visibility to the issues and challenges faced in the United States and Canada than they did in the previous edition of this handbook. The rationale is that those who are still concentrating their efforts on level one issues will have to face, sooner or later, level two issues and challenges. The chapters of this section are thus aimed at informing.

Bringing together recent developments, this section includes two updated chapters from the original 2008 handbook and five new chapters. The introductory ▶ Chap. 66, "Issues and Challenges Related to Digital Equity: An Overview," is updated by Resta and Laferrière. The five types of access, which delineated each of the five dimensions of digital equity identified in the first edition of this handbook, are updated with new research-based issues, challenges, and informed strategies. The chapter points to the new digital literacy demands placed on education systems while also continuing to underscore the challenges and need for basic literacy that allow individuals to access information and use IT to create value for their communities.

Warschauer and Xu, who wrote the ▶ Chap. 71, "Technology and Equity in Education," aim to create a broad picture of the relationship between technology and equity in primary and secondary education by summarizing research literature on socioeconomic status, racial/ethnic, and gender differences related to technology. Technology access, use, and outcomes are considered. They stress, however, that the differences in access and usage that affect the disparities in outcomes remain inconclusive.

Penuel and DiGiacomo point to relational equity in ▶ Chap. 70, "Organizing Learning Environments for Relational Equity in New Digital Media." They define "organizing for equity" as the act of attending both to the distribution of access to digital tools and opportunities to learn about and with them, as well as to the advantages such access and opportunity provide. Organizing for "relational equity" is about working to foster relations in which *all* participants' sensemaking is taken up and brought into joint activity in equally valued ways. The chapter identifies key principles for organizing learning environments that employ new digital media to promote relational equity and provides two examples of such environments.

With ▶ Chap. 72, "Advancing Equity Through Educational Technology: Promising Practices for Adoption, Integration, and Use in K-12," Zielezinski and Darling-Hammond focus on how digital tools can be used to support underserved and under-resourced students. They submit that with increased access to technology on the horizon, educators stand at a crossroads. These researchers put forward the following challenge: Do educators continue with the status quo or attempt to use the rising technology levels to support those students who need it the most?

▶ Chapter 69, "Learning Differences and Digital Equity in the Classroom," written by Treviranus, also addresses digital equity in the classroom for students with learning differences by attending to the role of technology in the provision of equitable education for the full diversity of students. The chapter points to the evolving opportunities and challenges that information technology in the classroom presents to students with learning differences and their teachers. It also highlights the benefits to all students of designing the classroom experience for students with learning differences.

Resta, Shonfeld, Yazbak Abu Ahmad, and Wallace are the co-authors of ▶ Chap. 67, "Information and Communication Technology Revitalizing Cultural Identity and Diversity." They propose that technology can be used to help revitalize cultural identity, language, and knowledge within marginalized groups. For instance, they exemplify how ICTs can be applied by indigenous peoples to strengthen and reinforce indigenous cultural identity, knowledge, and culture and to provide more culturally responsive learning resources and environments for their children. They include other examples and models from across the globe.

Finally there is ▶ Chap. 68, "A Sociocritical Perspective on the Integration of Digital Technology in Education, written by Ntebutse and Collin. They argue for the relevance of socio-critical perspectives on digital equity in education and put forward such a perspective on the integration of digital technologies in education, including foundations and research lines.

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Issues and Challenges Related to Digital Equity: An Overview

66

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Abstract

The chapter addresses two main concerns: Digital equity for social inclusion and digital equity in education. Five dimensions of digital equity are identified: (1) access to hardware, software, and connectivity to the Internet; (2) access to meaningful, high quality, and culturally relevant content in local languages; (3) access to creating, sharing, and exchanging digital content; (4) access to educators who know how to use digital tools and resources; and (5) access to high-quality research on the application of digital technologies to enhance learning. Issues, challenges, and informed strategies are pinpointed on the basis of what digital-divide and digital-equity research says.

Keywords

Social inclusion · Digital divide · Access · Digital tools and resources · Knowledge divide

Introduction

Digital equity is a highly challenging social justice goal. Stewart (2000) stressed that geographical, generational, cultural, and pedagogical issues and challenges combine to expand, or limit, school learners' participation in the determination of both individual and collective life chances. Physical access to devices is the first step in moving toward digital equity but, according to Gorski (2009), one that defines too narrowly the term digital divide. Referring to Light (2001), Gorski (2005) argued that a digital divide exists when a group's access to digital technologies and resources differs along one or more dimensions of social, economic, cultural, or national identity. In the first edition of this chapter, we adopted the following definition of the digital divide: "Situations in which there is a marked gap in access to or use of ICT devices" (Campbell 2001, p. 1). We retain it here while being aware that the meaning of the term keeps evolving.

In its 2015 resolution on the overall review of the outcomes of WSIS (The World Summit on the Information Society (WSIS) of the United Nations Educational Scientific and Cultural Organization (UNESCO) in Tunisia in 2005 stated: "*We underline* the importance of removing barriers to bridging the digital divide, particularly those that hinder the full achievement of the economic, social and cultural development of countries and the welfare of their people, in particular, in developing countries" (WSIS 2005, p. 1, article 10)), the United Nations General Assembly (2015) expressed five major concerns: (1) existing digital divides prevail and new divides emerge; (2) the ubiquitous use of ICT must be based on new levels of confidence and security; (3) the rights of individuals must be protected equally online and offline; (4) the progress brought in by ICT should be measured not only in economic terms but also in terms of the realization of human rights and freedoms; and (5) to serve as a development enabler, ICT must be grounded in ethical foundations. These concerns apply to many fields, including education.

In education, progress regarding physical access to digital technologies and resources (first-level divide) has revealed, as in other fields, second-level divides related to skill and usage patterns and production (The gap that separates the consumers of content on the Internet from the producers of content.) (Attewell 2001; Hargittai 2002; Solomon et al. 2003). Now third-level divides are surfacing, ones that will bring new challenges to those professional educators guided by the principle of equality of opportunity. According to Van Deursen and Helsper (2015), third-level divides are "disparities in the returns from Internet use within populations of users who exhibit broadly similar usage profiles and enjoy relatively autonomous and unfettered access to ICTs and the internet infrastructure" (p. 30). The authors report that their findings suggest that "the Internet remains more beneficial for those at the highest education levels, with higher social status, not in terms of how extensively they use the technology but in what they achieve as a result of this use for several important domains" (p. 46). Therefore, they claim they found a link between Internet usage and widening inequality.

Access to the digital infrastructure and technologies remains a challenging first-level issue for all countries. For instance, in the country that spends the most for student education, (In 2010, The United States spent more than $11,000 US dollars per elementary student and more than $12,000 US dollars per high school student. See http://www.cbsnews.com/news/us-education-spending-tops-global-list-study-shows/) 11.6 million students do not have the Internet access they need for digital learning (EducationSuperHighway 2017). Nonetheless, attention is, and must be, increasingly devoted to second-level divides. For instance, the National Education Technology Plan (US Department of Education, Office of Educational Technology 2016) emphasizes that digital use divide is the new challenge for teachers and learners. In its 2017 update, NETP articulates a vision of digital equity for reaching equity in learning.

This introductory chapter provides a conceptual framework for understanding issues and challenges related to digital equity. For Warschauer (2004), "digital solutions" do not come without consideration of the complex factors, resources, and interventions required to support social inclusion. Challenges and informed strategies related to each of five dimensions of the digital divide are identified. Issues and challenges are also discussed in detail within each of the seven chapters of this section.

Conceptual Framework

First and second-level digital divides set forth an alarming divide – the knowledge divide. Knowledge societies are becoming the aspiration of both Northern and Southern countries. Institutions and citizens are faced with an exponential growth in basic and applied knowledge: the world knowledge base doubles every 2–3 years, with similar growth trends in information on the Internet. With an increasing flow of information, national economies grow more internationalized. There is a social demand for higher levels of education as technology is reducing the need for many types of unskilled or low-skilled workers (Johal and Thirgood 2016). Digital labor is beginning to be studied for the design of better digital work experiences (Bucher and Fieseler 2016). The main assumption here is that the access and the use of the Internet and digital technologies are critical elements for individuals to participate and derive the benefits of a global knowledge society. Therefore, the conceptual framework that follows is built around two concerns: digital equity for social inclusion and digital equity in education.

Digital Equity for Social Inclusion

The growing efforts to move toward digital equity are fueled by the prospect that digital exclusion will add to social and economic exclusion of individual learners and citizens and, on the broader scene, whole populations. A requisite for participation in the global knowledge society is basic literacy. Literacy levels vary greatly across gender, nations, and the world (Fig. 1).

The fact that almost two-thirds of illiterates are women limits women's access to IT (UNESCO 2013). In the digital equity section of the 2008 edition of this handbook, a whole chapter was devoted to gender (Looker 2008). Another individual difference that impinges upon literacy and access to IT, even in developed countries with a high level of Internet penetration, is visual impairment and other disabilities. The visually

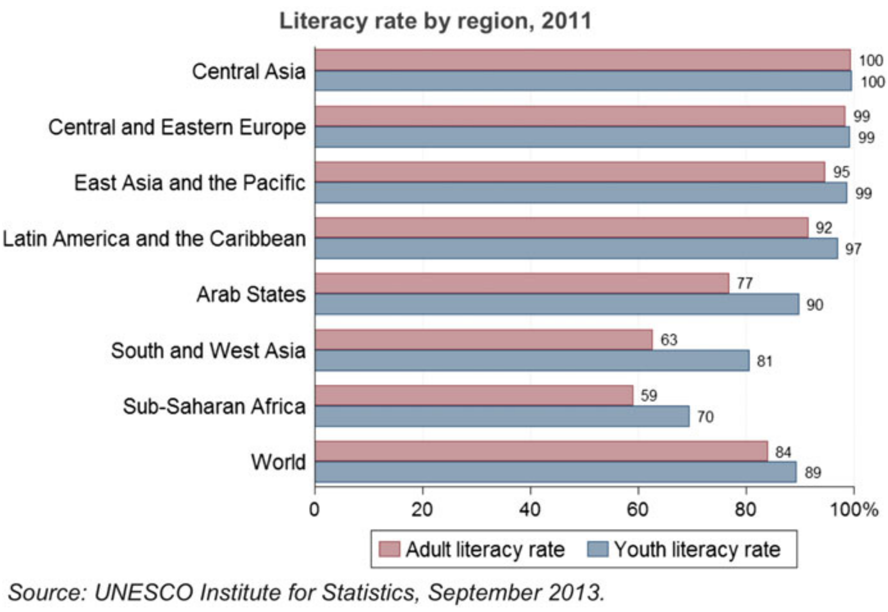

Fig. 1 Literacy rates by region and gender. UNESCO Institute for Statistics, Literacy data (2013). Available at http://uis.unesco.org/sites/default/files/documents/fs26-adult-and-youth-literacy-2013-en_1.pdf

impaired individual requires adaptive technology (Treviranus and Roberts 2008). In this second edition, Treviranus (► Chap. 69, "Learning Differences and Digital Equity in the Classroom") focuses on the needs of specific groups. Although the basic literacy or "print divide" remains an important issue in many parts of the world, the digital divide has become a growing concern in education, one based on the recognition of the strong relationship between education and socioeconomic development.

Digital Equity in Education

There are efforts being made throughout the world that attempt to put the potentials of IT in the service of education (Charania and Davis 2016; Gonzales-Perez 2014; Yuen et al. 2016). These efforts exemplify individual and/or collective emancipation (basic skills, twenty-first-century skills) through access to information or people, and to IT-supported content creation, including knowledge creation.

For such emancipation to occur, however, educators must understand that digital equity is more than access to computers and connectivity. The remaining of this chapter is structured around the following five dimensions of digital equity that we identified in the first edition of this handbook:

- Access to hardware, software, and connectivity to the Internet
- Access to meaningful, high quality, and culturally relevant content in local languages
- Access to creating, sharing, and exchanging digital content
- Access to educators who know how to use digital tools and resources
- Access to high-quality research on the application of digital technologies to enhance learning

Issues, Challenges, and Informed Strategies

This section presents issues, challenges, and informed strategies related to the five dimensions of digital equity.

Access to Hardware, Software, and Connectivity to the Internet

Issues

Internet providers are conscious of the value of their goods, and consumers want an affordable price, reliability of service, and speed. However, in the Southern hemisphere, there are great numbers of individuals who are disadvantaged. Geographical location matters a great deal when it comes to digital equity (Cleary et al. 2006). Although the Internet is spreading at a much faster rate than electricity, the latter is still missing in some rural areas of the world. The International Telecommunications Union (ITU 2003) states that the Internet infrastructure is now in place on all continents. According to Internet World Stats (June 2016), Asia has now half the number of Internet users (Fig. 2), and an Internet penetration level of 45.6% (Fig. 3). North America remains the region with the highest level (89%) of Internet penetration whereas Africa has the lowest (28.7%).

Looking at the distribution of people online worldwide (Fig. 4), one cannot help thinking that the digital equity goal is a far-reaching one. Contrary to radio, television, or print, computers are more complex, and this very factor keeps citizens from using them, including ones who are literate, wealthy, and living in the city.

Challenges

Cost. The cost of hardware, software, and connectivity to the Internet remains a continuous challenge. In developed countries, those connected to the Internet require increasing bandwidth for audio and/or video use. Exemplars of new limits reached are as follows:

- Internet connectivity is slow when students are asked to download a document at the beginning of a period.
- Early-adopter teachers less time than previously at the computer lab as more teachers are taking students to the computer lab.
- A suburban school in a wealthy city finds it difficult to keep up with the demand for bandwidth created by the 500 computers used by students during class time.
- A small student team from a remote rural school can hardly hear students from another school with whom they are doing a learning project because the latter students are part of a large school whose three computer labs take almost all of the available bandwidth.

Developing countries would be facing similar issues except that IT keeps improving. Leapfrog initiatives are expected as hardware costs are coming down (e.g., 25% per year in increased power and lowered costs), and wireless technologies are growing rapidly in number and range (e.g., WiMAX, Google's project LOON (https://x.company/loon/)).

Technology Leadership. "While many countries have broadband policies in place and many Ministries of Education have called for broadband in all schools, progress towards reaching these goals is irregular and difficult to track..." (Broadband Commission for Digital Development ITU and UNESCO 2013, p. 14) (See also Fig. 5).

The level of the ICT infrastructure was found to be the most probable predictor of technology-leadership profiles assumed by Turkish principals (Banoğlu et al. 2016). In their study, the authors refer to ISTE's (2009) five indicators of technology leadership: (1) visionary leadership, (2) digital-age learning culture, (3) excellence in professional practices, (4) systemic improvement, and (5) digital citizenship. Technology leadership is the key challenge on the part of educational administrators, including school principals or master teachers, even after the early stage of IT integration to teaching and learning (Dexter 2008).

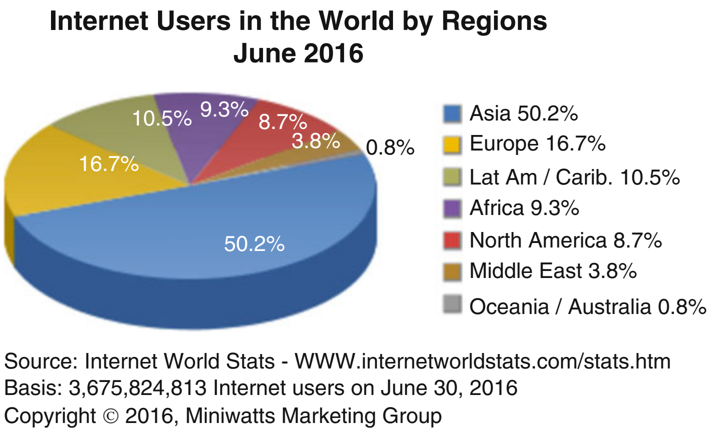

Fig. 2 Internet users by world region (World Internet Usage Statistics News and Population Stats, June 2016).

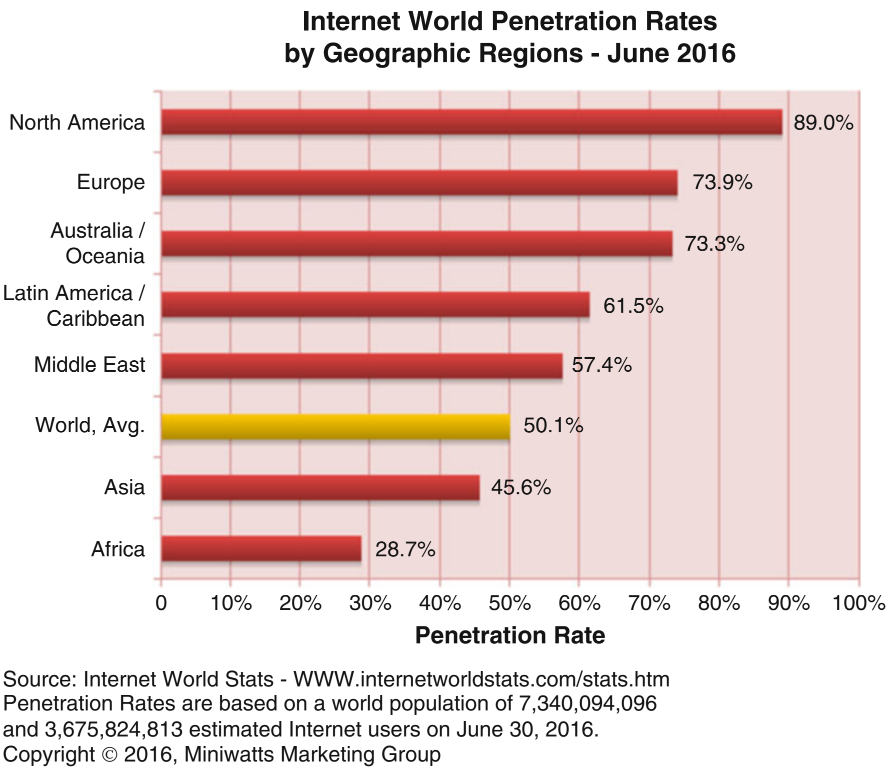

Fig. 3 Internet penetration (percent of population) by world region (World Internet Usage Statistics News and Population Stats, June 2016).

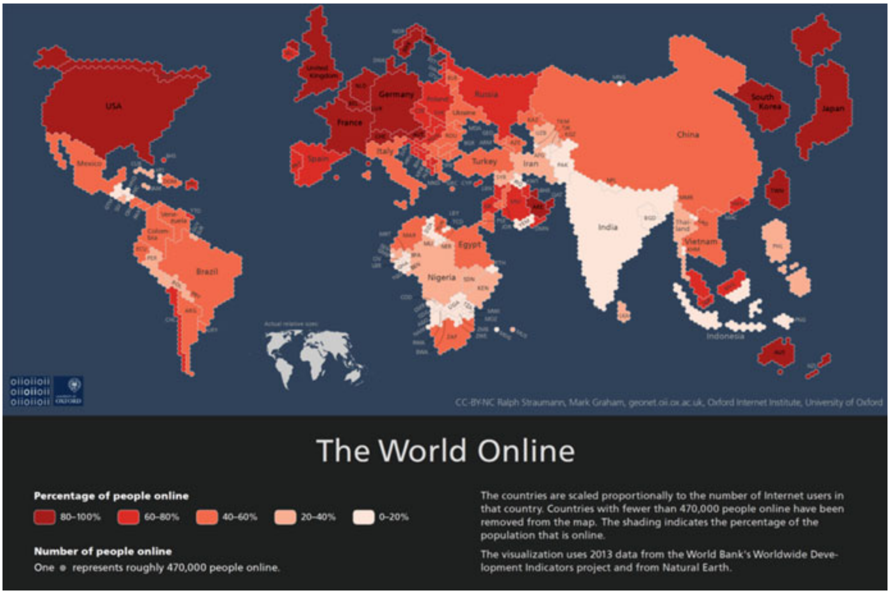

Fig. 4. Worldwide distribution of online people (Graham and Straumann 2015). Available at http://www.ox.ac.uk/news/2015-07-13-where-do-most-internet-users-live

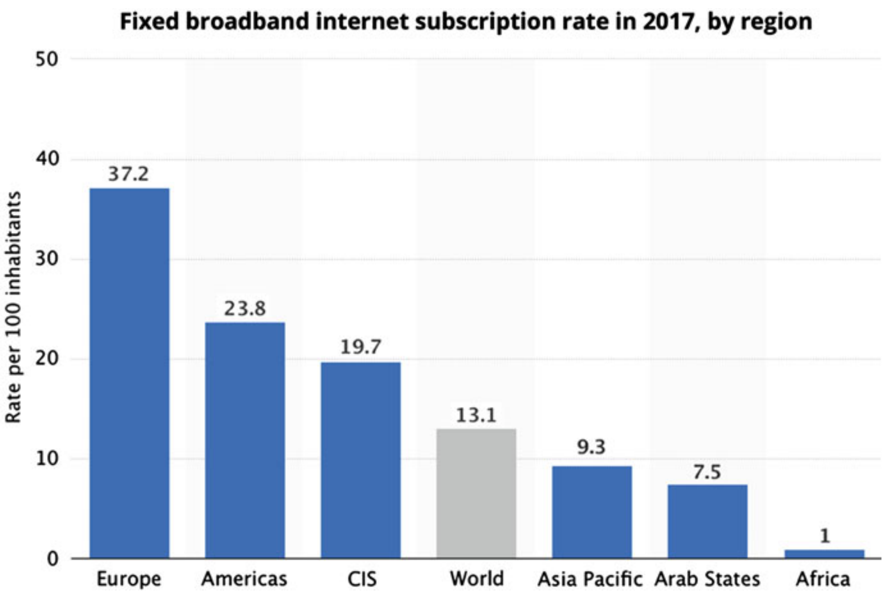

Fig. 5 Available at https://www.statista.com/statistics/370681/fixed-broadband-internet-penetration-region/

Informed Strategy

The societal passage from print to digital information is now well underway. Understanding the importance of broadband in education as part of a nation's strategy to prepare students with the twenty-first-century skills is key. ITU's, UNESCO's, and OECD's publications are remarkable sources of information for keeping oneself informed regarding global developments regarding digital technologies and bandwidth. While computers keep growing in interactive functionalities, countries can build capacity through dialogue and the development of partnerships between the governmental, educational, and the private sectors.

Access to Meaningful, High Quality, Culturally Relevant Content in Local Languages

Issues

The Declaration of Principles adopted at the World Summit on the Information Society (WSIS, Geneva, 2003, Article 1) highlighted "[the] common desire and commitment to build a people-centered, inclusive, and development-oriented Information Society, where everyone can create, access, utilize, and share information and knowledge." The impetus behind the Geneva Summit was the growing awareness of the digital divide. IT should be turned into "a digital opportunity for all" according to the Summit's Declaration of Principles and Plan of Action (UNESCO 2001). And Ronchi (2009) provided a broad overview of the issues of the e-culture and digital heritage (e.g., virtual museums issues and achievements, cataloging, digitizing, publishing, and sustainable exploitation of cultural content).

Although the Web offers vast resources that are of value to education and lifelong learning, which are increasing every day, it must be recognized that the quantity of information available on the Surface Web (i.e., what is normally considered the Web) is small compared to information on the Deep Web (i.e. resources stored in databases, and not in an HTML format). The Deep Web represents the part of the Internet (4% is often mentioned when one searches on the Surface Web) that is inaccessible to conventional search engines and, consequently, to most users on the Web. The content available in the Deep Web is over 500 times greater than what is available on the Surface Web, that is, the approximation referred to by Kumar and Mishra (2015, p. 137). They observe that the Deep Web is growing more rapidly than the Surface Web in all major sectors, including education. They argue for hidden data indexing, given the necessity for the public to access the Deep Web.

When one looks at the language of the users of the Internet today (Fig. 6), the dominance of the English language remains a major issue but the Chinese language is growing rapidly compared to all other languages on the Web. Web content in Chinese was only 3.9% in the first edition of this chapter. We stated: English has become the world's lingua franca through globalization.

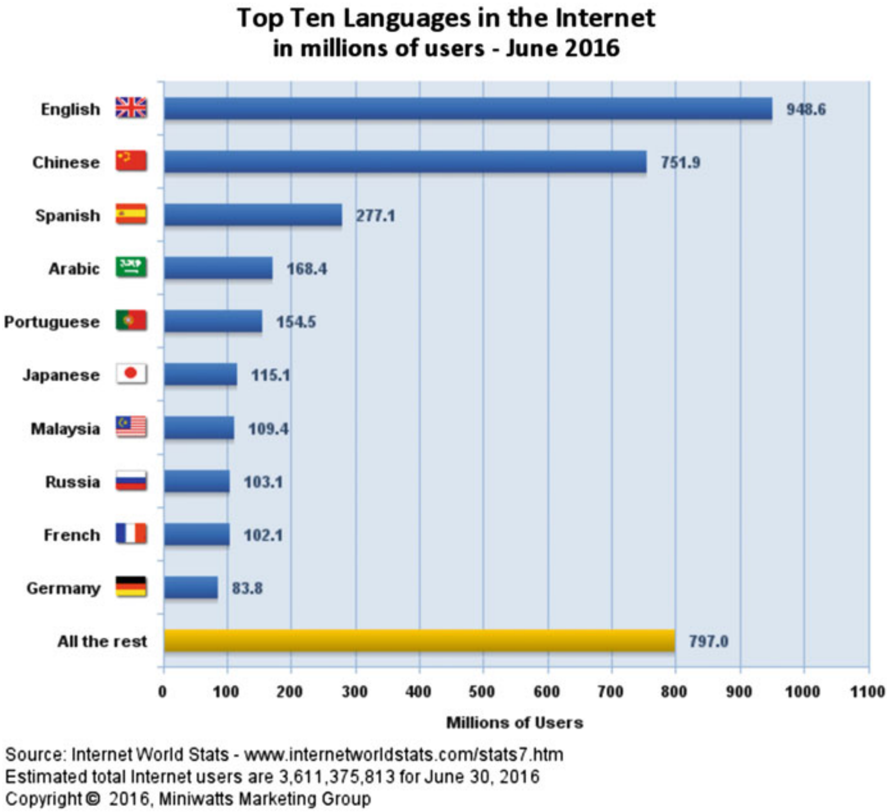

Fig. 6 Internet World Stats website, Miniwatts Marketing Group (2017). Available at: http://www.internetworldstats.com/stats7.htm

UNESCO has taken notice of the importance of access to content and promotes open Educational Resources (OERs) that are defined as follows:

> any educational resources (including curriculum maps, course materials, textbooks, streaming videos, multimedia applications, podcasts, and any other materials that have been designed for use in teaching and learning) that are openly available for use by educators and students, without an accompanying need to pay royalties or licence fees. (Commonwealth of Learning and UNESCO 2015, p. 5)

The Commonwealth of Learning and UNESCO (2015) identify four policy issues for making more effective sharing and use of OERs:

1. *Provision in policy of clarity on intellectual property and copyright* on works created during the course of employment (or study) and how these may be shared with and used by others.

2. *Human resource policy guidelines* regarding whether or not the creation of certain kinds of work (e.g., learning resources) constitutes part of the job description for staff and what the implications are for development, performance management, remuneration, and promotion purposes.
3. *ICT policy guidelines* regarding access to and use of appropriate software, hardware, the Internet and technical support, as well as provision for version control and back-up of any storage systems for an institution's educational resources.
4. *Materials development and quality assurance policy guidelines* to ensure appropriate selection, development, quality assurance, and copyright clearance of works that may be shared (pp. 16–17).

In an attempt to better understand educators' perceptions of collaborative OER development, Pirkkalainen et al. (2017) find that "emotional ownership" is a barrier to collaboration: "The stronger one's attachment to the ideas, the less unlikely one would engage in sharing or building new resources and related practices in a collaborative manner based on it. Thus, the educator becomes more hesitant to share that idea with others" (p. 127). Moreover, their findings also show that "increase in reputation and status in the network" does not seem to influence the intention to share knowledge. Emotional ownership becomes an enabler rather than a barrier "when working in a trusted environment with peers" (p. 129).

Challenge

Trust is key to collaboration, and the open online environment is both a place of opportunity and uncertainty for content producers. Cultural preservation and development through the creation of digital content in local languages, a major challenge confronting many countries across the globe, is enabled by affirmative culturally oriented actions such as declarations, conferences, and publications (e.g., International Symposium on the Measurement of Digital Cultural Products, Montreal 2016; Linked Heritage Cultural Digitisation Conference 2013; Ronchi 2009). There are also projects such as Europeana (http://antennalab.org/project-europeana-access-to-culture-and-heritage-in-the-digital-age/), the European SchoolNet (http://www.eun.org/), SchoolNetAfrica (http://196.1.95.39/schoolnet/english/index.htm), and the eGranary Digital Library (https://www.widernet.org/eGranary/) that are developing and/or providing access to high-quality educational content in local languages.

Informed Strategy

The use of open educational resources (e.g., open courseware initiatives, Carnegie Mellon Open Learning Initiative, MIT OCW, UNESCO), Creative Commons (some rights reserved), and open source software (e.g., Apache Open Office, G Suite (email, drive, group, etc.), GIMP, Nvu, Tux Paint, Open Source Initiative) for individual and community empowerment is the employed strategy. For instance, Native Americans have engaged in the digital repatriation of sacred or important artifacts that reside in national or regional museums. Indigenous communities are now able to use technology to develop educational resources and materials that reflect the language, culture, history, and resident knowledge of indigenous communities to help support culturally responsive teaching and learning in schools serving native children (Resta et al. 2004). The Broadband Commission for Digital Development ITU and UNESCO (2013) recommends the use of OERs to "accelerate free access to knowledge and facilitate the adaptation of content to local needs and languages" (p. 10).

Access to Creating, Sharing, and Exchanging Digital Content

Issues

The Geneva Declaration of Principles, which was adopted at the World Summit on the Information Society (WSIS 2003, p. 1), foresaw "an [...] Information Society, where everyone can create, access, utilize and share information and knowledge." The rapid growth of digital libraries and repositories is not without issues and challenges related to access to content but here the emphasis is on access to content creation opportunities. We understand the above quote from the Geneva Declaration to be an incentive toward the democratization of content creation, one to engage school learners through collaborative ventures and the recognition of students' voices, and ability to learn, create, and disseminate under the guidance of their teachers.

UNESCO (2011) promoted three teacher competencies – technology literacy, knowledge deepening, and knowledge creation. They are all necessary for content creation. The knowledge-building principles put forward by Scardamalia (2002) include one on the democratization of knowledge, meaning that primary and secondary school students are to be considered capable of knowledge creation. This is an advanced form of participation that may be exercised during both primary and secondary education. Robles Morales et al. (2016) address the relationship between digital participation and the digital participation divide: "The first concept refers to the use of the Internet to produce cultural goods that are subsequently shared on a global scale; the latter, refers to the inequalities generated by the uneven distribution of these creative uses of the Internet in a given population" (p. 97).

Challenge

This knowledge-building approach (Scardamalia and Bereiter 2006) has implications for education, culture, and democracy. It requires trust in school learners' capacity to produce content of value for their classroom-based knowledge building community. It also requires a less normative approach to the digital equity problem, one that takes advantage of local circumstances and expertise to make contributions to one's community and to other networked communities. The Knowledge Society Network (http://ikit.org/ksn.html) provides numerous exemplars of knowledge creation through the use of the same suite of digital tools.

Informed Strategy

The democratization of knowledge must be pursued at both ends, that is, both in access to knowledge and access to opportunities to create knowledge. Web 2.0

applications and user-created content are more available than they were in 2008. Both teachers and students have the right to produce as well as reproduce knowledge. In areas where there is a lack of content in local languages, teachers, teacher educators, elders, and students may use IT tools to create content that reflects their culture and resident knowledge. A global problem is a growing loss of local languages. Although media and technology have largely contributed to the loss of local languages, they may also be used to help preserve them. During the Four Directions Project, back in the nineties, a number of indigenous communities had very few fluent speakers of the native language. Teams of teachers, students, and elders worked together using digital technologies to develop audio recordings of the elders and to develop associated books and other materials to help students learn their native language. To be aware that social skills, as well as sociopolitical attitudes, may prevent the digital participation divide (Robles Morales et al. 2016) is part of the strategy we suggest.

Access to Educators Who Know How to Use Digital Tools and Resources

Issues

The relevance of IT to teaching and learning has been argued from the perspective of twenty-first-century skills, and now assessment methods and tools are unfolding (e.g., Griffin and Care 2015; OECD 2017). Innovation in teaching refers to new modes of delivery (e.g., learning object repositories), including online courses (see http://opentraining.unesco-ci.org), new approaches to learning (e.g., Bransford et al. 1999), and new pedagogies (OECD 2015). When education systems plan to innovate through the use of digital tools and resources for teaching and learning, they face the issue of teacher development. They can rely on a minority of innovative teacher educators and teachers willing to take risks (see Cuban 2001). The US National Education Technology Plan (US Department of Education, Office of Educational Technology, 2016) stresses the "digital use divide" that is now prevailing. Rather than recognize the immense potential to do things differently, teachers often use technology in accordance with old instructional practices, doing the same thing as before, but a little more quickly, a little more frequently, or a little better. Teachers who are transforming their primary or secondary classrooms into blended learning environments by combining onsite and online learning activities – the "flipped classroom" is the buzzword – are beginning to see it as "the new normal." To expand beyond this group, however, continues to pose significant challenges (Cuban 2001; Selwyn 2013) and stresses the need for leadership and administrative, collegial, and pedagogical support.

Challenge

IT partnerships that include universities, schools, and sometimes governmental agencies are challenging but instrumental for capacity building in the use of digital tools and resources: see, for instance, Lating's (2006) study on hybrid e-learning for rural secondary schools in Uganda. Partners face coordination and collaboration challenges. Passey et al. (2016) argue that third-party providers have to better ground their initiatives in local education systems to face the sustainability challenge of innovation with digital technologies.

Informed Strategy

In many instances, teachers are not able to realize the full potential of information and communication technologies to enhance the teaching–learning process because of lack of comfort and competency in using the new tools for learning. Thus, to achieve digital equity requires the provision of high quality and sustained professional development for teachers. This may be accomplished in a number of ways such as providing online learning and professional development resources for teachers and building online and onsite communities of practice (see Looi et al. 2008; Turcsányi-Szabó 2008), including for preservice teachers (De Neve and Devos 2017; Hall 2017). Another strategy would be to network teachers such as in eTwinning, a European-wide teacher network that has become "an incubator for pedagogical innovation in the use of Information and Communication Technologies (ICT) for cross-border school collaboration and for formal and informal teacher professional development" (Vuorikari et al. 2015).

Access to High-Quality Research on the Application of Digital Technologies to Enhance Learning

Issues

Effective uses of digital technologies to enhance learning are what governments, school principals, teachers, and parents want to see for evidenced-based decision regarding IT. High-quality research is often considered to include quantitative studies involving large numbers of participants, prepost testing associated with short-term experimentation, and a control group (gold standard research). Even such research, however, may be misleading. For instance, Archer et al. (2014) reassessed inconsistent outcomes presented in three previous meta-analyses, and found that training and support were mediating factors. They suggested that "researchers include implementation factors such as training and support, when considering the relative effectiveness of ICT interventions" (p. 140).

There is also an emerging trend toward ethnographic studies involving in-depth observation and/or analysis of a small number of subjects. The so-called gold standard research provides descriptive low-end information on what is being applied on a large-scale basis whereas the latter provides higher-end but small-scale information growing out of detailed observations or interviews with limited generalizability. Both types of research have value provided they are done according to the highest standards of rigor for both types of research.

Challenge

Innovation requires both the use of well-established research approaches as well as the development of new research strategies to better understand the complex environments and interactions in learning with the new digital technologies. Design research (Collins et al. 2004; McKenney and Reeves 2012) is especially conceived to these ends. The process is collaborative (university-based researchers and classroom-based teachers); it takes context into account and reinvests in the next iteration lessons learned as well as questions arising from the preceding iteration. Research is still needed for monitoring level 1 divide issues and challenges (access to Internet and digital tools and resources – Pittman et al. 2008), level 2 divide issues and challenges (uses of digital tools and resources; barriers and enablers of personalized learning or collaborative practices; learning outcomes as innovative practices are put into place – Terry et al. 2016), and level 3 divide issues and challenges (extended access to families, support services and communities of practice – Katz and Levine 2015; advantages of alternate certifications for students – Collins and Pea 2011; collateral benefits of being online – Van Deursen and Helsper 2017).

Informed Strategy

In places where the digital divide is the most pronounced, there is typically also a lack of access to high-quality research. One strategy for fostering research in these settings is through the creation of networked communities inclusive of experts, competent teachers, beginning, and prospective teachers (Hall 2017). This may also involve multi-institution collaborations to support innovative and enduring onsite/online experimentation with digital technologies (see Laferrière et al. 2015).

Conclusion

This introductory chapter provides an overview of the global challenge of the digital divide and the critical strategies that must be addressed to move toward digital equity. The major issues and challenges also appear and are discussed within specific contexts in each of the following chapters. In a rapidly changing, technology-based, and knowledge-based global economy, it is important to understand where we are now and how far we have to go to reach the WSIS goals of a global information society. As daunting as the task may be, the effects of doing little or nothing to move toward digital equity can only result in the greater social and economic exclusion of people and greater instability across the globe.

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Information and Communication Technology Revitalizing Cultural Identity and Diversity

67

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Abstract

Technology may be used to help revitalize cultural identity, language, and knowledge within marginalized groups. This chapter demonstrates how ICTs can be applied by indigenous peoples to strengthen and reinforce indigenous cultural identity, knowledge, and culture and to provide more culturally responsive learning resources and environments for their children. It includes examples and models across the globe that illustrate the ways that ICTs can be used as a tool to strengthen cultures and to foster understanding and respect for cultural differences and our common humanity. Governments are encouraged to work with universities and indigenous organizations to engage in similar initiatives and to establish policy structures that will enable indigenous peoples, and other unique cultural communities to work in partnership with ministries of education and universities, to provide culturally responsive learning opportunities for their children through the use of ICTs.

Keywords

Digital equity · Cultural diversity · Cultural identity · Indigenous knowledge · Indigenous identity · Cultural practices · Cross-Cultural understanding · Grandma stories

Introduction

This chapter focuses on the ways that technology may be used to help revitalize cultural identity, language, and knowledge within marginalized groups. This is as opposed to the thought that information and communication technology (ICT) leads to globalization and destroys cultural identity. Each of the initiatives described in this chapter offers evidence of the powerful ways that ICTs are being used across the globe to strengthen cultures and to foster understanding and respect for cultural differences and our common humanity.

Cultural Identity and Diversity

In an effort to understand the impact of ICT on cultural identity and diversity, we need to look at the meaning of these terms. Culture is defined as “institutions, communications, values, religions, genders, sexual orientations, disabilities, thinking, artistic expressions, and social and interpersonal relationships” (Baruth and Manning 2012). Cultural identity refers to a person’s sense of belonging to a particular culture or group. This process involves learning about and accepting traditions, heritage, language, religion, ancestry, aesthetics, thinking patterns, and social structures of a culture. As noted by UNESCO, “The current era of globalization, with its unprecedented acceleration and intensification in the global flows of capital, labor, and information, is having a homogenizing influence on local culture.

While this phenomenon promotes the integration of societies and has provided millions of people with new opportunities, it may also bring with it a loss of uniqueness of local culture, which in turn can lead to loss of identity, exclusion and even conflict. This is especially true for traditional societies and communities, which are exposed to rapid 'modernization' based on models imported from outside and not adapted to their context" (UNESCO 2017).

There is also concern about the ways that globalization contributes to the growing loss of cultural diversity. Cultural diversity encompasses the numerous cultural characteristics embraced by an individual as well as by a collective body. Cultural diversity has been defined as "the array of differences among groups of people with definable and unique cultural backgrounds" (Diller 2015).

Diversity is defined as "the condition of having or being composed of differing elements" (n.d.). Cultural diversity is complex because culture is not fixed and is constantly developing. Victor Frankl said, "When we are no longer able to change a situation, we are challenged to change ourselves" (Frankl 1942). Historical events and migration are just a few factors that have served as the impetus for change. The evolutionary nature of culture in the world is often a source of conflict within and among cultures sharing the same space and resources, which is due in part to the presence of subcultures that arise as change occurs. For example, the United States, as a whole, shares an American culture, which expresses freedom, equality, and entrepreneurial spirit as shared values of all persons residing in the country. However, there are subcultures within the United States that demonstrate behaviors, values, and beliefs, which are distinctly different from the dominant culture. Individuals identifying with the subcultures share common experiences, history, religion, regional affiliation, economic status, and values that may not appear in the dominant culture (Baruth and Manning 2012; Diller 2015). For example, first and second generation Asian Americans may embrace the dominant culture's entrepreneurial spirit but hold fast to the ceremonial customs for marriage and religion derived from their homelands. Cultural diversity enables us an opportunity to see the world through the multiple lenses provided by the uniquely different individual surrounding us.

ICTs and the Erosion of Culture Identity

Globalization has contributed to erosion of cultural identity and nowhere is the effect most evident as among indigenous peoples across the globe. As is the case for all people, technology has often had unforeseen and unwanted consequences. ICTs may be used to reinforce and accelerate the dominance of Western-based modes of thought, culture, and learning strategies. Media such as television, radio, films, and computer games have resulted in massive and continuous exposure of many indigenous youth to non-indigenous cultural values and information with few opportunities for reinforcement of their own cultural identity, heritage, and language. As a result, "After hundreds or thousands of years of development and evolution, we are facing the disappearance of unique human cultures and their intellectual heritages." According to UNESCO Atlas of the World's Languages in Danger (UNESCO 2016), there are approximately 3000 endangered languages across the globe. The loss of language contributes to the loss of cultural world views, knowledge, and identity (UNESCO 2017; United Nations 2007). It is estimated that approximately 600 languages have disappeared in the last century and they continue to disappear at the rate of one language every 2 weeks. Up to 90% of the world's languages are likely to disappear before the end of this century if current trends are allowed to continue (UNESCO 2017).

Television has also directly contributed to many societal ills of indigenous peoples including loss of indigenous cultural identity, lack of community involvement, disrespect toward others, violence, and obesity. It has also interfered with or replaced traditions that are held as sacred in Indigenous cultures. In addition, it has contributed to negative portrayals and images of indigenous peoples, further leading to their degradation and exclusion within the larger society (Mander 1991).

Elders are concerned that their children are losing ability in oral traditions and songs. They are concerned that ICTs can alter verbal communication and memory constructs while failing to build memory skills that indigenous peoples need to learn songs and dances about their culture (Leuthold 1999).

The Use of ICTS to Revitalize Indigenous Cultural Identity and Knowledge

There are examples of the ways ICTs, when appropriate and under the control of indigenous peoples, can be supportive of their language and cultural identity while also opening new doors and career opportunities through the development of ICT skills and knowledge. ICTs can also be used to extend learning opportunities to indigenous students who live in remote and isolated areas. The following are a few examples of the ways ICTs may be used in culturally responsive ways.

Examples of Ways ICTs Can Support Indigenous Identity and Cultural Diversity

There are many models across the globe that show how ICTs can be applied by indigenous peoples to strengthen and reinforce indigenous cultural identity, knowledge, and culture and provide more culturally responsive learning resources and environments for their children. A few examples include as follows.

The Four Directions Project: An Indigenous Model – United States

The Four Directions project involved 19 schools serving indigenous children in all parts of the United States. It demonstrates the benefits of indigenous communities partnering with private and public universities and other organizations to explore ways ICTs can be used to help develop culturally responsive curriculum. Features of this program included:

- Restructuring curricula to incorporate local cultures and values
- A strong school-home and school-community focus
- Collaborating across sites through on-site training, online tutoring, and cooperative teaming
- Creating networked “virtual communities” of indigenous teachers and students
- Encouraging life-long learning by extending technology support to communities surrounding project schools
- Maintaining a network database of culturally appropriate teaching, assessment, professional development, and student-created resources

As the core of this project, each school developed an advisory team consisting of students, parents, teachers, paraprofessionals, elders, and other community members. The teams developed authentic learning tasks that were relevant to students and drawn from the unique cultural context of each indigenous community. These tasks were then developed into “thematic cycles,” central components of core curricula that allowed the presentation of subject matter within a cultural context and integrated the cultural theme into other subjects. All members of the team, parents, and community members, including elders, were involved in the development of curricula and in the evaluation of the project and its relevance to the traditions of the community. Targeted curriculum areas included art, mathematics, science, social studies, economics, geography, language arts, and fine arts (Allen et al. 2002).

Teacher Education in Sub-Saharan Africa (TESSA)

The principal purpose of Teacher Education in Sub-Saharan Africa (TESSA) research and development network is to improve the quality of, and extend access to, teacher education in Sub-Saharan Africa. TESSA brings together teachers and teacher educators from across Africa. It offers a range of materials (Open Educational Resources) to support school culturally based teacher education and training. Currently, 12 African countries are actively engaged in TESSA activities and more than 700 African academic teacher educators have participated in the TESSA process including authoring and adapting the core TESSA study units. The TESSA study units for primary teachers have been adapted to ten country contexts and are available on the TESSA website in Arabic, English, French, and Kiswahili. All TESSA study units contain a series of activities that participating teachers can carry out in their classrooms. Guidance handbooks have been created for teacher educators to help integrate and make effective use of study units in their courses. It has served 500,000 teachers and teacher educators in 19 teacher education programs have benefitted from their engagement with the TESSA resources (WISE 2017).

Honey Bee Network: India

The Honey Bee Network comprises a comprehensive multimedia/multilingual database of primary educational resources in native languages as well as information relating to new innovations and ideas, including, horticulture, biodiversity, and herbal medicine. In the same way that honeybees thrive on pollen from flowers, the Honey Bee Network is designed around the principle of information and knowledge sharing for the common good. Just as taking nectar away from flowers does not make them poorer, the objective of the Honey Bee Network is to enrich the lives of the people who share their innovations and ideas by helping them realize the value of their knowledge. By facilitating the cross-cultural and multilinguistic exchange of ideas, the Honey Bee Network provides an opportunity to tap into the creative component of indigenous knowledge systems. Unlike the more developed segments of urban society, the creativity of knowledge-rich peoples in rural and isolated areas goes largely unseen, because they lack the necessary channels of sharing their ideas with the wider polity. By providing publicly available access points (e.g., kiosks) in remote villages throughout India, the Honey Bee Network affords these geographically disadvantaged peoples an opportunity to share their creations and ideas with their peers in other parts of the country and the global community (Honey Bee Network 2017).

Project Multimedia Systems for Ethnographic Materials, Apoyo Para el Campesino – Indígena del Oriente Boliviano (APCOB) – Bolivia

APCOB, **A**poyo **P** for the **C**ampesino-Indigenous of the **B**oliviano **O**riente, is a non-governmental humanist organization founded in the year 1980. The mission of APCOB is for the indigenous peoples of the Bolivian East to participate in society and in the national State by exercising their rights and articulating their development proposals within the framework of their culture (APCOB 2017). An important part of its mission is to:

- Investigate, recover, and enhance the knowledge and cultural practices developed by indigenous peoples to help strengthen their culture.
- Inform and make known to the national society the different aspects of history and culture of the indigenous peoples of the lowlands of Bolivia to contribute to the democratization of the country within the framework of interculturality.

APCOB has worked with indigenous organizations and other NGOs in Bolivia to build a vast collection of multimedia materials of indigenous knowledge about culture and economic practices in Bolivia. The project uses a variety of multimedia applications including video, audio recordings, and images to develop school materials about their indigenous cultures for use in primary and secondary schools. The materials are used to enrich subjects such as history, geography, culture, and languages and are also used for teacher training. Efforts are underway to integrate the materials in the national curriculum and to include this initiative as part of the Bolivia ICT policy for the education sector (IICD 2016).

Thailand Initiatives to Address the Digital Divide and Revitalization of Indigenous Knowledge

Thailand has a very high literacy rate of 93.5% as of 2014 (Kasichainula 2016). It also has a significant urban-rural digital divide. During 2005–2014, computer users increased both in urban and rural areas. In urban areas, computer users rose from 35.5% of the population in 2005 to 47.8% in 2014, while those in rural areas rose from 19.7% to 30.4%, representing a significant but narrowing urban-rural gap (Malisuwan et al. 2016). The national *Digital Thailand* plan includes four phases to eliminate this gap and develop Thailand into a fully digital country.

The *Thai Learning Technologies 2010* report (Ainley et al. 2010) notes that technology can be used to strengthen Thai knowledge and culture by providing wider contact with Thai culture so that people can access heritage sites that they might not be able to visit and have access to other resources central to Thai and indigenous culture. It recognizes that formal education provided in school does not provide sufficiently for learning about Thai culture. Many people who are capable of transferring this special knowledge are not widely available and are aging (Kaewdang 2000). Their knowledge and skills need to be made accessible using technology (Trankansuphakon and Khamphonkul 2006).

There is recognition of the challenges in using digital technologies to revitalize indigenous culture and knowledge. As noted by Oppeneer (2010), there is concern that when misapplied, the consequences of ICT can be to bring mass media, popular culture, and global languages that can potentially conflict with local traditions. Mander (1991), for example, describes the rapid negative impact of mass media on indigenous culture within a Native American community in Northern Canada. However, as noted in the earlier sections (e.g., Four Directions Project), there are ways to use digital technologies in appropriate ways that help support the continuity of indigenous language and culture.

The Inter-Mountain Peoples Education and Culture in Thailand (IMPECT) (Saenmi and Tillmann 2006) uses digital technologies to support cultural identity and knowledge. An example of their approach is the "Footholds in the Hills" project. The initial phase of the project emphasized the collection of local knowledge and forms of cultural heritage in conjunction with the communities. This collection and selection process served as the basis for the development of a series of media for cultural knowledge transmission involving the community to support implementation of teaching activities. The following four areas were identified as essential for successful implementation:

- A multi-faceted understanding of community life and inter-community relationships
- Techniques and training in format and nonformal teaching for elders and customary knowledge experts
- Participation of community members and community groups to maintain and sustain interest and motivation
- Interrelation between effective work on cultural knowledge transmission and early childhood development and solving wider community problems

The IMPECT approach provides an example of how digital technologies and media may be used to enable and empower indigenous communities to move toward self-determination and to create the conditions for the continuity of indigenous peoples lives and cultures in modern states.

Technology, Education, and Cultural Diversity Center (TEC) Program and Cultural Identity: Israel

The **TEC** at MOFET and Kibutzim College in Israel has been a leader in the use of technology to support cultural diversity and cross-cultural understanding. The center develops and implements a collaborative learning model based on advanced technologies for teachers, preservice teachers and pupils from different ethnic groups and religions, yielding constructive dialogue and cooperation between diversified groups, and eventually tolerance and mutual respect (Shonfeld et al. 2013).

The collaborative learning model of advanced internet technologies is implemented within small teams from diverse cultures by the educators of the participating groups, progressing gradually from on-line communication (written, oral, video) to face-to-face interaction. Through collaboration in joint assignments over a period of 1 year, team members get to know each other, develop mutual respect, eliminate stigmas, and reduce mutual prejudices. The in-service educators then implement the program in public schools, and thus serve as major agents of social change, having influence on generations of students. Research has shown that the TEC Model yields outstanding results and its impact (Walther et al. 2015).

Each year, the TEC center more than doubles its activities (TEC 2017). More colleges and schools join the project and more courses are offered. Research shows that the program is making a big difference in attitudes to technology and to other cultures (Magen-Nagar and Shonfeld 2017; Hershko and Shonfeld 2017). In addition, other countries in the world are using the TEC model. Since 2005, tens of thousands of Arabs and Jewish teachers, students, lecturers, and pupils have worked together on yearlong projects. The center provides a social network in three languages – Arabic, Hebrew, and English – for safe online collaboration, as well as a "virtual Island" where Arab and Jewish children can meet online using avatars to talk and carry out activities together. It is unique in that it brings together Arabs not just with secular Jews but also with religious Jews where fear and mistrust is the greatest. The activities of the center have created a ripple effect on the parents, the other teachers in the school, other pupils and the whole community. The fruit of all these projects is represented in the annual TEC International Online Day.

In 2017, "Grandma's Stories" was the theme for the TEC International Online Day where thousands of children, teachers, preservice teachers, leading scholars, renowned researchers, and policy-makers from different cultures locally and internationally connected to discuss/present grandma's stories and to interact together in protected online and virtual environments. The universal term Grandma's Stories may have different interpretations in different cultures. It may refer to her wisdom stories, or that her tales are something from the past and thus are not valid today, or it may refer to the healing cooking recipes she always offers for every disease/ailment.

For most people, grandmother's tales, stories, and recipes are viewed as the cure for everything. Grandmothers have a special charm and magic. For most children, even though their mothers may know a lot, grandmothers always have the answer for everything! Grandmothers across the globe always make time for their grandkids, share wisdom, show patience, give joy, and, of course most of all, they give love and affection (see URL: http://www.mofet.macam.ac.il/tec/tecday/eng/Pages/default.aspx).

The TEC Center's goal is to assimilate the model of online cooperative learning in the school system to change preconceptions, prejudices, negative opinions, and stereotypes that affect Arabs and Jews, and religious and secular Jews in Israel, from an early age. The program's goal is to develop intercultural relations in cyberspace, connect young children in the school system, and start a discussion that will lead to understanding between the different cultures in Israel's divided society.

As a preparation for taking part in TEC International Online Day, the students are asked to write a family story or any piece of knowledge, as prose or a poem, they have heard from an older family member, like their grandparents. The story must be significant to them in forming their identities. Prior to the participation of the TEC college students in the TEC International Day, the diverse groups share a google doc where each member writes about his/her cultural identities within their multiple identities and they discuss it together.

Conclusion

The above are examples of the ways that ICTs can be used as a tool to revitalize culture and to foster cross-cultural understanding. Such efforts are critically needed to prevent the further loss of local and indigenous cultural knowledge and resources that contribute to the cultural richness of our world. Concrete actions at multiple levels could use the affordances of modern technologies to preserve cultural richness. For example, governments could work with universities and indigenous organizations to engage in similar initiatives and to establish policy structures that will enable indigenous peoples, and other unique cultural communities to work in partnership with ministries of education and universities, to provide culturally responsive learning opportunities for their children through the use of ICTs. By doing so, they will help the indigenous and local cultures in their countries to fully participate in knowledge societies (World Summit on the Information Society 2003). Various cultures, having been diminished in previous centuries, now have a new opportunity to expand knowledge of their values and inherent specialties via the Internet and to share with everyone their diverse culture and colorful native customs. This is the way ICT may help revitalize and support cultural diversity and cultural identity.

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A Sociocritical Perspective on the Integration of Digital Technology in Education

68

Jean Gabin Ntebutse and Simon Collin

Contents

Abstract

This chapter aims to present what could be the contribution of a socio-critical approach for the benefit of digital equity in education. It begins with the presentation of the main issues of digital equity in education. It continues with the presentation of the need and the foundations of that socio-critical approach on digital technologies in education and ends with the main lines of research aligned with such a perspective.

Keywords

Sociocritical perspective · Digital technologies · Digital equity · Integration · Education

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Issue of Equity in Education

According to OECD (2013, p. 15), equity in education can be seen through two dimensions. The first dimension is **inclusion,** which means "ensuring that all students reach at least a basic minimum level of skills. Equitable education systems are fair and inclusive and support their students to reach their learning potential without either formally or informally pre-setting barriers or lowering expectations." The second dimension is **fairness** which "implies that personal or socio-economic circumstances, such as gender, ethnic origin or family background are not obstacles to educational success." In that case, an **equitable education system** can be considered as "high performance among students from all backgrounds, rather than as small variations in student performance only" (OECD 2016, p. 6).

Besides this OECD definition, the Glossary of Education Reform proposes a definition which is centered on the fairness dimension: "In education, the term **equity** refers to the principle of *fairness*. While it is often used interchangeably with the related principle of *equality*, equity encompasses a wide variety of educational models, programs, and strategies that may be considered fair, but not necessarily equal. It has been said that "equity is the process; equality is the outcome," given that equity – what is fair and just – may not, in the process of educating students, reflect strict equality – what is applied, allocated, or distributed equally" (Online, http://edglossary.org/equity).

Even if this definition presents only one dimension of the OECD definition, it adds an element that does not appear in it. That is the difference between equity and equality, suggesting that the first is a process whereas the second is an outcome. As a process, equity in education is complex and should be analyzed regarding the different levels of the social ecosystem in which education takes place and where inequalities and inequities occur. These levels are the following ones: the microsystem (e.g., inequities in families and classes), the mesosystem (e.g., inequities in a milieu where schools are located), and the macrosystem (e.g., societal inequities). Indeed, researchers in sociology of education clearly explain the process of reproduction of social inequalities in the social environment where learning and development occur. According to the French sociologist Duru-Bellat (2006), social inequalities become educational inequalities by the fact that they are drawn from: (1) the unequal environments through which children develop; (2) the differentiated socializations that cause unequal preparation of children for school requirements and inequalities in cognitive development and general skills; and (3) parental educational practices marked by material or cultural inequalities of families. These inequalities extend to the school setting, which then becomes the place of production of inequalities and hierarchies, and generates differences in the learning contexts. As consequences, within the school, the outputs of learning are not of the same value and lead to social inequalities of employment, income, and career. By the way, the vicious circle of inequalities has other facets, such as the fact that socioeconomic inequalities determine political inequality in terms of participation, representation, and influence (International Council of Science (ISSC), the Institute for Development Studies (IDS) and UNESCO 2016).

Apart from this introduction, which provides a general explanation of the factors that may affect equity in education, this chapter focuses on digital equity in education. This is one of the main challenges that education systems face because digital inequities reinforce pre-existing inequities at the different levels of the social ecosystem in which learning and development happen (Gorski 2009). It is therefore important to develop a sociocritical perspective on digital technologies in education in order to unmask these different forms of digital inequities that work for the benefit of dominant relationships and against the principles of equity, inclusion, and social justice.

Relevance of the Sociocritical Approach on Digital Technologies for the Foundations of Digital Equity

The relevance of the sociocritical approach of digital technologies in education is based on the observation that research on digital educational uses has mainly focused on teaching and learning in an institutional context (Bayne 2014; Erstad et al. 2013; Ito et al. 2013), in particular with a view to measuring their impact (Eynon 2012). Without calling into question the relevance of these studies, a growing number of researchers are calling for a better understanding of the digital era in education in terms of its dynamic relationship with educational actors in the social and cultural contexts within which this relationship takes place. From a pedagogical point of view, the sociocritical approach of digital education makes notice of the profound changes currently under way in learning (Le Douarin 2014): on the one hand, mobile digital technologies are increasing across educational and noneducational contexts (Erstad 2012); on the other hand, the boundaries with leisure, socialization, family, or work are increasingly porous (Sharples et al. 2006). This offers an opportunity to develop pedagogical and didactic innovations aimed to better link learners' out-of-school digital practices with the use of technologies in formal learning contexts. In doing so, it highlights fundamental contemporary issues such as lifelong learning, which is a growing professional demand, and digital inequalities that explain why individuals do not benefit from it in the same way (Bukodi 2017). As such, it helps to create the conditions for digital equity. As Resta (2011, p. 1) said, "Technology has transformed all aspects of society, including the teaching-learning process. It is critical that specific groups within our society not be excluded from the benefits of these new developments. Not only must digital equity continue as a priority goal of all nations, but efforts to move toward digital equity also must be mobilized, focused, and coordinated to prevent the development of a permanent underclass in global society."

Although the sociocritical approach has multiple origins (De Munck 2011) and is not uniform and homogeneous (George 2014), it has been widely developed in the disciplines concerned with the relations between technique and society. It also appears sometimes implicitly and always heterogeneously in the work of several researchers working in the field of digital education (Albero and Thibault 2009; Beynon et al. 1989; Bruillard 2011; Bulfin et al. 2015; Chaptal 2003; Collin et al. 2015; Cuban 1993; Dieuzeide 1982; Jacquinot 1981; Moeglin 1993; Selwyn 2010).

Foundations of the Sociocritical Approach for Digital Equity in Education

Three main premises can be considered as the basis of the sociocritical approach to digital education. First, the sociocritical approach is based on the main premise that students develop a “first” relationship to digital technologies in an out-of-school context as digital technologies are part of the family environment in developed countries. It is also now well established in the sciences of education that children do not arrive in school deprived of all representations and practices with regard to ways of being and behaving. For example, many works (e.g., Penoup 1999) show that students have an initial relation to writing before writing becomes the subject of learning in the school context. Thus, Barre-de-Miniac (2000) defines the relation to writing as the set of “conceptions, opinions and attitudes, with more or less great distance and more or less great involvement, but also values and feelings attached to writing and its learning and uses” (p. 13). The “relation to” is forged by each student on the basis of his own experiences (e.g., essays, failures, successes, self-interest) as well as in collective experiences (belonging to various social and cultural groups) in a complex interlacement. “The social and cultural groups in which students move develop the writing uses and their associated values which contribute to the development of the relationship to the writing of each individual and interact with different variables taken [...] from the standpoint of singularity” (Barre-de Miniac 2000, p. 14). Like in the case of the relation to writing, the sociocritical approach on digital technologies in education considers that students have prior representations, access, uses, and digital skills which will continue to develop in a concomitant manner with classroom-based uses of digital technologies.

The understanding of this relationship to digital technologies, constructed in an out-of-school context, leads to two other premises. First, the out-of-school context remains throughout the students’ schooling, the main context within which they construct their relationship to digital technologies. As such, several studies show that students’ access and digital use occur much more frequently outside school than at school (Buckingham 2007; Eynon 2008; OECD 2010), the latter struggling to take over digital technology (Cuban 1986; Leask 2011; Maddux and Johnson 2012; OCDE 2011; Underwood and Dillon 2011). The notable difference between out-of-school and school contexts leads some authors to speak of a new digital divide opposing the formal technology use at school and the many ways (e.g., formal, informal) learners are using them in their daily lives (Buckingham 2007). The extracurricular context is thus coconstitutive of the students’ relationship to the digital technologies since: (1) a great majority of students begins to develop that relationship at varying degrees before school, with accessible tools at home; (2) the out-of-school context remains the main context for students’ access and digital use. From this perspective, we argue that the school context, given its current low level of IT integration, plays a secondary role in the construction of students’ relationships to digital technologies. This interpretation requires a careful consideration of how one’s relationship to educational digital uses is built out of school. The results of the study reported by De Haan (2004) may be reported here. In this study, three competing hypotheses to explain variations in digital skills among students were tested: (1) **the hypothesis instruction**, which postulates that variations in digital skills are due to differences in computer equipment in schools and to the quality of digital skills; (2) **the selection hypothesis**, which states that variations in digital skills come from the general intellectual skills of pupils (which are the basis for students' selection by schools in the Netherlands); (3) **the social background hypothesis**, which states that digital skills vary essentially according to the sociocultural profile and context of the students. The results of the study indicate that only social origin could explain the variations in digital skills between students.

The third and final premise assumes that this first relationship to digital technologies, constructed in an out-of-school context, can impact students' learning and subsequent socio-professional development. Although this relationship remains to be clarified, several studies have already established links between the variable students' digital uses and their ability to benefit from them for educational and other purposes (Hargittai 2002; Livingstone and Helsper 2007). An OECD (2010) study on data from the 2006 Program for International Student Assessment (PISA) concludes that the academic performance of students is more strongly correlated with their digital uses in nonformal contexts than in school context. It is therefore possible to think that the relationship developed by students with regard to digital technologies in an out-of-school context offers more or less potential for learning and therefore influences their willingness to learn with digital technologies in school context.

To sum up, the sociocritical approach to digital education in education is based on three main premises rephrased here: (1) students have a digital relationship growing out of their individual experiences and their belonging to sociocultural groups; (2) this relationship to digital technology develops mainly in out-of-school contexts, both before and during schooling; (3) it is likely to influence their willingness to learn with digital, especially in the school context.

Anchored in education, the sociocritical approach is particularly concerned with the educational relationship that students develop, to varying degrees, toward digital technologies. On the basis of these premises, the proponents of the sociocritical approach postulate that students' digital educational uses can only be fully understood if their sociocultural context and profile are taken into account. Selwyn (2010) is explicit on this point by stating that "whilst perhaps not immediately apparent to the observer of a classroom setting, it would be foolhardy to attempt to explain any aspect of education and digital technology in the twenty-first century without some recourse to these wider influences [the social 'milieu' of technology use]" (pp. 67–68). Hence, it is important to analyze digital inequalities in education by considering their roots in the broad sociocultural context in which learners evolve, both in institutional and extrainstitutional contexts of learning (Gudmundsdottir 2010; Brotcorne and Valenduc 2009; DiMaggio et al. 2004). As an illustration of this, Gudmundsdottir (2010), who conducted a study in South Africa, explored factors influencing the digital divide in four schools in Cape Town, South Africa. Among those schools, three were for disadvantaged learners whereas the fourth was for privileged white students. The results indicated that even if all these schools use technologies in their curriculum delivery and despite substantial efforts made by educational authorities to increase ICT access for learners and teachers in public schools in Cape Town, digital equity has not been reached when digital competence for different groups was compared. “The differences in ICT skills were affected by learners’ opportunities outside of school to access and use computers… the vast differences in learners’ access and use outside of school are highly connected to wider social inequalities within society” (p. 98). The results of this study also show that the problem of digital equity cannot be apprehended by isolating it from the sociocultural context taken in the very broad sense and which secretes inequalities.

Main Lines of Research for the Sociocritical Approach

As the sociocritical approach addresses the sociocultural dimensions that contribute to shaping students’ relations to digital technologies, it necessarily implies a critical posture, which is in line with the work of the Frankfurt School (Friesen 2008). This critical posture assumes that “all knowledge, even the most scientific or commonsensical,” is historical and broadly political in nature (Friesen 2008, online). In a somewhat schematic way, it is based on two key principles (Bayne 2014; Buckingham 2007; Friesen 2008, 2013; Warschauer 1998): (1) The first places the object of study in its sociocultural context and in its historical evolution, on the assumption that no object of study is approached in a neutral and objective way; (2) The second brings to light the power relations and multiple and contradictory interests of a political, economic, social, or other nature that shape the object of study and the knowledge related to it. The aim of the critical posture is not to denounce the interests of some at the expense of others, but to start from this “state of affairs” in order to develop a complementary or alternative knowledge that takes into account social, economic, and cultural aspects, and ultimately aims at social justice.

Based on these two principles we suggest four important lines of research. The first line could be the **Contextualization of the digital technologies in the historical filiation of the technical objects that have penetrated education.** In this perspective, it is important to understand the extent to which digital tools should be placed in the long history of technical objects in education. The second line of research would deal with the **Contextualization of digital technologies in the economic, political, and ideological logics** that privilege certain values and purposes rather than others, and which are more or less compatible with the missions of the school. With this line of research, it should be important to understand the motivations and interests underlying the integration of digital technologies in education and grasp to what extent they serve the educational goals.

The third line of research should focus on the **Contextualization of the digital technologies in the daily life of the educational and para-educational actors, as social individuals linked by relations, roles and norms that vary according to the interlocutors, the places, the social classes, and ethno-cultural belongings.** For example, the research should focus on how digital technologies contribute to reconfiguring or maintaining educational roles, the school form, the relationship to knowledge, and the time and place of teaching and learning. It should also analyze the extent to which digital uses in institutional context are in continuity or in discontinuity with the noninstitutional digital uses of educational actors. This line of research is important when we take into account the profound changes induced by digital technologies in learning and in the relationship between educational actors.

Finally, given the complexity of the issues raised by digital technologies, the fourth area of research for the sociocritical approach to digital education should be the **Contextualization of digital technologies in relation to the disciplines concerned by the understanding of the relations between technology and society**, while specifying the educational issues that are specific to this field of study. The question that could guide research should be, for example: What are the interdisciplinary contributions to the understanding of the relationship between technical objectives and education?

Conclusion

The purpose of this article was to present what could be the contribution of a sociocritical approach on the integration of digital technologies in education to the understanding of issues related to digital equity in education. In order to do this, we began with a brief presentation of the main issues of equity in education. We then demonstrated the need for a sociocritical approach to grasp the contours of digital equity in education and we presented the foundations of this approach. Finally, we presented the main lines of research that we believe are fundamental for the sociocritical approach of digital education to advance knowledge in the field of digital equity in education. We believe that this approach is indispensable to complement learning methods that seek to reduce digital inequalities and thereby promote digital equity.

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Learning Differences and Digital Equity in the Classroom

69

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Contents

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Abstract

This chapter addresses digital equity in the classroom for students with learning differences, as well as the role of technology in the provision of equitable education for the full diversity of students. The chapter discusses the evolving opportunities and challenges that information technology in the classroom presents to students with learning differences and their teachers.

To meaningfully understand this topic requires an understanding of the complex context, the forces at play, and their relation to students with learning differences. Among the forces at play are policies, regulations, the accessibility movement, technical trends, instructional design strategies, educational publishing, open education resources, pedagogical trends, quality control approaches in education, and governance of formal education. The chapter highlights the benefits to all students of designing the classroom experience for students with learning differences.

Keywords

Inclusive design · Inclusive education · Accessibility · Open Education · Equity · Diversity · Inclusion

Introduction

Todd Rose (2015) in his book *The End of Average* amasses evidence that there is no average or typical student and that we all have learning differences. We are each a jagged, variable, and evolving set of characteristics and skills. There is no one that fully conforms to the collective notion of average and individually we rarely conform to our notion of our typical selves.

Despite this insight, our formal education systems are still largely based on the industrial model of education: attempting to create standardized learners by socializing conformity and then rating, ranking, sorting, and thereby assigning the destinies of students. If our aim is to produce a standardized learner, learning differences become a problem.

Other fields view diversity as a necessity for survival, not a problem. Our formal education system lags behind in recognizing the benefits of diversity. Economists and natural scientists have long understood the importance of diversity and diversification for dynamic resiliency and innovation. Even corporate cultures have integrated the insights of researchers such as Scott Page that diverse perspectives make for better planning, problem solving, prediction, and innovation (Page 2007).

Students identified as having disabilities are at the extreme edges of the jagged scatterplot of difference. We assign the label of "disabled" when it is either impossible or extremely difficult to conform to standard expectations. As such these are the students that most feel the effects of educational inflexibility. Conversely, they may also be the greatest impetus for greater systemic adaptability, to the benefit of all students (Treviranus 2016).

What Is Disability?

Conventional views of disability frame disability as an absolute and personally defining trait and thereby divide the world into people with disabilities and people without disabilities. This is reinforced by services or exemptions for people with disabilities, which require certification of disability status (e.g., individual education plan, wheelchair accessible parking, funding programs for assistive technology; see https://www.ssa.gov/disability/professionals/bluebook/listing-impairments.htm). A definition of disability arising from the design domain contests this binary view. The definition frames disability as a mismatch between the needs of the person and the environment, product, or service offered. In the realm of education, this would be a mismatch between the needs of the learner and the learning experience offered. This implies that anyone can experience a disability if presented with a design that does not match their needs (Treviranus 2014a).

Given that needs are personal and diverse, this also implies that it cannot be determined whether something is accessible until one takes into consideration the unique needs of the individual, their context, and their goals. Accessibility is relative and evolving. All students potentially face barriers to learning. Like barriers faced by students with disabilities, these can be seen as a product of a mismatch between the needs of the learner and the learning experience and environment. Learning needs that affect learning can include:

- Sensory, motor, cognitive, emotional, and social constraints
- Individual learning approaches
- Linguistic or cultural preferences
- Technical, financial, or environmental constraints

Using this framing, an accessible learning experience is a learning experience that matches the unique, diverse, and evolving needs of each student.

Formal Education System and Impetus for Change

Our formal education system is a highly complex system of systems, in part constructed to buffer or resist external influences for change (Treviranus 2016). The classroom itself is a complex system with connections and dependencies to many other nested and overlapping complex systems including the school administration, educational authorities, the digital technology industry, the publishing industry, parents, the local community, policy frameworks, and sources of funding. Any fundamental change of the education system to adapt to learning differences at the edges of the jagged spectrum of student needs must take these nested and entangled systems into account.

Education as a Human Right

The formal education system has encountered many forces for change over the last 50 years. One precarious force is a nearly global commitment to education as a human right (e.g., the Salamanca statement with 95 nations as signatories, the Convention on the Rights of Persons with Disabilities (2007)) (Ainscow and Cesar 2006; United Nations General Assembly 2007). The commitment has yet to be kept. The response has been varied. One compromise has been to create segregated, separate systems of education for students with extreme differences. This has been countered with the social justice demand for integration (Dixon 2005). The integration argument comes from the perspective of students that are excluded, but an equally cogent argument can be made from the perspective of the mainstream in that segregation denies the majority the positive influences for diversification, flexibility, and adaptability. All students are different and benefit from education designed to support and nurture that difference. Society benefits when that difference can be leveraged to create more choices, provide more perspectives, find new competencies, and see innovative approaches not considered before.

Digitization and Global Connectivity

Another hugely disruptive force, which has demonstrated the change-resistant nature of our formal education system, is the move to digitization and global connectivity. Beyond the buffer of our classroom walls, digital technology and connectivity have significantly changed the reality, or future, students are to be prepared for by education. Formulaic and standardized skills can be taken over by machines, computers generally have more accurate factual memories than people, and mechanistic calculation can be left to computing (National Research Council (U.S.). Committee on Defining Deeper Learning and 21st Century Skills et al. 2012). At the same time collective, distributed production has never been easier, expertise is publicly available, and we are drowning in unfiltered information. Reduction through a popularity and affinity filter appear to be our primary means of synthesizing information and dealing with growing complexity; this has resulted in rising populism, tribalism, and social fragmentation (Treviranus and Hockema 2009).

Currently, there is a dawning understanding that as a society we need collaborators, critical thinkers, and the skills and characteristics that machines do not address. One of these characteristics is the fostering of divergent skills, combined and thereby multiplied, to address the complexity of our current global reality (Weigel 2002). Our formal education systems appear to be structurally biased against answering this challenge. A positive transfer effect, of the demand to accommodate students with learning differences, may be to disrupt this structural bias and stretch our education systems to support and even foster diversity. Redesigning education to address the needs of students with learning differences logically benefits all students and society as a whole. Disability, often occupying the outer edges of difference, crosses all cultural, geographic, political, economic, age and divides and touches all lives. Accessibility for students with disabilities is in everyone's interest.

The Opportunities and Challenges of Digitization and Global Connectivity

For students with learning differences, digital systems and computer-mediated learning provide both an opportunity and a risk. If designed correctly these systems can unlock previously inaccessible learning experiences and overcome many barriers to access. However, if not designed inclusively, these systems amplify and speed disparities between students that have digital equity and those who don't. These systems then not only feed into vicious cycles of exclusion but also exponentially amplify their effects.

Opportunities

When computers are configured to enable alternative means of presentation and alternative means of control, they act as powerful translation devices for students and teachers who cannot use the standard means of accomplishing academic tasks. Visual information and text can be translated into speech, sounds, or tactile signals: through screen readers, refreshable Braille displays, or haptic interfaces, for example. A variety of voluntary actions can be translated into the equivalent of keyboard and mouse/trackpad input. These voluntary actions might include speech, pointing with your head or foot, or activation of switches through discreet movements of any body part, including blowing or sipping, and contracting muscles, or even through repeatable patterns of brain activity read by an electroencephalogram (EEG) device. For students who face barriers to traditional modes of engaging in academic activities, computers thereby act as a path to speaking, writing, reading, experimenting, manipulating learning materials, and researching (Alper and Raharinirina 2006).

Digital content is far more flexible and mutable than print. Many students experience what has been termed a "print impairment" that makes access to traditional printed curriculum difficult or impossible, including students who:

- Cannot see print
- Have difficulty seeing print because of the size and contrast of standard print materials
- Have difficulty decoding text
- Cannot hold and manipulate a physical book or page

Digital learning materials, if designed correctly, offer many advantages (Thomson et al. 2015):

- Text can be translated to speech for students that cannot see or decode text (e.g., students that are blind or have dyslexia).
- Content can be magnified, spaced, and presented in higher contrast for students that have difficulty seeing.
- Distracting materials or complexity can be reduced or hidden for students that have difficulty with focus.
- Manipulation and navigation of content can be controlled through available alternative voluntary actions (e.g., head movements, vocal command, puff or sip, for students with paralysis or reduced dexterity).

Networks and global connectivity can connect students, teachers, and parents, who have minority or outlying needs, with connections to others that share these needs. Global connectivity can also reduce redundant production of learning material variants (e.g., a text description of a visual graph or a text caption of a video). Global networks have been used to crowdsource and cooperatively create alternative formats such as captions of audio in videos for students that have difficulty hearing (http://amara.org/en/).

Rapid prototyping tools allow the rapid customization of physical materials and tools. These include holders, handles, stabilizers, switches, buttons, and device casings to make controls easier to hold and manipulate (Buehler et al. 2014). Internet of things' sensors, monitors, and actuators enable the creation of smart environments that can be responsive to diverse personal needs (e.g., controlling light, heat, and security) (Domingo 2012).

The major caveat to all these disruptive opportunities is *if* designed correctly. The systems and their associated practices must be designed to support human diversity. To accomplish any of these potentially liberating functions, digital systems must support the flexible transformation, augmentation, and replacement of both presentation (e.g., visual, through speech and sound, or tactile), and means of control, and the integration of scaffolds and supports. The design must acknowledge that humans are diverse, not typical or average.

Risks and Challenges

Since the emergence of personalized computers and the ubiquitous proliferation of network connectivity, there have been numerous trends that have both threatened and promoted support for human diversity in the socio-technical ecosystem.

Some of the most change-resistant systemic threats are associated with traditional market models. A competitive market compels a producer to strive to address the largest customer base and to protect their hold on their market share through proprietary practices. Proprietary practices hamper interoperability, excluding anyone who does not fit into the constrained boundary of the customer majority.

Supporting human diversity requires interoperability between the various components or parts in the socio-technical ecosystem (Treviranus 2014a). The range and extent of diverse human requirements demands a plurality of developers and suppliers. The original designer, developer, and producer cannot be expected or relied upon to anticipate or address all of the diverse human requirements. In as far as digital systems are modular and “mashable,” new, unanticipated, alternative interfaces or user experiences can be added, or the existing ones can be adjusted or augmented. This requires open, transparent, commonly agreed upon protocols or open interoperability standards for software and hardware and open data formats. These provide the common meeting place from which the human interface can diverge.

Entities at the margins of a domain are the first to feel the effects of problems within a domain. Such is the case for the alternative computer access system (or assistive technology) producers at the edge of the digital market. Most mainstream applications and devices are designed to address the needs of a typical customer. Assistive technology is relied upon to bridge the divide between the needs served by the standard product and the needs of people with disabilities. For students who can’t use a standard computing device, they must acquire both the standard device and an assistive technology that more closely fit their unique needs.

The producers of these assistive technologies face two major challenges. Because they are serving a customer base that is more diverse than any other (the only common characteristic of disability is difference), if they do their job well, they will have a relatively small customer base for any one design. At the same time, they need to ensure that their product will interoperate with all of the applications, browsers, operating system utilities, and peripherals on the computing device their customers use. This means interoperating with a huge variety of frequently updated applications that may be mashups of many components, with difficult to determine provenance. To make matters worse, most of the developers of these mainstream applications are reluctant to share information about how to interoperate with them. As a result the alternative access system industry is struggling, causing a limited supply in even the most well-resourced countries. Because of limited supply, and public funding rules that restrict funding to only qualified vendors and products, alternative access systems available to students with disabilities are relatively expensive. The systems frequently suffer from interoperability problems, meaning that many functions or applications are not available to students that rely on alternative access systems. Because of the technically and economically difficult market, there is a decrease in the alternatives available to students with needs at the edges of this already marginalized group, such as students that have severe motor limitations. As a result, it may cost more than ten times as much for students with disabilities to get online (Khetarpal 2014). Digital access is getting less expensive, faster, more reliable, more multifunction, and more ubiquitously available for students that can use mainstream products. The opposite is often true if you have a disability and cannot use a standard access system. This produces a broadening technology gap that compounds the disparity these students already encounter.

Promising Trends

One promising trend that circumvents some of these limitations is when the manufacturers of the standard products include and integrate assistive technology features directly into their products. Examples of this include the availability of screen reading functions in touch screen devices, voice recognition as a standard feature, and word prediction or character disambiguation in on-screen keyboards (Brunet and Ramachandran 2016). Another promising trend is the availability of open-source assistive technologies. This is especially beneficial to students in the many countries that do not have an assistive technology industry (Ptolomey 2011).

Another very promising trend is the adoption of inclusive design as a corporate-wide design strategy, as has been exemplified by Microsoft Design (https://www.microsoft.com/en-us/design/inclusive). Microsoft is leveraging the insights and innovations inherent in designing for and with people with disabilities to improve their products overall. The design team has adopted and advanced the inclusive design toolkit of the Inclusive Design Research Centre as an enterprise-wide strategy (Kuang 2016). The trade press has suggested that this has helped to make Microsoft "cool again" (Anderson 2016).

The ease of copying, which digital systems afford, has acted as a disruptive counterforce to proprietary systems that cater only to the typical consumer. This has created "zero marginal cost" markets for many commodities, including books and music, or replication and mass production with negligible cost after the first instance of a product (Rifkin 2014). New market models, which leverage the diversity and innovation that comes from openness and interoperability, have emerged in the form of platforms that leave the creation of variants to the world at large (e.g., IOS apps, Android, YouTube, etc.). These provide ecosystems that enable diversification of designs, but also means of finding variants that fit unique needs.

The Promise and Challenges of Open Education Resources

This market tug-of-war has played out in the education domain in the form of competition between established educational publishers and nascent openly licensed education resources or open education resources (OER). OER provide greater equity for disadvantaged regions globally and students who are economically disadvantaged. OER are openly licensed to support what are referred to as the "5R Permissions of OER," the right to:

1. Retain and make your own copies
2. Reuse in a wide range of ways
3. Revise, adapt, modify, and improve
4. Remix by combining two or more
5. Redistribute to share your contributions with others (Lumen Learning 2014)

OER thereby offer the potential to create many variants and choices to match the variability and diversity of student needs. This same latitude and variety is not available to mass-produced, copyright-protected traditional publishing.

Students who require alternative formats (and their parents and support services) report spending inordinate amounts of time and energy addressing digital rights management (DRM) restrictions that prevent the creation of variants and lock out the opportunity to translate from one modality to another (Whitehouse 2008). While hard-won exemptions to DRM restrictions for students with print disabilities have been granted in certain markets (e.g., the Marrakesh Treaty) (Fitzpatrick 2014), the burden to prove that a student has a disability and the parallel supply chain that is required to acquire an alternative format textbook result in an onerous process for an already taxed student and their support system. The open licenses of OER would circumvent this complex and difficult means of acquiring accessible learning material.

The most acrimonious battlefield has been in the United States where educational publishing has been an extremely lucrative and well-entrenched market. In the primary and secondary grade market, large textbook publishers are aided by a highly competitive "textbook adoption" framework that structures competition for public funding in such a way that large profits are guaranteed to the winning textbooks and other choices are left with little support (Petrides et al. 2011). Textbook adoption was enacted to promote, protect, and curate the quality of textbooks that receive public funding. The design of the curriculum and textbook ecosystem then further entrenches this competitive advantage by granting management of textbook clearinghouses to these same winners in the adoption contest, thereby granting further advantage to the dominant publishers. Students with disabilities have been used as a "pawn" of sorts in this battle. To understand the complex role that students with disabilities have played in this struggle requires an understanding of regulatory frameworks that support accessibility.

Accessibility Regulations and Laws

Accessibility, or design that works for people with disabilities, is a precarious value: most people agree that it is important, but it is one of the first things to be compromised when other pressures arise, such as time and budget constraints. To protect this precarious value, progressive public institutions and governments have been compelled to create laws, regulations, and policies that oblige accessibility. However, laws, regulations, and policies are very blunt instruments. They are most effective in changing behavior when compliance can be easily tested using consistent, objective measures. Creating clear, concise, objectively testable criteria inevitably requires reduction and compromise. It does not lend itself to enumerating the broad, complex spectrum of diverse needs. Thus certain needs are inevitably left out or compromised.

The Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C) is the primary manifestation of the movement for digital equity for people with disabilities (https://www.w3.org/WAI/). The Web Content Accessibility Guidelines (WCAG), one of three foundational sets of WAI guidelines, are embedded in laws, regulations, and policies in many jurisdictions around the world. The WAI has produced and maintained three sets of guidelines:

1. **Web Content Accessibility Guidelines or WCAG 2.0** (Caldwell et al. 2008) define how to make web content more accessible to people with disabilities. The guidelines are divided into four overarching principles:
   – **Perceivable** – Information and user interface components must be presentable to users in ways they can perceive. This means that users must be able to perceive the information being presented (it can't be invisible to all of their senses).

- **Operable** – User interface components and navigation must be operable. This means that users must be able to operate the interface (the interface cannot require interaction that a user cannot perform).
- **Understandable** – Information and the operation of user interface must be understandable. This means that users must be able to understand the information as well as the operation of the user interface (the content or operation cannot be beyond their understanding).
- **Robust** – Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies. This means that users must be able to access the content as technologies advance (as technologies and user agents evolve, the content should remain accessible).

Although the WCAG guidelines address barriers to accessibility in web content, they can be applied to all digital content. WCAG also includes useful techniques and documents that demonstrate how to develop accessible multimedia content. Following these guidelines removes barriers to content and user interface transformation, making it possible to personalize Web-delivered learning resources.

2. **The User Agent Accessibility Guidelines (UAAG) 1.0** (Jacobs et al. 2000) and 2.0 in draft (Allan et al. 2010) guide

> developers in designing user agents that make the web more accessible to people with disabilities. User agents include browsers, browser extensions, media players, readers and other applications that render web content. A user agent that follows UAAG 2.0 will improve accessibility through its own user interface and its ability to communicate with other technologies, including assistive technologies.

3. **The Authoring Tool Accessibility Guidelines (ATAG) 2.0**
Richards et al. (2015) provide information to web authoring tool developers about how to design tools that will produce accessible web sites as well as how to design authoring tools that have accessible interfaces. The purpose of these guidelines is to make it easier for web developers to produce accessible content even when they are not aware of or motivated to follow accessibility guidelines and to enable individuals with disabilities to participate in the construction of web content. Authoring tools that comply with the seven guidelines of the ATAG document can support accessible web authoring through prompts, alerts, checking and repair functions, and help files and automated tools. Additionally, the authoring tool will be accessible to authors with disabilities. The goal of ATAG is to encourage development of accessible web content that reaches a broader, more diverse audience as well as enable individuals with disabilities to participate fully in web culture as active creators of content.

The Challenge of Enforceable Regulations

The simplest, most easily enforced, interpretation of accessibility is an absolute definition. Any relative framing leaves room for subjective interpretation and compromises compliance testing and enforcement. This creates a dilemma in the global community that supports digital inclusion for people with disabilities. Absolute criteria inevitably compromise or negate accessibility for individuals at the edges of the jagged spectrum of human needs or individuals that don't fit established categories of needs (e.g., individuals with multiple disabilities, individuals with disabilities that don't as yet have an associated advocacy group). These individuals are therefore, also, most vulnerable to exclusion. On the other hand, relative criteria are largely impervious to enforcement. One approach to addressing this dilemma is to require interoperability, open standards, and open formats and thereby protect the opportunity for diversification and enable the creation of variants. However, for companies that view accessibility as merely a legal risk and rely on closed, proprietary business practices, this demand for openness is seen as something to lobby against. The struggle for greater accessibility through regulations then becomes a battle of influence between established industry and advocates for excluded consumers.

Laws, regulations, and policies are also slow to change. Therein lies a further dilemma for legally enforced digital inclusion. The pace of change in the digital domain is unprecedented. Survival within the digital market requires constant innovation and responsiveness to this change. Laws that constrain freedom of movement within this environment are seen as hostile to innovation and corporate survival. Many strategically wily corporations have walked the fine line of obstructing regulations without the public appearance of hostility to accessibility and the associated public relations mistake of showing lack of concern for people with disabilities (Stienstra et al. 2007).

Diversity-Supportive Regulatory Design

Ironically, therefore, movements to legally enforce digital inclusion have been pushed to support inflexibility and to oppose innovation. To support diverse learners requires flexibility. To address unmet needs requires innovation. Several promising alternative regulatory designs have emerged, but these have not received the popular support that prescriptive accessibility checklists have received. One reason may be that popular support favors simple, literally graspable concepts rather than nuanced and indirect strategies.

Legislative strategies that are supportive of diversity and innovation include:

1. Providing a process to validate new strategies that achieve equivalent accessibility as the criteria in a regulation. This would facilitate innovative advances and would also provide a mechanism for updating the regulations.
2. Giving priority to strategic pivot points, or common meeting places that enable divergence and diversification, such as requiring open interoperability standards that allow alternative access systems to more easily connect, and open formats that can be played on a variety of browsers and players.
3. Regulating a process that results in inclusive design rather than requiring a specific outcome. This would encompass prioritizing regulations that require

that the tools used to create digital content and interfaces support designing for diversity. This approach would have the advantage of requiring compliance and understanding from a much smaller group of legally obligated entities, namely, the developers of authoring tools rather than the myriad of web content authors. An example of this strategy would be to give priority within the global Web Accessibility movement to authoring tool guidelines that represent the process, in contrast to web content guidelines that represent the outcome or product.

Compounding the phenomenon that popular support favors simple and direct ideas is the tendency to also favor immediate or short-term rewards. This combination may cause the bias against systemic interventions. System-wide interventions are more diffuse but afford far greater and more lasting impact. These interventions include:

- Requiring education and training of future producers and suppliers to include an understanding and competency in designing for diversity
- Ensuring that currently excluded individuals can participate not only in the consumption but also in the production of knowledge and products
- Requiring the participation of diverse perspectives in decision-making bodies that influence socio-technical directions

Aligning Open Education Resources with Accessibility

The legislative compromises that the accessibility field has had to make, to create regulations that can be broadly understood and enforced, has meant that the accessibility movement has become misaligned with the OER movement. OER are a potentially powerful ally that favors diversity and the innovation that is birthed by variability in education. The OER ecosystem boosts flexibility and the more long-term systemic growth that supports the emergence of designs that span the spectra of human diversity. As far as OER provide a means to create a rich array of choices, and a process for finding satisfying choices for the full diversity of students, the OER ecosystem will offer more inclusive and long-term digital equity in education. The largely unregulated, organically organized, opportunistic OER production effort, however, does not naturally lend itself to absolute criteria. Publishers that see OER as a threat have used this to their advantage and have claimed that the adoption of OER in formal education systems should be disallowed because they do not adhere to accessibility laws. A simple response, which has yet to be formally articulated by the adjudicators of this struggle, is that compliance with accessibility requirements should be judged at the system level rather than the individual resource level. Thus if the pool of resources offers options for the full diversity of learners, it is compliant with the accessibility requirements, and each resource does not need to meet all the fixed criteria. This would reduce the compromise that students, which don't fit defined categories or criteria, need to make. It would also support the innovation that comes from diversification.

This however requires a system that matches the diverse individual requirements of students with a satisfying resource or learning experience. Resourceful parents, educational assistants, and teachers have been attempting to perform this function. OER portals such as OER Commons (https://www.oercommons.org) and GOORU (https://www.gooru.org/welcome/) have begun to integrate search features that stretch to the edge requirements of students with disabilities.

The FLOE Project (http://www.floeproject.org) is helping to provision the OER ecosystem with an infrastructure or platform to deliver a learning experience that matches the needs of students with learning differences. FLOE aims to use the platform model to pool and share reusable resources and supportive tools that enable a growing, diverse global community to create a rich pool of learning experience variants. To achieve this ambitious goal requires OER resources that are amenable to reuse a large, diverse pool of OERs. If the default OER is inaccessible to a specific student, the inclusively designed system would either:

(a) Transform the resource (e.g., through styling mechanisms)
(b) Augment the resource (e.g., by adding captioning to video)
(c) Replace the resource with another resource that addresses the same learning goals but matches the learner's specific access needs

To achieve this functionality requires:

- Utilities that help learners discover, explore, refine, and declare their learner preferences (thereby also supporting learning to learn and metacognition)
- Markup, metadata, or algorithmic means of locating resources that match specific learner needs or preferences
- A private and secure means of storing and transporting personal learner preference files from one learning experience to the next
- A matching service that can reconfigure, augment, or search and find a resource that matches a learner's preference specifications
- Supports to help OER producers to create reconfigurable resources and provide helpful metadata regarding the learner preferences the resource can match. Ideally these supports should be embedded in the tools used to create OER

The FLOE Project has created the necessary pluggable building blocks that are being integrated into projects that deliver OER. Fortuitously these steps are not foreign to the OER effort but can be seen as impetus to advance the OER agenda as a whole. However this approach is helped by conceptual and practical adjustments in both the OER and accessibility communities. The approach requires that the OER community:

- Fully adopt and support the principles of cumulative authoring, derivative works, reuse, and repurposing that is already a part of the OER mantra
- Improve learner-focused resource discovery and the prerequisite labeling

- Promote an authoring attitude that lets go of the tight control on a fixed presentation or rendering
- Invest further in a learner-centric approach to resource design
- Commit to support open interoperability standards for both file formats and programming/scripting environments
- Support open source tools with open communication protocols to enable interoperability with assistive technologies
- Improve portability or device independence of resources

The accessibility community must:

- Adjust the interpretation and implementation of accessibility legislation and policy to judge accessibility by the ability of the system (rather than each resource) to address the individual needs of each student; notably this does not require that the letter or spirit of existing legislation be changed, only the interpretation and implementation
- Recognize that OER are a viable alternative to the complex, confounding, and deeply entrenched Digital Rights Management conundrum that is consuming so much accessibility effort and passion
- Let go of the focus on equivalent content and focus on equivalent learning
- Recognize that in the digital realm it is possible and effective to shift from a one-size-fits-all to a one-size-fits-one approach to providing universal access

A growing community of interest in OER accessibility, including the FLOE Project partners, supports this shift in both communities through practical tools, advocacy, and education.

The following diagram provides an overview of the FLOE process and infrastructure (Fig. 1):

FLOE leverages an international interoperability standard called AccessForAll. This is expressed both as an International Organization for Standardization (ISO) standard (ISO/IEC 24751) (http://www.iso.org/iso/catalogue_detail?csnumber=41521) and an IMS specification (IMS AccessForAll) (Jackl et al. 2004). AccessForAll supports a common language for describing personal needs and preferences (or student accessibility requirements) and a common language for describing resources that might match the needs and preferences.

Diversity-Supportive Pedagogy

Several pedagogical movements assist in the changes required by the individualized AccessForAll approach to learning design. AccessForAll and FLOE are well aligned with pedagogical models that support accessibility and equity such as Universal Design for Learning (UDL) (Rose 2000) and differentiated learning. UDL promotes three principles:

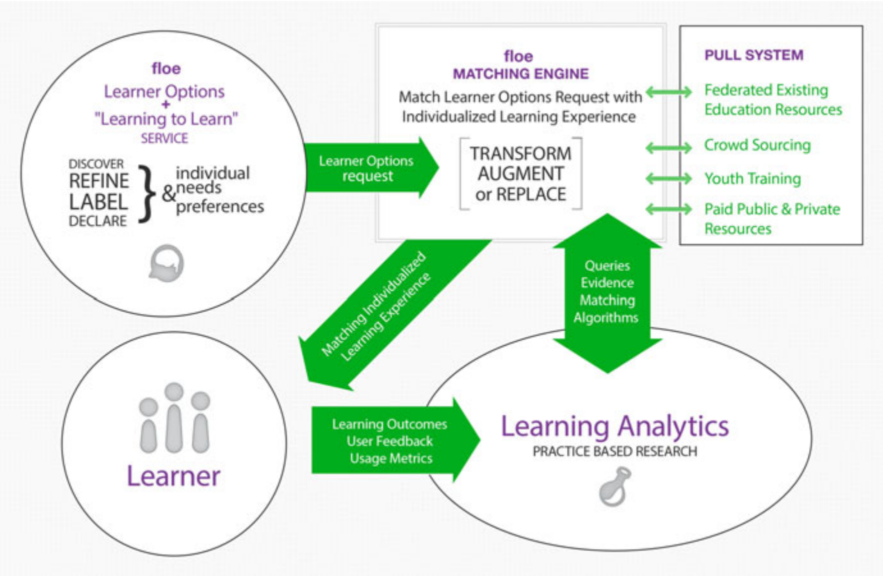

Fig. 1 The FLOE ecosystem enables the learner to refine their understanding of their needs and preferences, request a matching resource, and provide feedback regarding the match provided. This feedback provides important evidence regarding what works for learners who are outliers

- Principle I: Provide Multiple Means of Representation (the "what" of learning). This addresses perception, language, expressions and symbols, and comprehension
- Principle II: Provide Multiple Means of Action and Expression (the "how" of learning). This addresses physical action, expression and communication, and executive function
- Principle III: Provide Multiple Means of Engagement (the "why" of learning). This addresses recruiting interest, sustaining effort and persistence and self-regulation

FLOE can be said to be the network-enabled instantiation of these pedagogical frameworks.

Personalization

Projects such as FLOE, which implement AccessForAll, are also aligned with diversity-supportive e-learning trends toward personalization. Both are promoting one-size-fits-one education rather than one-size-fits-all education and the rejection of mass, "cookie-cutter" education. The trend to personalization is in part motivated by evidence that better learning outcomes are associated with personalized learning (Beetham and Sharpe 2007).

The label of personalization has been used to cover a broad range of very different initiatives. These initiatives differ in the following ways:

1. What is personalized, including the:
   - Path or sequence of steps to achieving a learning outcome, including repetition of specific items
   - Pace or how much time is devoted to each part
   - Personalization of the content used, including using local information, a favorite topic (e.g., teaching math using dinosaurs), using first and second languages at the same time, etc.
   - Presentation of the content including the style of text, magnification, color contrast, spacing and layout, density of content, etc.
   - Modality of delivery including video, audio, text, images, immersive content, etc.
   - Degree and type of interactivity, including games, quizzes, collaborative exercises, etc.
   - Form of pedagogy used, including constructivist, didactic, experiential, project based, problem based, collaborative, competitive, etc.
   - Form of motivation, including external feedback, internal feedback, affinity topics (e.g., trains, panda bears, or currently popular personalities), peer support (e.g., buddy system)
   - Form of social support, including peers or instructor
   - Scaffolds provided, including prompting, calculators, dictionaries, thesaurus, etc.
2. What kind of learning trajectory or plan is supported? This could include the following forms of planning:
   - Predetermined by education authority or instructor
   - Self-guided by students themselves
   - A formal and constrained trajectory
   - A responsive and opportunistic learning plan
   - A life-long learning plan that has no terminus
3. Who decides what and how things are personalized? This could include the following strategies:
   - Machine intelligence makes the decisions based on fixed algorithms or adaptive algorithms (and either informs the learner or does not inform the learner).
   - Educators or teachers control the factors to be personalized.
   - The learner is informed about the choices and what has worked for them and decides what is personalized and how it is personalized.
4. What data is used to guide personalization? This includes:
   - Personal data for each student
   - Representative data from previous students or a pool of students
   - A combination of representative data and personal data
5. Who the data is presented to? This includes:
   - The machine intelligence engine and company creating it
   - The students and learners themselves through dashboards and visualization tools
   - The teachers and educators

Metacognition, Smarter Machines, and Smarter Students

Projects such as FLOE differ from mainstream personalization initiatives in one important respect. Personalization initiatives are often used as a raison d'être for applying artificial intelligence to education. Adaptive education systems make data-backed decisions regarding the learning design that will bring optimal results for a student (Schunk and Zimmerman 2008). The FLOE Project is guided by the ethos that students should become experts in their own learning and that students should be able to experiment and draw conclusions about what works best for them. The FLOE Project asserts that machine learning should not supplant student metacognition, self-regulation, and self-determination but assist students in making informed decisions about their own learning requirements. FLOE and similar projects also support students in developing their own learning plan.

Becoming an expert in your own learning requirements rather than leaving this up to a data-driven inference engine is better suited for students who are outliers (Treviranus 2014b). Research, including big data and learning analytics, aspires to draw generalizable conclusions that can be applied to the majority, or a large prescribed group, with predictable results. The veracity of the conclusions depends upon an accurately representative group of "subjects," and the accuracy of predictions depends upon statistical power through numbers. By definition these generalizations do not hold true for learners who are outliers. This is in large part due to the fact that there are no representatives that meaningfully reflect the unique interconnected complexity of requirements to be represented, let alone a large enough group of representatives to garner conclusive results. The only viable alternative is to represent yourself and to iteratively discover and refine your understanding of your own learning requirements with the help of supportive facilitators or tools. Tools can support this discovery by measuring and presenting "small" (personal) and "thick" (contextualized) data about the conditions under which you learn best for a given context or learning goal, allowing you to refine these conditions and monitor the results (Welles 2014). Taking from models in sports and gaming, students can hone their learning performance.

Quality Control

Prescriptive quality standards, especially centrally controlled determination of quality, are often an impediment to more diversity-supportive inclusive design of formal education. Ironically, safeguarding equal access is frequently used as the motivation for centrally imposed quality standards (Goldberg and Cole 2002). Unfortunately this removes self-determination from teachers and students and restricts leeway for diversification and thereby customization and personalization or designing for diversity. However, common education standards such as the US Common Core can be used to provide useful descriptive metadata regarding the learning goals met by a learning resource (Achieve n.d.). When this is combined with accessibility metadata or metadata regarding the accessibility requirements met by the resource, this Common Core metadata can be used to find learning resources that address personal needs and also achieve an equivalent learning goal.

New Challenges for Inclusive Design

The tension between a one-size-fits-one and a one-size-fits-all "checklist" approach to accessibility and inclusion becomes even more complicated as learning resources become more interactive, multimodal, immersive, and collaborative. This is especially the case for learning experiences that do not translate easily from one sensory modality to another. It can often be argued that a legally accessible learning resource is not an equitable learning resource.

For example, a text description of an interactive science simulation is not an equivalent learning experience and is not likely to achieve the same learning outcome. A real-time sonification of the simulation that matches the student's personal mental models and codification of sounds would be far more equitable. A partnership between the University of Colorado's PhET project and the Inclusive Design Research Centre is developing a framework for sensory translation from vision to sound (real-world audio combined with speech) that enhances the experiences of the simulations for all students (https://phet.colorado.edu). The IDRC is also developing a means to express charts and graphs through sounds. Students can choose a sound codification system that makes the most sense to them (e.g., a long tone for tens, followed by short sounds for single digits to indicate the size of a pie slice; see http://floeproject.org). Both the DIAGRAM Center in the United States and the Inclusive Design Research Centre in Canada are exploring the use of 3D printing to create tactile models for individuals that cannot see images (http://diagramcenter.org). Both initiatives are also exploring the combination of audio and touch, whether it is tactile graphics and audio in the case of the DIAGRAM Center or haptic artifacts and effects (e.g., flow of river, extrusion of province or state to feel the boundaries better, effect of elastics to indicate latitude and longitude) combined with audio for maps and geographic information in the case of the IDRC (Treviranus 2000).

A text caption of an evocative piece of music is not as instructive as the original. A visualization of the music accompanied by vibration, such as provided by the "Emotichair" developed at Ryerson University, is much more equivalent for someone that is deaf (Karam et al. 2010). The Emotichair project translates sound to vibration and provides a means of composing vibro-tactile music, thereby enhancing the experience for both Deaf and hearing students.

A text description of an immersive environment is not equivalent to exploring the space. A responsive 3D soundscape that can be explored, with speech labels that can be selected according to the student's interests, would be far more equitable. These are experiences that are being explored by a number of museums including the Virtual Museum of Canada (http://www.virtualmuseum.ca).

One currently unsolved challenge is interactive collaborative experiences in which the collaborators each have different preferences or requirements. This can be resolved if the collaborators are remote as they can each have a personalized view of the interaction, but becomes more difficult if collaborators are sharing an interface. The Canadian Museum for Human Rights (https://humanrights.ca) has implemented multi-touch tables in which each zone can adapt to the needs of the user, but the overall experience continues to be collaborative. Another very promising practice is to enlist peers to provide and refine translation. This works best if it is supported in the collaborative interface.

Inclusive Life-Long Learning

Socio-technical trends and the inevitable transformation of work require a rethinking of education. Education suited to emerging realities inevitably includes radical diversification and continuous refreshing of competencies only achievable through life-long learning. To supply this diversified and perpetual education requires self-guided learners. However, the structural barriers to an approach that supports students in fully taking control of their own learning are many. Education itself has a history of paternalism and the belief that students do not know what is best for them. Students who have disabilities or students who are at risk often face a strange duality of infantilization or demonization. Either there is an added layer of protection or assumed vulnerability and incapacity or the students are distrusted and blamed for failure (especially students who face mental health issues or invisible disabilities or who don't "respond to treatment") (Epp 2003). Any understanding of the students' "condition" is usually hidden from them.

Our systems of education must also recognize the beneficial role of mistakes and failure. Using failure and error as a tool for learning is rare. Learners with disabilities are often protected from failure. In education failure is viewed as deterministic; it is used to predict all future performance, putting students further at risk.

Standardizing, establishing norms, and corralling and guiding performance through measurement (e.g., bell curve) or statistical evidence are inextricably fused with the values and aspirations of formal education. Individualization would lead to divergence and would reduce control. The individually chosen approach would not conform to the target metrics set up for formal education systems, causing systemic disruption to established reward systems (e.g., student awards, educator promotion, and institutional ranking). It is uncertain at what point formal education systems would be willing to risk devolving quality control to the student and supporting each student in refining their own learning performance.

However, an established phenomenon in inclusive design is that designing for the margins benefits the majority (Jacobs 2002). A mass approach to education has many casualties. All learners are multifaceted and unique. The systemic advantages of diversity are well documented. Like all relatively free-form discovery, the necessary diversification of education and divesting of control to students is an evolving, messy, risky process requiring trial and error, play, mistakes, failure, and patience. Students at the periphery are practiced in navigating this type of terrain.

Conclusion

Evidence and exemplary models are mounting that resoundingly support the principle that designing for students with learning differences and stretching to make room for a diversity of perspectives in our formal education system benefits all students and society as a whole. To successfully serve the purpose of preparing all students to meet their full potential and become prosperous, self-guided contributors to our global community, formal education systems must undergo a significant culture shift. Students with learning differences may be the impetus that pushes our complex system of education to make room for diversity to the benefit of all.

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Organizing Learning Environments for Relational Equity in New Digital Media

70

William R. Penuel and Daniela K. DiGiacomo

Contents

Abstract

This chapter theorizes the notion of *relational equity* in the context of new media-supported learning environments. Drawing upon examples from multiyear investigations into the social organization of learning activity in an elementary afterschool program in Colorado and an adolescent music and journalism production program in California, we outline an emerging framework for how to organize learning ecologies in ways that encourage more symmetrical relations among adults and youth across various lines of difference. In articulating design principles at the

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level of the technology tool, the social interaction, and the broader learning environment, this chapter offers empirically grounded insight for those interested in organizing learning opportunities with new digital media in expansive and equitable ways. Further, it makes visible how attention to (in)equity must not constrain itself to one place, space, or time – cognizant of the ways in which power operates through a multiplicity of relations and processes that serve largely to reproduce inequality in society. It is with this understanding of power that we foreground the ways that new educational technologies might reorganize social relations in educational practices in schools and the community, with careful attention to how such technologies might change the normative yet deeply entrenched relations of power and privilege that exist in contemporary societies.

Keywords
Relational equity · Digital media · Teaching and learning · Social relations

Organizing Learning Environments for Relational Equity with New Digital Media

Within educational research and practice, the notion of *equity* is broadly conceived of as the measure of fairness and opportunity within a given interaction, activity, or institution. Distinct from *equality*, a concept which falls short due its guiding assumption of a level playing field (Chang 2012; Carter and Welner 2013), equity in education is about recognizing and attending to the unequal ways in which opportunities, spaces, policies, and/or systems are distributed. It also takes into account how this distribution provides advantages for dominant individuals or groups within particular societies and political economies while marginalizing nondominant individuals or groups. In the field of educational technology research, organizing for equity thus means attending both to the distribution of access to digital tools and opportunities to learn about and with them, as well as to the advantages such access and opportunity provide.

The access to valued digital tools and contexts to learn with them that members of some social groups enjoy is a function of the operation of power. Power, as we understand it, is not the property of an individual or an institution, but rather operates through a multiplicity of relations and processes that serve largely to reproduce inequality in society. As articulated by Foucault (1978), power is "omnipresent," that is, "not because it has the privilege of consolidating everything under its invincible unity, but because it is produced from one moment to the next, at every point, or rather in every relation from one point to another" (p. 93). It is with this understanding of power that we foreground the ways that new educational technologies might reorganize social relations in educational practices in schools and the community, with careful attention to how such technologies might change the normative relations of power and privilege that exist in societies. These relations today do not exist in a single public sphere, but in multiple "networked publics" (Varnelis 2008), that is, within different online and face-to-face places where we interact with others.

Organizing for "relational equity" is about working to foster relations in which *all* participants' sense-making is taken up and brought into joint activity in equally valued ways (DiGiacomo and Gutiérrez 2015). Working toward relational equity requires more than just attending to the unequal ways that social hierarchies of power structure social institutions and social interactions (The Politics of Learning Writing Collective 2017) – it requires that those in positions of relational power continually reflect and reposition themselves in activity in ways that trouble the unequal status quo. It also proceeds from the understanding that contemporary educational settings are organized in ways that privilege the experiences and knowledge of some while marginalizing, and often oppressing, those of others (Moll 1998). For example, contrary to a widely circulated rhetoric of equal opportunity within educational practice, racialized relations between a predominantly White teaching population and a largely Latina and Black student population continue to shape and delimit learning opportunities for Brown and Black youth (Matias and Zembylas 2014; Nasir 2012). Especially within our contemporary local and global climate of heightened racism, xenophobia, and nativism, we understand relational equity as integral to creating the conditions for young people to take on increased responsibility, to shape the production of knowledge, and/or to contribute authentically to the *telos* of learning activity.

Our chapter defines key principles for organizing learning environments that employ new digital media to promote relational equity, and we describe two examples of such environments. Both environments – perhaps not by chance – are out-of-school learning contexts, where young people participate by choice, where there is a purposeful effort to position young people as capable producers of knowledge, and where race, class, and disparities in access to resources and opportunity are focal within the design of the learning environment. In these environments, young people collaborate with peers and adults and use digital tools to play, make, or produce new meanings and imagine new ways of relating and being together. In this way, the kinds of learning supported allow adults and youth to use digital tools in ways that promote relational equity.

Defining Relational Equity

Relational equity is evident when educators design experiences that enable youth to discover new goals and possibilities through joint engagement with peers and adults in tasks where they make, produce, and critically reflect on new understandings of themselves, the world, and their relation to the world. Relational equity is *consequential* (Beach 1999) to the extent that these activities of making, production, and critical reflection also change people's relation to the world. To be sure, working toward relational equity does not free us from being a part of relations of power, but by critically reflecting on our relation to the world, we make what is taken for granted something human-made and malleable.

In a learning environment characterized by relational equity, expertise is brought and shared, as well as made together. People develop new forms of expertise by observing others performing tasks competently and pitching in to ongoing activities led by others (Rogoff 2014). The expertise needed in the learning environment is both related to the task at hand – whether that is making a new app or creating a social media campaign – and interactional. Interactional expertise entails know-how with respect to different ways to organize joint work successfully, which includes eliciting and making good use of expertise available in the environment (Edwards 2011). Sometimes, how people's expertise is relevant to a task is not apparent to others in a group, because we tend to rely on privileged categories of expertise, and we view people through these lenses. We are less likely to see easily – except when we collaborate to create new knowledge together and produce it unexpectedly – the expertise of others whose knowledge is not typically valued (McDermott and Raley 2011). Environments characterized by relational equity are counter-normative, that is, they challenge relations that typically exist in schools between teachers and students. As lead organizers of learning activity through lectures, assignments, or adult-led discussions (Gutiérrez et al. 1995), teachers often struggle to organize learning activity in more symmetrical and equitable ways. Transforming such relations requires a conscious attention to and reflection on asymmetries of power to which we have become accustomed in typical teaching and learning environments (Jurow et al. 2012).

Relational Equity and Learning with New Digital Media

This chapter focuses on relational equity in the context of learning with new digital media. To us, the term *new digital media* encompasses not only applications people use to compose, compute, draw, animate, and produce digital artifacts but also the digital locations where people can share artifacts with others, read or experience what others have produced, and obtain content that they remix for themselves. It contrasts with traditional educational technology applications primarily in the degree to which the notion of "producer" and "consumer" is blurred. Jenkins (2006), following Toffler (1980), calls the new user a "prosumer," which is part of what he sees as a new, participatory folk culture in which participants reshape media content to serve their own personal and group interests.

In this sense, learning with new digital media involves *production for others*. In the process of producing things for others, people imagine audiences whose thoughts and actions they hope to influence and whose responses will shape their own assessment of what they have produced. Critique inheres in the process of production, as learners "produce these imaginary contexts by conjuring hypothetical scenes, responses, and consequences for the decisions made within the process of production (Soep 2006, p. 754). Further,

> Learning is, in its manifestation through critique, a way of making. Young people in critique are constantly producing contexts for learning, producing situations in which they need to act and judge. And they are constantly reorganizing their environments in ways that extend their situated cognition beyond a given here and now – a video shoot in an alley within a crisis of choreography, an e-mailed refusal to make changes to a poem – into a future beyond that moment. (Soep 2006, p. 754)

Below, we describe how production with new digital media can support relational equity, as well as the pedagogical foci that support this aim.

Supporting Discovery of New Goals and Possibilities for Relating to Others

One of the ways young people can learn in production is through experimenting with different tools for producing new digital media content. Video production has long been a means to support youth in both developing new skills they might apply in the workforce and as a means of finding new means for self-expression (Goodman 2003). Today, audiences for video can be reached more broadly through a wide variety of free sharing platforms, and young people are using digital video to share visions for social change, attempt to change broad social norms, and influence policies at the local, state, and national level (McDermott et al. 2015). These platforms are relatively easy to use, but there remain advanced skills in production that have value to youth in the marketplace, if they have opportunities to develop those skills (Soep 2014).

A wide variety of new materials associated with the "Internet of Things," in which a variety of "smart" objects are networked together, enable young people to discover entirely new forms of self-expression. For example, "BlockyTalky" is a set of hardware and software that enables learners to create their own networked devices that can perform different tasks and that bridge the digital and material world (Shapiro et al. 2014). Through using these tools, youth can learn introductory principles of programming, robotics, and setting up digital communication networks. Collaborative design with BlockyTalky enables very different possibilities for interaction and for promoting equity than production with laptop and desktop computers, where keyboards are the primary means by which young people can share in the effort. Multiple interfaces and devices enable very different configurations of young people, even challenging us to define and measure "equity of participation" in new ways (Deitrick et al. 2016).

Supporting the Development of Expertise for Co-producing New Media

Some of the pedagogies for developing new media expertise are "school-like" in that they involve learners in acts of interpreting and making sense of texts and multimedia products that others have produced, or even acts of "overt instruction" (The New London Group 1996, p. 86). For example, young people might engage with case studies of how others have managed or mismanaged their digital identities (Soep 2014). They might receive instruction and practice in how to evaluate critically different information they find on the Internet (Britt and Aglinskas 2002). Young people might, as part of a course, be asked to "remake" a media product in a way that frames it critically, that is, makes clear how that product reflects or helps reproduce unequal relationships in society (Garcia et al. 2013).

There are other ways that young people can develop expertise in new media production. Young people can learn through legitimate peripheral participation (Lave and Wenger 1991) in ongoing professional activities, for example. That is a form of learning akin to an apprenticeship in which people contribute from the periphery to tasks that are part of a larger set of interlocking practices. From a relational equity standpoint, what is critical is that such apprenticeships are not exploitative: learners must have the opportunity to move flexibly and easily into new roles within activity and gain access through apprenticeships to valued networks (O'Connor 2003). There needs also to be an expectation that those in organizing roles learn from apprentices; that learning helps the relationship grow and transform over time into a clearly mutualistic one.

Another pedagogy that is particularly valuable for promoting relational equity is that of joint work. In joint work – as opposed to apprenticeship learning – youth and adults work side by side on goals that they mutually decide upon. For example, young people working side-by-side with adults on issues related to student voice might become fluent in communication tools and discover through their use of those tools to perform joint action how different groups use such tools to their advantage and to maintain power when others threaten it (Goldman et al. 2008). Or, by working side by side with adults to study issues of concern to them, youth may learn different aspects of social inquiry, including sophisticated forms of data analysis that can help them with arguments that persuade others to take action to address those concerns (Penuel et al. 2004).

How New Digital Media Can Support Alternative, More Equitable Participant Structures

New digital media technologies, with their emphasis on low barriers to entry, joint production, and shared, networked connection and expression, are well positioned to support alternative participant structures in learning activity with the potential for more symmetrical participation among adults and youth (Resnick and Rosenbaum 2013). Encouraging in-the-moment research using smartphones or tablets, for example, can support teachers in organizing for side-by-side learning on topics of interest to youth (DiGiacomo 2017). And inviting youth to share out their work by posting it on designed social media platforms not only encourages a sense of community by making visible the contributions of all participants but promotes opportunities to reflect, remix, and extend one's own thinking (Nacu et al. 2014). According to Barron et al. (2014), many tools for production today are free and give students the ability to create designs that previously could only be created by trained professionals. Used in this way, new media tools can serve in the development of alternative means for distributing youth work, as well as support the development of more equitable participant structures among adults and youth.

Arrangements That Help Adults Follow and Support Youth Initiative Rather Than Lead

Working toward relational equity requires purposeful attention to the spatial organization of activities and interactions, including the ways in which material and physical artifacts are engaged. Pedagogical arrangements organized to allow the adults and youth to be at the same height while engaging in activity, while manipulating a material medium large enough to allow for the simultaneous work of multiple hands, can serve to amplify and multiply the contributions of the youth in shaping the course of ongoing activity. For example, ensuring that the shortest participant's hands are able to reach the string lever and view the path of the moving marble on a Rube Goldberg machine might be a small but significant way of spatially ensuring that the youth's position within the activity remains equally valued throughout (Schwartz et al. 2015).

In the next section, we present two examples of projects that illustrate how new digital media can support relational equity in intergenerational learning environments. One focuses on teens and young adults and the other on preservice teachers and elementary-age students. Both are out-of-school programs, where – in our view – it seems possible for more equal teaching and learning relationships between youth and adults to emerge from joint activity.

Youth Radio: Amplifying Youth Voice Through Critical Engagement with Media

Youth Radio is an organization that prepares young people for communications and technology careers while also supporting critical forms of civic engagement supported by digital media. Youth in the organization develop and produce radio stories, blogs, online articles, and video. Though based in Berkeley, California, the organization has affiliate programs across the United States and operates bureaus in Los Angeles, Atlanta, and Washington, DC. The stories that youth develop appear in different media: on National Public Radio and American Public Radio programs, in periodicals, and on Youth Radio's website. In addition, youth in the organization's Youth Radio Interactive program have produced interactive websites and mobile applications that focus on issues of concern to youth and their communities.

By all accounts, Youth Radio is a successful program in promoting relational equity through its partnerships with media outlets and community-based organizations. The largely low-income participants not only experience individual academic success – 97% graduate from high school and 87% go on to college – but graduates have also gone onto successful communications careers and employment within the broader organization itself. Youth Radio's youth-driven stories have won acclaim and prizes (including the prestigious George Foster Peabody Award for journalism) for their critical examination of issues such as teen prostitution and hazing of gay military personnel. Their stories reach an audience of 30 million people, according to the program's website.

Through Youth Radio's different classes, internships, and jobs for youth, youth encounter professionals in radio, video, and music production, interactive application design, media studies, journalism, and education. These professionals act as teachers within programs, as production and story editors, and as mentors who broker youth access to further opportunities to develop academic and career skills. They engage young people in what Soep (2014) calls different "forms of know-how" that enable young people to use activities of production to "achieve desired effects on issues of public concern" (p. 51). These include using interactive storytelling to get the public's attention and influence viewpoints; designing platforms that invite members of the public to engage with issues in particular ways; identifying, interpreting, and representing data relevant to those issues; managing self-disclosure on the web; and mobilizing peers.

Youths' exposure to new media-related expertise isn't limited to what is available from adults in the program. Youth learn from near peers who have graduated from basic programs and become teachers in advanced classes. In addition, youths' stories put them in the community, asking questions and developing new expertise through their interactions with informants. In researching stories, digital media figure prominently. For example, in one of the award-winning stories focused on the hazing of a young gay sailor in the Navy, youth used a social media site for veterans and military personnel to locate the young man. They used social media as part of dissemination, adding materials to a website they could not use in the radio story to allow people to deepen their understanding of the issues raised in it.

The project's pedagogy can't help but be critical, given their commitments to supporting youth-driven storytelling. Youth stories inevitably push up against more traditional power relations that limit youth voice and access. As Soep (2014) describes it, when youth knowledge

> reflects unfavorably on powerful people, utilizing it can require sophisticated knowledge of everything from computer programming to stats to design principles to techniques for sweet-talking or bamboozling one's way into networks that have every reason to block youth. (p. 32)

Youth knowledge has a privileged place in Youth Radio. For radio spots, youth pitch stories that are rooted in their own interests and experiences. The form, tone, and angle of stories are all shaped by youth participants. The tone and angle of stories often cut against the grain of mainstream media portrayals of youth. The youth perspective explicitly "unsettles standard media conventions" (Soep and Chávez 2010, p. 56). Importantly, the adult guides in the setting are well aware of the challenge that youth's voice presents, that is, the ways that hearing youth voices on radio challenge the privilege that adult perspectives on youth institutions like schools have in most media accounts.

But adult expertise also shapes stories as they evolve. The process of story development itself helps to surface and develop expertise. It involves multiple occasions of what Soep and Chávez (2010) refer to as "collaborative framing," in which youth and adults shape one another's ideas as together they "confront obstacles, challenges, and unexpected curves in a story's developmental trajectory" (p. 57). Adults are especially helpful in guiding youth to help them anticipate audience responses and the potential impact of their stories on both listeners and the people they interview. Adults may also use their institutional positions, relationships with others, and past experience to help youth navigate difficult positions. For example, Youth Radio producers helped one interviewer assert their right to interview a student on a school site in the face of principal opposition. They made sure the student understood their rights ahead of time and how to present themselves as youth journalists seeking a fair, balanced account of a local movement to opt out of taking standardized tests.

The participant structures explicitly support side-by-side learning of youth adults in the process of story development. Youth facilitate editorial meetings, and adults have to request permission of youth facilitators to speak or comment. Youth pitch story ideas, while adults help them clarify their perspective and develop it. Because the stories have to do with youth culture and lives, adults often find themselves in the position of "learner" rather than teacher, lacking knowledge that youth have and that is essential to story development. Pitching stories based on topics of their choosing, young people in Youth Radio are "in a strong position to contribute knowledge informed by their own experiences, their social networks, and their research into wider social trends and public policy" (Soep and Chávez 2010, p. 50).

Another way in which adults follow – rather than lead – youth in Youth Radio is through the pedagogy of youth-led inquiry. Youth conduct investigations for stories, with suggestions from adults along the way. Through these investigations, youth develop initial ideas that often reflect personal opinion and experience into more multi-perspectival stories. In the process, they learn to "contextualize their own experiences" and how to situate stories within "wider debates that circulate around them" (Soep and Chávez 2010, pp. 63–64). They learn what it takes to convince others and themselves of the truth and value of a story through the process of investigating a story. Leaders within the program acknowledge that positioning youth in this way challenges power relations in the broader society, where youth are often positioned as learners not teachers and consumers of news rather than producers of it.

El Pueblo: A University-School Partnership Focused on Equity

El Pueblo is a maker-oriented afterschool program in the Denver suburbs that serves predominantly Latina, elementary-age students. Offered as an option for the students 3 days a week within the school's broader afterschool programming, El Pueblo is designed as playful learning environment that invites the young people and their adult guides to jointly engage in new media-supported activities such as digital storytelling and game design, as well as in making and tinkering activities like squishy circuits and scribbling machines. At El Pueblo, the adult guides are undergraduates from the nearby university who are enrolled in an upper division Educational Psychology class (most of whom are preservice teachers) and who are required as part of this course to attend the practicum afterschool site once a week. El Pueblo is an example of a university-school partnership aimed at supporting relational equity through its theoretically grounded approach to side-by-side learning as well as its strategic inclusion of digitally supported activities that allow for immediate feedback in activity.

In the Educational Psychology class, the undergraduates' coursework involves extensive engagement with sociocultural and critical theories of learning and culture (e.g., Vygotsky's theory of human development and Freire's pedagogy of the oppressed). Through a combination of lectures, discussions, reading and writing assignments, and hand-on activities, the instructors of the course encourage the undergraduates to examine their oft-unexamined assumptions about the practices of teaching and of learning, including how conceptualizations of culture intersect with issues of power and privilege within social relationships (Gutiérrez and Vossoughi 2010; Gutiérrez and Jurow 2016). The undergraduates are challenged to consider how these social relationships, constituted by discourse and the organization of interactions over time, mediate learning opportunities for young people. In particular, given the demographic of the El Pueblo practicum site (predominantly Latina, low-income children from and predominantly White, middle-class adults), the undergraduates are asked to critically reflect on the ways in which their own social positionality at the site vis-à-vis the children and other adults serve to both promote and delimit opportunities to learning meaningfully through joint engagement in site activity.

At El Pueblo, the undergraduates are also encouraged to consider the social organization of the activities in which they are participating with the youth. This means paying attention to the ways in which the spatial, material, and physical properties, as well as discursive practices, of the activities themselves both afford and constrain more or less equitable social engagements and pedagogical arrangements among the youth and adults in activity. The course instructors promote this type of attention in part by allowing time in class for the undergraduate themselves to think about how learning activities are designed by watching instructional videos and using a "social organization of learning" worksheet to document spatially the organization of material, physical, and discursive artifacts of the learning environment, alongside noting how these arrangements intersect with children's participation in activity.

By making the relationship between the undergraduates and the youth at El Pueblo an explicit object of analysis and design, El Pueblo attempts to lay bare the multiple levels of power and privilege that tend to inhere in traditional teacher-student relations in educational settings, in particular those among largely White teachers and students of color who attend the program. In so doing, the course-practicum experience works toward relational equity in one way by unearthing the human-made and malleable nature of such historically rooted relations in an attempt to reorganize them toward more equitable ends.

The course instructors of the Educational Psychology class encourage the undergraduates to leverage innovative designed learning activities that bring together insights from "making and tinkering" (Vossoughi and Bevan 2014; Vossoughi et al. 2016) and "scalable game design" (Repenning et al. 2015; Her Many Horses 2016). The learning affordances of certain making and tinkering activities, such as "squishy circuits" and "scribbling machines," have been documented to promote relational equity at El Pueblo due to the in-the-moment "material and relational feedback" of the activities (DiGiacomo and Gutiérrez 2015). In the case of 'squishy circuits' (see Johnson and Thomas 2010), as youth work together to create a circuit through the manipulation of insulating and conductive molding clay, LED lights, and wires, they receive immediate feedback regarding the viability of their design thinking, which supports their sense of ability and accomplishment in the STEM-related activity. At the same time, the immediate feedback stemming from the materiality of the activity itself makes room for the adult guides working with them to not only provide as-needed assistance but to witness the ingenuity in the moment of the youth's tinkering process (see also Resnick and Rosenbaum 2013).

In a purposeful attempt to position the youth as producers, rather than consumers, of the activities in which they engage, El Pueblo provides students with the opportunity to engage in practices of scalable game design. Cognizant of the racial disparity in access to and participation in high-quality computer science opportunities, Her Many Horses (an El Pueblo graduate researcher and site support) encourages the youth at El Pueblo to create their own video games by using the AgentCubes platform for game design. With the in-the-moment material feedback of the platform, the youth and adult guides are able to readily see the movement of the designed agents and their paths on the computer screen. And to increase autonomy over time on the part of the youth in the design process, Her Many Horses designed a web-based scaffolding tool that made the design process even more concrete and visible. As a result, the youth "not only completed the design process but also accessed much of the information that would help them to make their games" (Her Many Horses 2016). In this way, scalable game design serves as an activity at El Pueblo that promotes relational equity by working to shift the agency and responsibility in STEM activity design and action toward the youth.

Looking to the Future: Organizing for Relational Equity at the Community Level

In this chapter, we have outlined the importance of attending to relational equity when engaging with new digital media in educational practice. Cognizant of the "social hierarchies of power" that shape how learning ensues in and outside of the classroom (Philip et al., 2017), we argue for the need to explicitly organize learning environments in ways that continuously privilege the knowledge, experiences, and sense-making of those whose social identities have been historically marginalized. In particular, we have suggested the following considerations for creating the conditions for relational equity to emerge in new media-supported practices: attention to pedagogical arrangements, participant structures, support for the development of youth expertise, and space for the reimagining of social relationships. And in highlighting the cases of Youth Radio and El Pueblo, we have shown the ways in which programs can embody, through their design, aspects of relational equity.

The organization of these learning environments are ones that – despite being out-of-school environments – require similar kinds of efforts as designing classroom-based environments. They do not attempt to reorganize relations at the community or citywide level. Some emerging uses of digital media do in fact support broader efforts to promote more equitable relations and address historical inequities associated with the operation of power related to class and race in cities. Below, we present one such example in closing our chapter as an illustration of how the concept of relational equity might be applied at the community scale and in the context of contemporary movements to create more "smart and connected" cities and communities.

The example we offer for the potential of community-level transformation is the *Chicago City of Learning.* The Chicago City of Learning is a citywide partnership in which more than 170 organizations engage young people in roughly 4000 out-of-school learning activities. The partnership's website enables youth and their families to identify activities based on their interests. The website is also used to recognizing youths' accomplishments in these activities, recording digital badges such as "Science Research," "Robot Instructions," and "Peer Mentor."

A key aim of the Chicago City of Learning is to promote more equitable distribution of and access to learning opportunities across the city. To that end, researchers are mapping the locations and diversity of learning opportunities in each of the neighborhoods in the city. The partnership, for its part, is beginning to use these data to identify where there are "learning deserts" (Pinkard et al. 2016) and where new kinds of programs might be offered to support young people's interest discovery and development.

The Chicago City of Learning is exciting, because it shows the possibility for enhancing access to programs like Youth Radio and El Pueblo and for transforming the relations among programs. Ultimately, young people should have the opportunities not only to find programs like the ones we have highlighted nearby, but they should also know where they can develop advanced skills and connect with new people who share their interests across the city. The Chicago City of Learning partnership is intended to do just that.

Like the Chicago City of Learning effort, our chapter has been purposefully *utopian,* in that we point to ways that digital media largely might – but does not reliably or broadly at present – support relational equity in learning environments. We have envisioned a possible world in which youth produce new media tools and content side-by-side with adults to transform relations among groups in society and work toward more just social futures. We recognize that there are many obstacles to transforming social relations in inequitable societies and in political economies that regularly reproduce race, gender, and class-based hierarchies. But we think efforts to organize technology-supported learning environments ought to offer alternative visions for the future, rather than simply prepare people to live in and with inequity.

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Technology and Equity in Education

71

Mark Warschauer and Ying Xu

Contents

Abstract

The development and diffusion of information and communication technologies (ICT) is having a profound effect on contemporary education, which adds new elements to the long-standing issue of educational equity. This chapter aims to create a broad picture of the relationship between technology and equity in primary and secondary education by summarizing research literature on Socio-economic Status (SES), racial/ethnic, and gender differences related to technology. We organize our review around the framework of technology access, use, and outcomes. Regarding access, it is clear that gaps in home and school technology access are narrowing but still persistent across SES and racial/ethnic

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groups. Regarding usage, youth groups differ in the manners and the extent digital technologies are used at schools and outside of schools. Since there is a wide range of technologies available and groups' usage pattern varies among forms of technology, it is challenging to summarize a single trend of inequality of technology usage. Regarding outcomes, how the differences in access and usage affect the disparities in outcomes remains inconclusive. The challenge for the reader in consuming studies on outcomes of technology is that what is often reported as a result of using technology may in fact just be that two broad factors – technology and learning – are observed to go together but may not cause one another. The technology use may affect learning, or other factors, such as SES, may shape both learning and technology use.

Keywords
Technology access · Technology usage · Achievement gap · Twenty-first-century learning skills · Educational equity

Introduction

The development and diffusion of information and communication technologies (ICT) is having a profound effect on contemporary education, which adds new elements to the long-standing issue of educational equity. In many countries, the issue of educational equity typically centers on the disparities of academic achievement among groups of students, especially groups defined by socioeconomic status (SES), race/ethnicity, and gender. Therefore, when examining the relationship between technology and educational equity, research generally focuses on whether technology may exacerbate or ameliorate the achievement gaps or have no effect.

There are two existing perspectives regarding this relationship. On the one hand, technology access and usage in education are unequal across SES, racial/ethnic, and gender groups. Groups with lower academic achievement are generally less likely to access and use technology and thus may benefit from technology to a lesser extent than their more advantaged peers. This unequal access and usage may result in amplifying existing educational inequality. On the other hand, if deployed effectively, the affordances of technology in providing scaffolding and enhancing engagement can help facilitate learning of students with lower achievement, thus ameliorating educational gaps. Both perspectives are supported by a wide range of research. This seemingly conflicting evidence may result from methodological differences in the studies. For example, studies may be conducted in different contexts with diverse segments of the population and diverse forms of technology or interventions. Therefore, results generated from one study may not hold true in another context.

This chapter aims to create a broad picture of the relationship between technology and equity in K–12 education by summarizing research literature on SES, racial/ethnic, and gender differences related to technology. We organize our review around the framework of technology access, use, and outcomes (cf. Warschauer and

Matuchniak 2010). Research concerned with the inequality of access and usage of technology is generally descriptive, articulating the patterns of technology access and usage among different groups. Studies focusing on the inequality in outcomes prioritize the examination of the causal impact of technology access and usage upon a youth's learning. The challenge for the reader in consuming these kinds of studies is that what is often reported as a result of using technology may in fact just be that two broad factors – technology and learning – are observed to go together but may not cause one another. The technology use may affect learning, or other factors, such as SES, may shape both learning and technology use.

Access

The notion of technology access encompasses two components: physical access to digital devices (e.g., computers, tablets, the Internet) and access to digital content. Physical access to a device is a necessary first step for digital equity, but studies also have suggested that access to content that is both of high quality and educational value is a secondary concern. In this section, we will first examine the gaps in the two forms of access among SES, race/ethnicity, and gender groups and then link these gaps to the related social factors, both in home and school environments.

Access at Home

Home access is defined as a student having access to digital technology at home, regardless of whether it is a shared item in the household. However, despite the steady progress that has been made in boosting home technology access for minority and lower-SES households around the world, access remains unevenly dispersed, even within developed countries.

For example, in the USA, the overall home computer and Internet access divide as well as its evolution over time is well documented by several national reports, among which is the National Telecommunications and Information Administration (NTIA) report, based on the Current Population Survey (CPS). The NTIA report provides the most robust evidence on this issue. In the latest released report, household computer and Internet access continued to show an unbalanced pattern, with Asian or White, higher-SES, metropolitan households more likely to have access than their counterparts (File and Ryan 2014). This finding is consistent with common assumptions, as well as other nationally representative surveys (e.g., Anderson 2015). When longitudinally comparing the NTIA reports over a period of 15 years, we can see that as the technology access rate increases steadily across all groups, the gaps between more advantaged and less advantaged groups are narrowing but remain substantial (White House Council of Economic Advisers Issue Brief 2015).

Among those with Internet access at home, the conditions of access differ, ranging from access to broadband connections to relying solely on a cell phone data plan. Broadband offers Internet speeds fast enough to facilitate full interaction with advanced online platforms, while online activities via circular data plan are usually constrained by slower speeds. According to a report by Pew Research Center, for 7% of American youths, cell phones are their only means of accessing the Web (Pew Research Center 2015a). Those who are younger, of lower financial status, and with less education are more likely to fall into this category. Blacks and Latinos are also more likely than Whites to lack other means of accessing the Internet. However, on the positive side, the dramatic increase in smartphone penetration has helped bring the Internet in some form to those who lacked home Internet access (Connected Nation 2013).

While economic constraints tend to be viewed as the primary reason for the divides in home technology access, other social factors also play a critical role in this issue. For example, some literature emphasizes the importance of social support for technology access (DiMaggio et al. 2001). Many immigrant households may lack social networks that would enhance their opportunities to acquire digital access. In contrast, individuals with many friends and relatives who own computers and use the Internet are more likely to do so as well, because their network can help them acquire necessary technology skills, and they have greater return in using technology due to their large social network online. As Ono and Zavodny (2008) pointed out, these network effects to some extent explain why the divides in technology access reflect or even exacerbate the existing social inequality.

Examining inequality in the amount and quality of content available via home digital devices, it is generally hypothesized that youth groups who are more likely to access digital devices tend to be exposed to richer digital content. However, as it is implausible to comprehensively measure the volume and quality of the content a youth may access from their device, most existing research focuses on measuring the access to specific forms of content. For example, recent research has noted an "app gap," which refers to inequality of accessing educational applications on smartphones or tablets (Prensky 2012). These applications are frequently assumed to be beneficial for children. According to a study by Common Sense Media (2013), while wealthier parents load their children's iPads with brain-boosting educational apps, less advantaged parents rarely do so. This divide may reflect parents' perceptions about the value and role of technology. Lin et al. (2012) believed that lower-SES parents may have less confidence in teaching or regulating their children with digital technologies, thus leading to a lower likelihood of equipping their digital devices with educational content.

School Access

Technology investment in schools worldwide has increased substantially in the last two decades, on the rationale that digital access and usage improve learning. However, school divides in technology access have not yet been eliminated. Internationally, the gap in school technology access between developing countries and developed countries is, not surprisingly, large. While school technology access rates have almost reached saturation in some developed countries, such as the UK, Canada, and New Zealand, many developing countries are just beginning to introduce computers and Internet connections in schools. Within developed countries, gaps are narrowing but still exist. In the USA, for example, high-poverty schools still have fewer students per Internet-connected computer than low-poverty schools, and underrepresented minority students are less likely to have technology access at school than their White counterparts (Snyder et al. 2016). At the same time, only 16% of schools in poor counties (i.e., with county-level median household income less than $35,000) have high-speed Internet connection, whereas the percentage for schools in wealthier regions (i.e., with county-level median household income more than $35,000) is almost four times higher at 62% (Connected Nation 2013).

Similar to home access, school technology access is supported or constrained by economic factors as well as socio-technical contexts, often in ways that heighten educational inequity. Previous lessons have shown that, by merely increasing access to technology, schools may still not be able to take advantage of these facilities (see, e.g., Warschauer et al. 2011). For example, the Los Angeles public school system undertook a $1.3 billion effort in 2013 to give each teacher, administrator, and 640,000 pupils an Apple iPad preloaded with educational software. This program was seen as a way to boost the city's low-income students, who had limited access to digital education tools at schools until the program. However, the program did not achieve its original goal and soon resulted in a breakdown. After an investigation, the US Department of Education (2016) identified a lack of district-wide instructional technology strategy and insufficient instructional support of technology as among the causes of the failure. Recommendations made in the report include the following:

> Require each school to create a clear but light-weight Instructional Technology Plan aligned to individual school improvement goals. . .this plan should ideally include input from all stakeholders and be posted publicly for parents and community input. Pilot approaches for integrating technology professional development as part of the districts' overall professional development strategy.

These recommendations reinforce the complexity of technology integration, which goes beyond simply equipping schools with technological resources.

Usage

What is more critical of course than mere access to technology, both inside and out of school, is whether and how it is used. This is also often related to issues of SES, race/ethnicity, and gender.

Out-of-School Usage

The majority of youths from all SES backgrounds and racial/ethnic groups find ways to use digital technology. According to the research from the Organisation for

Economic Co-operation and Development (OECD), in 2012, disadvantaged students spent at least as much time online as their wealthier peers, on average across 40 OECD countries. However, despite the equivalent time spent online, different groups are found to use different devices and in different ways. Higher-SES teenagers were more likely to use the Internet to search for information or to read news rather than to chat or play video games (OECD 2016). This finding resonates with a survey in the USA, which found that lower-SES youths use technologies more for leisure rather than for learning-related activities, which is substantially different from those with higher-SES backgrounds (Rachel 2012).

This raises the question of whether more time using digital media adds or subtracts educational value. Researchers put forth the concept of the time-wasting gap, which refers to the disparity of time spent online for pure leisure by different population groups. This gap may produce negative effects for the youths who use technologies: the more time spent online, the less gained. Traditionally marginalized groups are believed to be more prone to this situation. Therefore, it is important to take the quality of technology usage into consideration. This is typically discussed around three common types of out-of-school technology usage: media consumption and creation, communication, and video gaming.

Content Consumption and Creation

Children consume content via digital devices in various ways, including viewing videos, browsing websites, listening to music, and reading eBooks. Among these activities, viewing online videos takes primary position. According to multiple sources, the average viewing time for teenage children of online videos may be up to an average of 3 h daily. However, not all groups spend the same amount of time watching videos. A study surveyed 2000 teenagers and discovered that those with low family income and low parent education levels tended to watch online videos 1 h more than their better-off peers (Common Sense Media 2015). Possible detrimental effects of video watching include distraction from time available for reading or studying, as well as negative effects from problematic programming, such as media portrayals of drinking and alcohol advertising.

Children also use a variety of tools to create content, including blogs, websites, videos, fanfiction forums, and programming. Researchers view the practices of content creation as a knowledge construction experience, in which children develop their skills as well as creatively engage with information. However, again, differences exist among groups. Lower-SES youths, while avid content *consumers*, appear to spend less time than higher-SES counterparts in content creation (Pew Research Center 2005; for a more recent study of college students, see Hargittai and Jennrich 2016). Differences in technology access and usage as well as motivation appear to be the factors that underlie and perpetuate differences in online content creation (Blank 2013). This gap in content creation could contribute to social inequality, both by limiting minority youth's opportunity to gain important skills that are necessary in the contemporary workplace and also by rendering their voice and opinions less likely to be heard by the public.

Communication

Digital technologies are seen by teenagers as a tool for social networking with their friends. Communication encompasses a range of older and newer forms of Internet communication such as sending email, instant messaging, blogging, going to chat rooms, and social networking communication. How children use online communication tools varies on two levels – whether they use particular tools or not and in which activities they engage. The variation in these two levels correlates with children's backgrounds to some extent.

Facebook is shown to be the most popular of all the social media platforms among teenagers, and background characteristics do not seem like a strong indicator of whether or not they use Facebook. However, the activities performed do vary along socioeconomic and racial/ethnic lines. Junco (2013) demonstrated that students from lower-SES environments were less likely to use Facebook for communication, connecting, and sharing, i.e., the exact types of activities for which Facebook was created. Another study revealed that lower-SES students were less likely to engage in classroom-related academic collaboration on Facebook than their higher-SES peers (Khan et al. 2014).

Concern thus arises that lower-SES students may not be able to take full advantage of online social networks to help strengthen real-world connections with friends and schools, as they perform activities that are less communication-oriented. Another contrasting view is that lower-SES students, with less social capital in the real world, may benefit from the virtual network more than their better-off counterparts. Relatedly, Wohn and colleagues studied the role of Facebook in the college application process of high school students. The authors found that, for first-generation high school students, Facebook use was associated with higher feelings of efficacy, thus facilitating their college application emotionally and practically. However, Facebook did not provide the same degree of help to students who had at least one parent who graduated from college (Wohn et al. 2013).

Video Gaming

Video games are pervasive among most teens – and, for boys in particular, video games serve as a major venue for the creation and maintenance of friendships. The amount of time teens spent on gaming varies little by family income, education, or race/ethnicity. However, nuances in gaming preferences and behaviors still exist among groups. First, SES appears to play an important role. A study in which 200 high schoolers were surveyed showed that nearly half of the low-SES students preferred sports-themed video game consoles, whereas only 20% of high-SES students reported this preference (Andrews 2008). In contrast, high-SES students were shown to be more likely to engage in literacy practices related to the games they played (e.g., view screenshots, use walkthroughs, post scores), while low-SES students rarely performed these activities (Andrews 2008). Additionally, higher-SES students appeared to be more likely to use networked games to connect with their in-person friends than their less well-off peers (Pew Research Center 2015b). This finding resonates with the results from other studies: higher-SES people tend to take better advantage of digital technologies for socializing and building relationships.

Regarding gender differences in gaming preferences and behaviors, in sharp contrast with boys' avid interest in gaming, girls generally reject being identified as "gamers." Among girl gamers, the majority reported favor for casual games with fewer challenges. In contrast to the majority of boys, who favored the sports genre, very few girls reported that they enjoyed these games (Andrews 2008). Some scholars suggest that high-challenging video games favored by boys may potentially foster interest for STEM careers, especially in computer science and engineering, or similarly develop technology skills helpful for those careers.

Usage in School Settings

Despite teenagers' frequent home usage of technology, their school technology usage is not paralleled. In most OECD countries, more than 80% of 15-year-olds use computers frequently, yet a majority do not use them much in school, even though most schools are equipped with computers and Internet access (OECD 2010). Among the schools using technology frequently, the ways in which they implement technology into instructional activities differ. It is generally believed that poorer schools tend to use technology for drill and practice activities, whereas in higher-SES schools, technology is exploited fully to enhance students' problem-solving skills (Warschauer and Matuchniak 2010). For example, findings from a recent study showed that students attending low-SES schools were given more limited opportunities to use technology to engage in student-centered critical thinking learning activities, compared with their counterparts in higher-SES schools (Lee 2013). And while computer-based writing and revision is viewed as a valuable activity for enhancing academic achievement (see, e.g., Warschauer 2011), the 2011 US National Assessment of Educational Progress (NAEP) found that only 33% of students who are eligible for free or reduced price lunch use computers very often for writing assignments in school, according to their teachers, compared to 51% of students who are not eligible for the national school lunch program.

The disparity in technology use patterns between higher-SES and lower-SES schools is believed to be a result of the interplay of economic conditions, teachers, social dynamics, and institutional culture differences. Among these factors, the most examined by researchers is teachers' knowledge, including their knowledge of using technology and the knowledge of integrating technology into teaching. First, the computer skills and knowledge of teachers are important determiners of the efficient use of technology. Since teachers in poorer schools are reported to receive less technology training, they may possess lower proficiency in using technology than teachers working in wealthier schools (National Education Association 2008). Second, teachers' knowledge in integrating technology matters. Teachers in poorer schools may have limited opportunities to understand how to use technology in ways that engage students in discourse with peers to collaboratively solve problems (see discussion in Kitchen and Berk 2016). As a consequence, students in these schools often work in isolation from their peers on digital devices, resulting in limited opportunities to develop their reasoning and conceptual understanding collaboratively.

In addition to the role of the teacher, technical support is another factor that influences technology use. Technical problems, such as slow network performance and inadequate computers, can make it difficult to use technology in classrooms, thus frustrating teachers. In a qualitative study comparing technology use in low-versus high-SES schools, Warschauer et al. (2004) found that high-SES schools tended to invest more in hiring full-time technical support staff than low-SES schools. Additionally, in high-SES schools, technology facilitators were selected from teaching staff, who received intensive in-service technology training. These facilitators provided technical and pedagogical support to their colleagues. Student aids were also trained to help in classrooms. These groups were facilitated by clear channels of cross-communication and coordinated effort. Low-SES schools in this study were less likely to have the same degree of interconnected support networks.

Outcomes

Important outcome measures from technology use include student attitudes, traditional school achievement measures, and twenty-first-century learning skills. A number of studies have looked at the relationship of technology access and usage to these outcomes, but frequently using non-experimental designs that are unable to identify the *causal* effect of technology access and usage from other unobserved differences across students and schools. Therefore, while reviewing these studies, we should keep in mind that the true impacts of technology access and usage on student outcomes may be over- or underestimated.

Attitudes Toward Technologies

As computer technology becomes ubiquitous in schools and the workplace, attitudes toward technology may be as important as skills in using a specific device. Individuals who view computers positively, and are confident about their ability to use computers, will be more likely to learn whatever new skills are required by future technological developments.

There is considerable interest in the literature in studying the influence of gender on technology acceptance. Generally, most of the earlier studies conducted before 2005 showed that males held a more positive attitude toward technology than females. These gender differences in attitudes may be caused by many factors. For example, some research has also suggested that the masculine image of the computer deters females from benefiting from technology, as this has made them less confident or more anxious (Culley 1988). However, a recent research has revealed changing attitudes among female computer users. Dündar and Akçayır (2014) studied 183 high school students in Turkey and found a lack of support for gender differences in attitudes toward computers. This lack of gender differences in attitudes toward computers could be attributed to the increased use of computers for teaching and learning in schools or in other settings. Females may have been socialized differently in today's digital era to become more comfortable with computers, which may serve as a good starting point to remove barriers to technology training.

Several studies examined differences in attitudes across SES and race/ethnicity groups. The "digitally disadvantaged" groups have been found to have similar beliefs in the usefulness of technology as their more privileged counterparts. Generally, youths believe that they can benefit from interacting with digital technology. For example, English language learner (ELL) students are reported to have high interest in using Facebook, Twitter, and text messaging for literacy learning purposes. These results may reflect their motivation to improve their English language skills through multiple exposures across multiple contexts, since these students typically do not have access to English in their home environment (Li et al. 2015).

Academic Achievement from Home Usage

A large body of research focuses on whether using new technology can help students acquire mastery of academic content. It is common practice for most researchers to use traditional school achievement measures to answer this line of related questions, due to the clarity of these outcome measures as well as their high level of acceptance among educators and the general population. These studies take one of two emphases: either examining the impact of technology availability (e.g., whether a computer is available at home) or the impact of technology use. Since youths can perform a wide array of activities on computers or tablets, the research on effects of technology use generally focuses on a more specific kind of activity such as Facebook use and video gaming, rather than vaguely asking the effects of "computer usage."

The results on the impact of home technology access are inconclusive. A few studies find significant positive effects on various educational outcomes such as grades, test scores, and cognitive skills (e.g., Fairlie et al. 2010), while an almost equal number of studies find evidence of modestly sized to significant negative effects of the use of home computers on educational outcomes (e.g., Vigdor and Ladd 2010).

Regarding whether home technology access may benefit underrepresented students' learning, one field experiment study that offered low-income high school students the opportunity to own home computers provides a compelling test (Fairlie and London 2012). Fairlie and his colleague conducted a randomized control experiment with 1,123 students in grades 6–10 attending 15 schools across California, USA. Although the experiment substantially increased computer ownership and usage without changing school technological environments, the research found no evidence that home computers had an effect (either positive or negative) on any educational outcome, including grades, test scores, credits earned, attendance, and disciplinary actions. A follow-up survey was conducted to provide information on several less-commonly measured intermediate educational inputs and outcomes such as homework effort and time, receiving help on assignments, software use, and computer knowledge. Consistent with the previous findings, access to a home computer did not yield any impact on these measures. This result indicated that computer ownership alone is unlikely to have much of an impact on short-term schooling outcomes for low-income children.

Another line of study regarding the association between different forms of technology use and academic achievement also finds mixed results. This may be because different forms of technologies each have their own unique affordances and thus generate different effects on users. Common themes explored by the researchers include video gaming, social media, and digital homework. Generally, nonacademic usage of technology (e.g., passive gaming, SNS) negatively relates to academic achievements, while home technology usage for educational purposes (e.g., serious gaming, accessing to educational information) is reported to have positive effects on academic performance (Biagi and Loi 2013).

Only a handful of studies investigated the effect of home technology usage on minority, low-SES teens. Jackson et al. (2006) conducted a longitudinal study to examine the impact of home Internet use on low-income family teenagers' academic performance. Participants were 140 teenagers, mostly African-American (83%), mostly boys (58%), and mostly living in single-parent households (75%) in which the median annual income was $15,000 or less. During the 2-year study, participants' Internet use was continuously recorded, including time spent online, numbers of domains visited, and numbers of emails sent. Findings indicated that children who used the Internet more achieved higher scores on standardized reading tests and higher grade point averages (GPA) than did children who used it less.

Academic Achievement from School Usage

Studies on the effects of school technology usage are more likely to adopt experimental design than those on home technology usage. Most existing literature is based on non-nationally representative samples and tests the effect of a specific kind of technology/intervention. Since these studies are highly contextualized, the results may not be interconnected. Several meta-analysis reviews have attempted to depict a broad picture from these mixed studies. For example, Zheng et al. (2016) reviewed 65 journal articles and 31 doctoral dissertations published over a period of 15 years (2001–2015) in order to examine the effect of one-to-one laptop programs on teaching and learning in K–12 schools. Based on a subset of these studies that met the requirements for meta-analysis, they found an overall significant positive average effect on academic achievement with effect size of 0.16. Significant positive impact on achievement was also found in the subareas of English, writing, math, and science.

Another important question is whether the use of laptops by diverse learners helps bridge the achievement gaps among student groups. The positive impact of school technological programs on disadvantaged students was identified in a number of studies (see, e.g., Warschauer et al. 2014). However, these positive goals for at-risk learners are not achieved in all programs. For example, a study in the USA explores the impact of one-to-one computing on student achievement in Ohio high schools as measured by performance on the Ohio Graduation Test (Williams and Larwin 2016). The sample included 24 treatment schools that were individually paired with a similar control school. Overall, examining the full sample, student performance and content-specific achievement in math, reading, science, social studies, and writing were not significantly affected by the introduction of the one-to-one program. However, when broken down into demographic groups, the results show that Black students in the treatment group performed lower than their peers in control groups.

These contradictory results initiate further investigations into the reason why technology access and usage generate distinct impacts on disadvantaged learner populations. Wenglinsky (2005) noted that "the drill and practice" activities favored in low-SES schools tend to be less effective, whereas the constructive integration of technology disproportionately found in high-SES schools achieves positive results. The author argues that it is not whether the schools use technology, but rather how they use it that makes the great difference. If used appropriately, technology does have the potential to enhance low-achieving students' learning through various pathways.

Some studies offer insight into how to maximize the benefits of technology for disadvantaged students. For example, some have found that when students are engaged in content creation projects involving technology, they demonstrate stronger engagement, self-efficacy, and attitudes toward school, thus enhancing their academic achievement (see, e.g., Sadik 2008). This may especially benefit disadvantaged students. Content creation projects include a wide array of activities such as engaging in multimedia content creation to communicate ideas about the material they are studying by creating reports, graphic representations of data they have researched or developed, websites, slides presentations, video production, digital storytelling, and other means. Darling-Hammond et al. (2014) described a technology-rich classroom for at-risk students, in which the teacher used one-to-one computers with wireless Internet connection to engage students in "word processing, spreadsheet, database, web page production and presentation software in a variety of contexts" (p. 9). Results showed that the students in this particular classroom ultimately outperformed other higher-tracked classes in their school in the state tests. According to the authors, the process of content creation allows students to develop their personal and academic voice with the scaffolding of technology. Due to their affective involvement with this process and the novelty effect of the medium, students are more engaged than in traditional assignments.

Citing research by Reeves (2004) and others, Warschauer (2011) argues that informational writing is a critical level for improving academic achievement among at-risk students and that technology-based writing instruction is thus especially valuable for promoting educational equity. He and his colleagues provide evidence from school districts with technology-based writing forms that have helped bridge performance gaps (Warschauer et al. 2014; Zheng et al. 2013).

Twenty-First-Century Learning Skills

Knowledge of core content is necessary, but no longer sufficient for success in postsecondary institutions and workplaces. Higher education and information economics place increasingly high value on people who can use their knowledge to communicate, collaborate, analyze, create, innovate, and solve problems. It is widely believed that technology use plays a pivotal role in helping students develop these so-called twenty-first-century skills. This broad concept can be categorized into three related skill sets: information, media, and technology skills; learning and innovation skills; and life and career skills. Even though we conceptualize twenty-first-century skills as a separate ability from traditional academic achievement for our discussion, these two components are highly correlated.

Ritzhaupt et al. (2013) provided a comprehensive examination of gaps in the three components of twenty-first-century skills among student groups. In this study, a large sample of students were asked to complete a performance-based assessment of digital literacy skills. Five domains were assessed: technology operations and concepts, constructing and demonstrating knowledge, communication and collaboration, independent learning, and digital citizenship. Results showed that high-SES and White students outperformed their counterparts in all domains. It is hinted in the study the divides in twenty-first-century skills may stem from different patterns of school technology use and out-of-school use among student groups.

In school settings, well-implemented technological programs are believed to facilitate acquisition of twenty-first-century skills. In a large-scale laptop program, for example, more than one-third of students reported using laptop from once a week to several times daily to gather and evaluate information, solve real-life problem, and visually present or investigate concepts. Warschauer (2006) interviewed teachers, students, and parents; conducted observations in the classrooms; and analyzed student work. He suggested that these kinds of learning activities may help enhance students' twenty-first-century skills and have important implication to other technology-based interventions.

Another question is whether low-SES schools provide students with equitable supports for achieving such skills compared with high-SES schools. A study demonstrated that students in lower-SES schools had less digital resources, used technology less frequently, and had more limited technical support and service, so as their teachers (Hohlfeld et al. 2008). These differences provided evidence of the existence of the divide in technology literacy among K–12 schools.

Youths could also develop their twenty-first-century learning skills from using technology in out-of-school environments. As at school, whether or the extent to which technology use can help enhance such skills depends on what kinds of activities youths perform with technology. Ito and her colleagues found that some youths are "geeking out" in interest-driven activities, which refers to an intense commitment or engagement with media or technology (Ito et al. 2009) and mastering sophisticated skills such as media literacy, creativity and innovation, communication and collaborations, and initiative and self-direction. Ito's interviews revealed some of the factors that may contribute to what she termed "information magic," including adequate access to technology, high levels of commitment, and "an advanced media ecology that is finely tailored to youths' interests" (p. 69).

Unfortunately, not all youths benefit from these kinds of digital activities at the same level. There has long been a concern that girls are not gaining the same knowledge and skills about technology that boys are, because of differential attitudes toward technology and use at home. Fields et al. (2014) mapped out the gender difference in the online Scratch community, by far the largest online informal programming community primarily for young programmers aged 11–18, where they post Scratch programs that they create, view and comment on each other's work, and seek and provide help on forums. Drawing on a random sample of 5,000 youth programmers and their activities over 3 months in early 2012, Fields and his colleagues found that girls only represented one-third of all registered members on the Scratch site. The authors then classified the users into four different levels (i.e., beginner, intermediate, advanced, experience) based on their programing work. Girls were dramatically less likely to reach advanced and experience levels than boys. Additionally, since low-SES and minority children are reported to use technology in a less sophisticated way outside of schools (see discussion in Warschauer and Matuchniak 2010), we believe these groups may less likely to gain technology skills from the usage than their counterparts.

Conclusion

The research reviewed above hints at the complexity of equity issues intertwined with the rapid expansion of digital technology and its impact on students' access, use, and outcomes. Regarding access, it is clear that gaps in home and school technology access are narrowing but still persistent across SES and racial/ethnic groups. Regarding usage, youth groups differ in the manners and the extent digital technologies are used at schools and outside of schools. Since there is a wide range of technologies available and groups' usage pattern varies among forms of technology, it is challenging to summarize a single trend of inequality of technology usage. Regarding outcomes, how the differences in access and usage affect the disparities in outcomes remains inconclusive. The lack of concrete conclusion may partially be due to the inherent difficulty of causal inference – that is, to prove access and usage of technology *causes* the change of students' learning outcomes. Additionally, the majority of existing literature concerned with outcomes is based on non-representative small samples and tests the effect of a specific kind of technology/intervention. The mixed findings are thus highly contextualized and noncomparable.

Future research is needed to offer deeper understanding of the relationship of technology and equity. First, descriptive research which only examines SES, ethnic/racial, and gender differences in access and use is important but not sufficient. The inequalities have been confirmed. The future task should be to understand the reason for these inequalities as well as the possible approaches to alleviating the inequalities, other than merely describing the problems. For example, how family contexts or school contexts influence teenagers' technology usage patterns may be an interesting question to explore. Second, to understand the outcomes of digital technology access and usage, it is crucial to have more studies with rigorous design, such as experimental research (e.g., random assignment, natural experiment) or longitudinal research. Third, researchers may want to further investigate the possible different effects of technology access and usage across SES, racial/ethnic, and gender groups, which may shed light on how technology may contribute to the achievement gaps.

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Advancing Equity Through Educational Technology: Promising Practices for Adoption, Integration, and Use in K-12

72

Molly B. Zielezinski and Linda Darling-Hammond

Contents

Abstract

School technology access has become an issue of international priority. With increased access to technology on the horizon, educators stand at a crossroads. Do they continue with the status quo or attempt to use the rising technology levels to support those students who need it the most? The work in this chapter aims to contribute to this dialogue in two ways. First, it introduces the Digital Learning Ecosystem as an empirically grounded framework that provides a holistic perspective of the mutually interdependent variables shaping a technology-enabled learning environment. In addition to proposing the Digital Learning Ecosystem, this chapter continues the tradition of identifying and sharing promising research-based practices that are empirically linked to improved learning outcomes by underserved students.

Keywords

Influence of technology · Technology uses in education · Technology integration · Elementary education · Secondary education · Disadvantaged youth

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Introduction

For many years, educators, researchers, and policy makers have looked to technology as a tool for closing the achievement gap. However, the results of various technology initiatives have failed to provide the silver bullet that proponents anticipated. As often as not, the introduction of technology into classrooms has failed to push the needle on student outcomes. Furthermore, the wide variability within and between classroom, school, and district technology access and use is consistent with notions of a growing digital divide (Gray et al. 2010a, b; Zielezinski and Darling-Hammond 2016) which serves to further the achievement gap rather than fix it. Beyond school walls, disparities in hardware ownership, Internet access, and access to community-based resources contribute even more to the troubling lack of digital equity and educational opportunity in the USA (Madden et al. 2013; Purcell et al. 2013; Barron et al. 2010). For many years, the focus has been on increasing access to technology to reduce the digital divide, and while addressing access is an essential element of this effort, increased access alone is not sufficient for improving educational outcomes for underserved students. Once *access* is granted, we must consider how technology can be *used* to support learning by those who need it the most.

To further develop the understanding of how digital tools can be used to support underserved and under-resourced students, we conduct a comprehensive literature review, taking into account more than 50 studies, white papers, reports, and reviews primarily published between 2003 and 2013 (Zielezinski and Darling-Hammond 2016). The focus of this work was on underserved, under-resourced, and underprepared students who have been placed at risk by the organizations that serve them and societal structures in which they live, specifically students in grades 6–12 who have been labeled as minority, low-SES, low achieving, or not on track to graduate. Moving forward, use of the term "underserved" in this chapter will refer to students with one or more of these social markers (This is not intended to be a comprehensive definition of "underserved." Instead it is the operational parameter used to delineate the scope of the studies reviewed.). In this chapter, we first introduce and describe the research-based framework called the Digital Learning Ecosystem that we developed for understanding technology use in schools. Next, we share the key findings from our comprehensive literature review (This chapter is adapted from an extensive literature review (Zielezinski and Darling-Hammond 2016) and US policy brief (Darling-Hammond et al. 2014). See the original literature review for methodological details and additional research-based examples of promising practices for digital equity.). We end the chapter with a synthesis of findings and conclusion.

Conceptual Framework and Methodology

The Digital Learning Ecosystem (see Fig. 1) was developed in our review process and is based on an in-depth analysis of 23 highly relevant reports and reviews that synthesize the findings from over 2,000 empirical articles about technology for

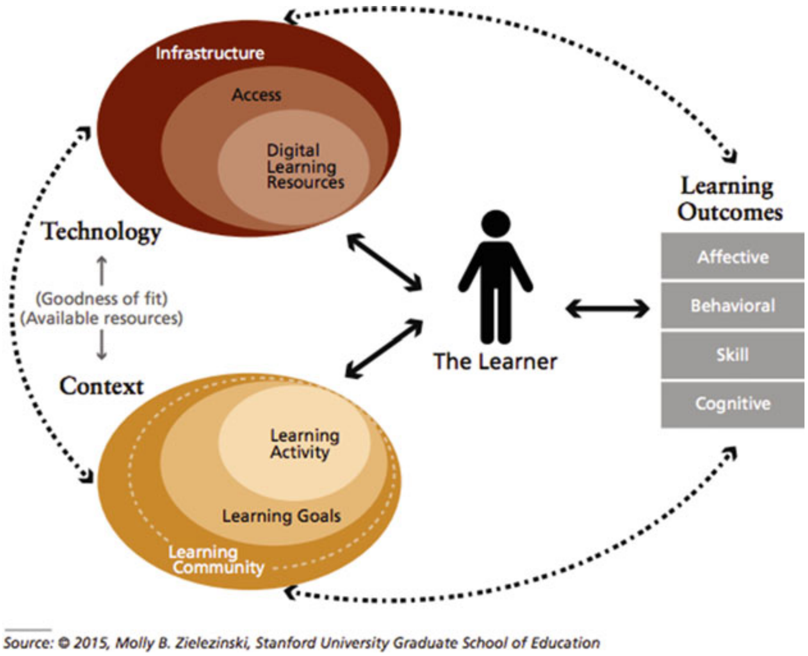


Fig. 1 The Digital Learning Ecosystem. (Source: © 2015, Molly B. Zielezinski, Stanford University Graduate School of Education)

learning (The initial 23 reports and reviews synthesized literature on digitally mediated learning for students in grades 6–12 but were not limited to literature specifically reporting outcomes for minority, low-SES, and underprepared students. This collection was used specifically to develop the Digital Learning Ecosystem as a frame for analyzing factors that influence learning with technology. Later, the literature search for empirical works specifically reporting outcomes for minority, low-SES, or underprepared students in grades 6–12 yielded 34 studies. These articles were coded and analyzed. Results of this analysis are presented in the findings section.). Taken as a collection, these reviews illustrated that learning outcomes are the result of interactions among numerous variables within a given learning environment. No single variable can ensure a desired outcome because learning environments are complex systems governed by sets of mutually interdependent elements. The Digital Learning Ecosystem is a representation of the most critical elements as revealed in the research as they pertain to learning outcomes for students using technology. In the coming section, each element of the Digital Learning Ecosystem is introduced. In the subsequent section, this ecosystem is used to frame the findings from the review of a decade of empirical work about underserved students learning with technology.

The ecosystem was designed with the learners at the center. What learners bring to their learning environments – their previous experiences, content knowledge, skill level, technological literacy, and social emotional state – plays a distinct part in mediating the outcomes of a learning activity. These outcomes are often narrowly conceived in terms of academic achievement, but our analyses indicated that this idea is somewhat shallow (Ritzhaupt et al. 2011; Beltran et al. 2006; Barron et al. 2010). Instead of solely academic outcomes, learning outcomes can be considered across four domains: academic, affective, behavioral, and cognitive. We determined that two major spheres of influence shape the learners' experience and outcomes: the technology and learning contexts.

When considering technology as a context, the most influential elements are related to infrastructure, access, and the specific features of a digital tool. Infrastructure refers to the "back end" of the technology setup. This includes categories such as bandwidth, servers, storage, and data hosting models. Access refers to the hardware used in the learning environment but also includes the model for access, which describes the organization of the learners and devices as well as the time, place, and frequency of access to this device. In schools, common models for access include one-to-one stationary computer labs, mobile computer labs, and bring your own device (BYOD).

Infrastructure and access are closely related, and each provides a set of enabling (or constraining) circumstances surrounding the use of technology in service of various learning outcomes. Each also plays a part in either limiting or extending the success of a particular digital learning resource. Digital learning resources can be characterized in terms of the platform or application being used and the specific features of that digital tool. These features influence the way content is presented, stored, and revisited, as well as whether and how information is manipulated or shared. The features of a digital tool make visible a wide variety of design specifications that shape a learner's experience with a digital tool and thus influence the resulting outcome.

Considerations about technology alone are not sufficient for drawing conclusions about the potential effectiveness of technology. The learning context is equally relevant and thus constitutes the other major sphere of influence in the Digital Learning Ecosystem. As with technology, the learning context is also subdivided into three categories: the learning community, the goals and objectives for learning, and the actual activities that learners engage in as they are using the digital tools. Fig. 2 delineates the aspects of the learning context at each of these levels as they commonly appear in the literature.

The technology and the learning contexts interact to provide a unique set of conditions for learning. Learners' previous experiences and beliefs shape their responses to these conditions dictating patterns for interaction and engagement. Together, these variables constitute a distinct experience for each learner, and the experience in turn enables a wide variety of outcomes that come to be associated with the use of particular digital resources. This ecosystem is more evolved than the binary conceptions of technology for learning common at the end of the twentieth century. The early years of the digital divide were characterized in terms of having or lacking access, and little information was collected or reported about the details of use. Even now, it is common for researchers to report on some but not all aspects of

Fig. 2 Learning contexts in the Digital Learning Ecosystem. (Source: © 2015, Molly B. Zielezinski, Stanford University Graduate School of Education)

Learning Community

Factors within school/local communities. For example:

- Approach to learning
- Pedagogical values
- Norms and cultures
- Parent involvement

Factors within classroom communities. For example:

- Grade level
- Teacher experience level
- Classroom management strategies

Learning Goals

Objectives for using technology:

- Mastery of basic skills
- Promote higher order skills
- Remediation of skills
- Promote technological literacies
- Promote skill development
- Influence learner behavior
- Make or build something
- Exploration of interests
- Pursuit of friendships

Learning Activity

Academic subject(s) or other content area

Interaction model(s):

- Content consumption
- Content creation
- Content sharing
- Interactive simulation/games

Source: © 2015, Molly B. Zielezinski, Stanford University Graduate School of Education

the Digital Learning Ecosystem as it is presented here, and there is little explanation given for what is included and what is left out.

The major benefit of the ecosystem approach is that it makes clear the need to understand outcomes for learners with regard to the multiplicity of variables that impact both the learners' experiences and the potential outcomes associated with technology use. We cannot assume that the success of digital learning activity in one classroom will generalize to success in another classroom without also understanding details about the technology, the learning context, and the desired learning outcomes.

In the remainder of this chapter, the ecosystem is used as a frame for presenting the findings from the literature about technology use and learning by underserved students. Each finding points to a specific variable in the Digital Learning

Ecosystem, offering details from the literature on how it can be leveraged to best support learning outcomes for underserved students. **When considering these levers for change, remember that strong alignment among all the elements within the Digital Learning Ecosystem in a given context supersedes any of the specific practices listed below**. The potential for achieving the positive outcomes associated with these practices decreases when there is poor alignment between a given practice and the other elements within the ecosystem – and likewise increases when a practice is clearly aligned with the available technology, specified context, characteristics of the learners, and desired learning outcome.

Findings

Technology in Context

When considering technology in the learning context, the most critical elements are infrastructure, access, and features of the digital learning resources available to the learners. Several key recommendations are presented below given the potential of each to set the stage for learning and development by underserved youth. In the research reviewed, learning and development include cognitive gains, skill development, increase in desired behavior, and positive changes in student affect.

Underserved students benefit from opportunities to learn that include one-to-one access to devices. One-to-one access refers to environments where there is one device available for each student. There is wide variation within one-to-one environments, including the time spent using devices, the overall availability of devices (e.g., whether the students can bring them home), and the quality of the instructional materials used on the device. While this variation can be profoundly influential, the literature supports the notion that students often benefit from opportunities to learn when there is at least one device per student (Grimes and Warschauer 2008; Maninger 2006; Ritzhaupt et al. 2010, 2011; Shapley et al. 2009). For example, Grimes and Warschauer (2008) studied "the implementation of a one-to-one laptop program in three diverse schools in California. The program was carried out in one largely Hispanic low socioeconomic junior high school, one largely Asian–American high-SES K–8 school, and the gifted program in a medium-SES elementary school" (p. 305). Their findings indicate that a majority of teachers found the laptops to be useful for learning by "at-risk" youth and that low-SES students demonstrated significantly higher gains in mathematics as compared to the high-SES students in the laptop program. Regardless of SES, the one-to-one laptop implementation increased students' likelihood to engage in the writing process, practice in-depth research skills, and develop multimedia skills through "interpretation. . .and production of knowledge" (p. 319).

High-speed Internet access is needed to prevent user issues when implementing digital learning. Digital learning often requires Internet access, and this need is growing with the proliferation of online audio and video resources. Kim and Lee (2011) found that underprivileged students participating in blended and online courses reported that a faster Internet connection would have improved their learning experiences. Grimes and Warschauer (2008) found that when students were given one-to-one laptop access as well as access to the Internet at school, they made use of this at least several times per week: “We witnessed online information access by students for three main purposes: to provide background knowledge, to facilitate ‘just in time’ learning, and to support research projects” (p. 317). Fast and reliable Internet access allows teachers and students to support learning in real time.

Underserved students benefit from digital activities designed to promote high levels of interactivity and emphasize discovery. The design of technology tools allows for different types of interactions between the learner and the technology. In the literature, designs that support certain types of interactions repeatedly demonstrated support for learning by underserved students. Several design considerations that promote interactivity and exploration are presented below.

First, underserved students benefit from technology interactions designed to promote high levels of interactivity (Bos 2007; Callow and Zammit 2012; Elam et al. 2012; Figg and McCartney 2010; Watson and Watson 2011). The level of interactivity refers to the amount and type of interactions permitted between learners, technology, and content, where a high level is characterized by frequent opportunities to manipulate, examine, and create new content in a variety of forms. For example, in one study, students measure the heart rate of their peers during various activities and use this to generate and test hypotheses. In another, students used handheld GPS devices to participate in a scavenger hunt. Using interactive approaches such as these has been found in several studies to be successful in helping low-income students pass state competency tests (Bos 2007) and master complex new materials (Hannafin and Foshay 2008).

Second, underserved students benefit from technology interactions designed to emphasize discovery and exploration rather than direct instruction (Bos 2007; Harness and Drossman 2011). For instance, a design that includes features of technology that “generate fluency, [and allow students to] create and modify representational forms is used to develop the dimensionality of a quadratic function through exploration, problem solving, and through making and exploring virtual environments” (Bos 2007, p. 356). Students who were allowed to explore the concept of quadratic functions in this study significantly outperformed those who learned via lecture and note-taking. In this example, students constructed understanding by working directly with graphs and tables. Afterward, they answered guided open response questions to help further develop their understanding of quadratic functions and checked this understanding through dialogue with other students (Bos 2007). Experiential learning such as this allows students to develop their own understanding through exploration prior to direct instruction. This strategy is augmented when combined with built-in opportunities for students to synthesize and apply what they are learning, for example, by engaging in face-to-face or digitally mediated dialogue with peers and teachers, capturing emerging knowledge through written reflection, or completing other informal formative assessments.

Third, underserved students benefit from technology environments that allow the learner to engage with data and complex content and represent thinking in multiple *forms.* Technology tools and their specific features and affordances structure the interactions students have as they engage in digital learning activities. Such features and affordances can be leveraged to provide learners with opportunities to engage productively with their peers or directly with content. In the literature, highly interactive tools that promote data analysis (Bos 2007; Elam et al. 2012; Grimes and Warschauer 2008; Marino 2009), engagement with complex content (Bottge et al. 2006; Samsonov et al. 2006), and opportunities to convey understanding in multiple forms (Bos 2007; Callow and Zammit 2012; Hall and Damico 2007; Marino 2009; Watson and Watson 2011) repeatedly demonstrated support for learning by underserved students. For detailed examples of these strategies from the cited literature, see Zielezinski and Darling-Hammond (2016).

Learning Context Sphere

The context sphere consists of the learning community, the learning goals, and the learning activity. While there is some overlap between the digital resources considered in the previous section and the learning activity presented in this sphere, there is a distinction. Discussion of the digital resources in the technology sphere is related to the specific design of the technology, while the learning activity has more to do with the choices about using technology to meet certain lesson objectives and goals within a learning environment. Within this sphere, three major recommendations were identified that show promise for stimulating active participation in effective digital learning activities for underserved youth.

Underserved students benefit from learning activities that focus on the development of higher-order thinking skills (such as problem-solving, making inferences, analyzing, and synthesizing) and twenty-first-century skills. These should be prioritized over activities that target basic skill development (such as memorizing facts and applying rules). Consistent with the literature on technology for learning by the general population of all K–12 students, the literature regarding underserved students reveals that digital learning supporting problem-solving and other higher-order thinking skills has more positive effects than digital learning opportunities that emphasize the development of basic skills (Barley et al. 2002; Bos 2007; Ringstaff and Kelley 2002; Wenglinsky 2005). Warschauer and Matuchniak (2010) conducted a literature review about the equitable use of and access to technology by various learner populations concluding that "the drill and practice activities favored in low-SES schools tend to be ineffective, whereas the uses of technology disproportionately used in high-SES schools achieve positive results" (p. 205).

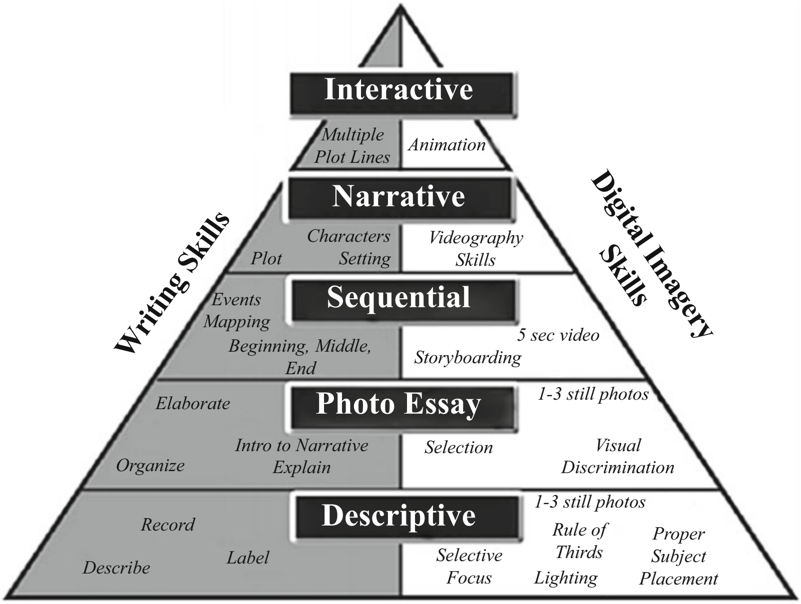
Warschauer and Matuchniak (2010) utilize differences in standardized test scores across low- and high-income schools as evidence to support the idea of prioritizing digital learning opportunities that focus on higher-order thinking over those that focus on basic skill development. Another instance of this in the literature comes from a study of 48 "at-risk" high school mathematics students in Texas. In this experiment, students spent 55 min per day, working through six lessons that followed the cycle: "engage, explore, explain, and elaborate" (p. 356). Through this cycle, students utilized simulations to manipulate information on interactive graphs and tables. They followed an exploration and were prompted to explain and elaborate on certain phenomena they observed. Students who engaged in this intervention outscored those learning in more traditional forms. The authors conclude that "results are deeply embedded in the core of the learning process and the necessity to create an environment that involves all students in high level thinking skills and to promote problem solving versus a more drill-practice approach" (Bos 2007, p. 366).

These examples point to the utility of simulations and digital games for the development of higher-order skills. The literature also indicates that these are useful for promoting twenty-first-century thinking skills and brain development (e.g., working memory and vocabulary development). Specifically, educational games have been linked to skill and concept development for underserved students (Alloway 2012; Ritzhaupt et al. 2010, 2011). Ritzhaupt et al. found that students who played single and multiplayer games demonstrated an increase in motivation, interest, and self-efficacy (and potentially academic achievement). Others have noted the importance of using digital learning environments (such as games and simulations) with features that are appropriate for the students' prior knowledge and skill level (Marino 2009; Samsonov et al. 2006).

Underserved students benefit from learning activities that draw on culture and community, specifically activities that integrate culturally relevant practices, foster student development of expertise, and highlight this expertise by providing opportunities for students to share their knowledge and skills with authentic audiences. Digital learning activities that were connected to the learners' cultures and communities were more successful than those that were not culturally relevant. One form of cultural relevance was observed when students engaged family and community members in authentic content creation tasks such as creating a family movie (Figg and McCartney 2010). Another form of cultural relevance was seen when Hall and Damico (2007) provided African-American 10th, 11th, and 12th graders with interest-driven opportunities to create representations of their thinking about local social justice issues, prioritizing cultural relevance by encouraging students to make use of language that they were typically asked to suppress but is common within their communities.

Meaningful activities foregrounding culture and community were observed with respect to authentic audience, opportunities for communication, and the development of student expertise. In one study, peers, family, and community members were mobilized to act as an authentic audience for students' multimodal presentations. Parents enjoyed authentic opportunities to communicate with their children about learning (Figg and McCartney 2010). Additionally, authenticity was created through opportunities that honored students' roles as experts, for example, the provision of opportunities for the teacher to learn from the students and opportunities for parents to see children as experts (Figg and McCartney 2010).

This project conducted by Figg and McCartney (2010) was culturally relevant because the students were asked to "draw upon oral or biographical family history," making them each experts in their own topic (p. 54). This cultural relevance was



Source: © 2005, Candice Figg (as cited in Figg & McCartney, 2010).

Fig. 3 The model of digital storytelling. (Source: © 2005, Candice Figg (as cited in Figg and McCartney 2010))

successful in part because of the well-designed, highly scaffolded structure of implementation. Another way this project was a model for culturally relevant activity is through the active involvement of family and community members as participants and audience members. Fig. 3 outlines the process of scaffolding in terms of writing and digital imagery skills. Stepping the students from the bottom to the top of this pyramid over a 2-week period allowed them to become active and engaged daily writers. Another way this project was a model for culturally relevant activity is through the active involvement of family and community members as participants and audience members. Students were asked to participate alongside a very important person or people (VIPs) from their life, such as a parent, grandparent, or close member of their community. VIPs committed to several sessions where their students taught them computer skills while working on the project and presented the final versions of digital stories they had created. The presence of the VIPs and the opportunity for real conversations between VIPs and students raised the stakes for students by invoking community as an authentic audience. This combination of cultural relevance, scaffolding, and authentic audience led to improvement in students' writing skills, motivation, and interest.

With the rise of the networked world, neither culture nor community needs to be local anymore. Students can and often do identify with a number of cultures both on- and offline. Each of these subcultures has digital and/or face-to-face audiences that can be mobilized as students prepare to share their developing expertise. For example, imagine a student that creates a Minecraft how-to video, posts this on YouTube, and links to it within a Minecraft community forum post. This student is invoking a form of cultural identity and honing her skills by putting her emerging expertise on display to be evaluated by an authentic audience. These are the types of interest-driven activities that connected youth regularly engage in today (Ito et al. 2013). As such, relevant cultures and communities, rooted in either the digital world or local context, can have powerful transformative potential when integrated within learning activities. These types of authentic activities can be leveraged in formal learning environments more frequently as a way to increase engagement and support learning by underserved students.

Underserved students benefit from learning activities that provide them with opportunities to drive their own learning. These include learning opportunities that allow students to become content creators. This type of student agency was featured in several different studies and included the use of technology to provide students with a choice of instructional materials and allow them to become active agents in their learning (e.g., making decisions about how a task was done) (Watson and Watson 2011). Similarly, technology was used to allow students the freedom to determine the structure and framework of learning tasks when engaged in multi-modal content creation (Hall and Damico 2007). Finally, technology was used to promote agency in the context of choices about whether or not to use the technology at all (Edmonds and Li 2005).

In a study by Hall and Damico (2007), African-American high school students attended a precollege summer course focused on digital media construction. The course was aligned to standards put forth by the International Society for Technology in Education and was focused on meaningful creation of digital texts by students. In this case, students were able to drive their own learning on multiple levels. First, students, working in groups of four or five, "were encouraged to explore a social justice problem related to their respective communities" (p. 82). Thus, they were given the choice to engage in a topic that was both relevant to their community and interesting to them. The student teams next exercised agency in the project by choosing to make either a website or an iMovie. The course provided the students with the skills and resources necessary to complete these learning activities *and* offered a choice as to which path they pursued. Finally, students were given complete authority over their plans for completing the project. This included the way the work was divided among the team, their design choices, and the order in which various parts of the project were completed. By the end of the summer program, instructors were facilitating student-driven learning rather than directing it.

Activities like this one that involve students as content creators show promise in terms of student engagement, self-efficacy, and attitude toward school and learning. In a number of studies, students engaged in content creation projects demonstrated improved engagement, self-efficacy, attitude toward school, and skill development (Bottge et al. 2006; DeGennaro 2008; Elam et al. 2012; Figg and McCartney 2010; Hall and Damico 2007; Lang et al. 2009). Content production can take a number of forms. For instance, students might engage in multimedia content creation that communicates their ideas and thoughts about culturally relevant themes and events (Figg and McCartney 2010; Hall and Damico 2007; Watson and Watson 2011). This may be accomplished through video production (Cohen et al. 2012; Harness and Drossman 2011), digital storytelling (DeGennaro 2008; Figg and McCartney 2010), or other forms.

The cases detailed above are clear illustrations of the way content creation might look as a single ongoing project. An alternative example comes from Lang et al. (2009), who worked with 55 Latino adolescents on a number of shorter content creation projects. In this study, students attended 16 2-h sessions that met weekly. Within these sessions, each student had a computer and engaged in original content creation projects, such as the production of posters using Broderbund's The Print Shop software that advertised positive traits about a student's ethnic group. In another lesson, students were asked to create materials for a business they envisioned themselves starting. They used software such as Microsoft Excel to track expenses, The Print Shop to advertise to potential employees, and Microsoft FrontPage to mock up a website for their business. Although this instantiation of content creation differs in terms of scope, it shares common characteristics with the earlier illustrations, including cultural relevance, interest-driven activities, structured choices, and student agency within the learning activity. Historically, these types of activities are associated with large projects, but the underlying characteristics could be designed into much smaller content creation projects such as blog posts, comments on articles, article annotations, social shares, tweets, or even emails. For content creation to support learning outcomes, the scope, task, and digital tool must be well aligned to the other elements of the Digital Learning Ecosystem. When these elements are well coordinated and scaffolded, underserved students benefit from the opportunity to drive their own learning, create original digital content, engage meaningfully with content knowledge, or hone their digital literacy skills.

Synthesis of Findings

School technology access has become an issue of international priority. With increased access to technology on the horizon, educators stand at a crossroads. Do they continue with the status quo or attempt to use the rising technology levels to support those students who need it the most? Research on technology for learning by underserved students has revealed that patterns of technology use and access vary along socioeconomic and demographic lines. Underserved students use technology to practice basic skills far more frequently than others, and these types of drill and practice activities contribute little to actual learning. Additionally, evidence indicates that these students experience stronger learning benefits from tasks that promote higher-order thinking skills. These are not, however, the types of opportunities that underserved youth commonly experience (Warschauer and Matuchniak 2010). These findings indicate that educators who continue with the status quo are likely to reinforce patterns of inequity, not solely in terms of access to technology but also in terms of how the technology is used. Although issues of equitable access are far from resolved, the rising tide of technology access necessitates a new wave of dialogue dedicated to identifying and disseminating promising practices for technology use that support learning by underserved students.

The work in this chapter aims to contribute to this dialogue in two ways. First, it introduces the Digital Learning Ecosystem as an empirically grounded framework that provides a holistic perspective of the mutually interdependent variables shaping a technology-enabled learning environment. The application of this framework has both benefits and limitations. A major benefit of the Digital Learning Ecosystem is that it provides a detailed picture of the variables that are present when students are learning with technology. In this framework, we begin to see how these interconnected elements collectively mediate student outcomes. As such, the framework can be applied in either research or practice. As a research tool, the Digital Learning Ecosystem can be used to frame inquiry and situate findings. In practice, it can be used to support strategic planning, preparation, or evaluation. As districts, schools, and teachers prepare to use new digital tools or transform their existing digital practices, they can use the Digital Learning Ecosystem to identify elements within their systems that are strongly aligned and those that need additional support.

The limitation of this framework is that it fails to take into account variables that were not highlighted by the researchers and educators within the studies reviewed. Examples of missing variables include peer interactions as well as district, state, and national policies. Each of these variables influences the learning environment, which in turn impacts the outcomes for learners. Fig. 4 depicts the Digital Learning Ecosystem version 2.0, which has been lightly revised to depict peer interactions as an additional variable that influences digital learning. This limitation can be mitigated if we consider the Digital Learning Ecosystem to be a living artifact that must be updated and revised based on the shifts in the larger educational landscape. Future waves of scholarship, widespread changes in educational practice, the evolution of new technologies, and the way these technologies are adopted in schools will all shape future iterations of this framework.

In addition to proposing the Digital Learning Ecosystem, this chapter continues the tradition of identifying and sharing promising research-based practices that are empirically linked to improved learning outcomes by underserved students. This chapter provides abridged outtakes from a more extensive review of the literature conducted by Zielezinski and Darling-Hammond (2016). The review indicated that in terms of technology, best practices for supporting underserved youth include one-to-one access to devices and high-speed Internet connectivity. Additionally, technology tools that promote student engagement with data and provide a variety of interactions with complex content in multiple forms were identified as features of digital learning resources that support underserved students. These resources best support learning when they promote high levels of interactivity and allow students to discover insights about complex concepts (rather than receiving direct instruction on the concepts). These recommendations for infrastructure, access, and digital learning resources were evident in literature published between 2003 and 2013. Given the rapid technology evolution cycles and the shift in national adoption patterns, this list

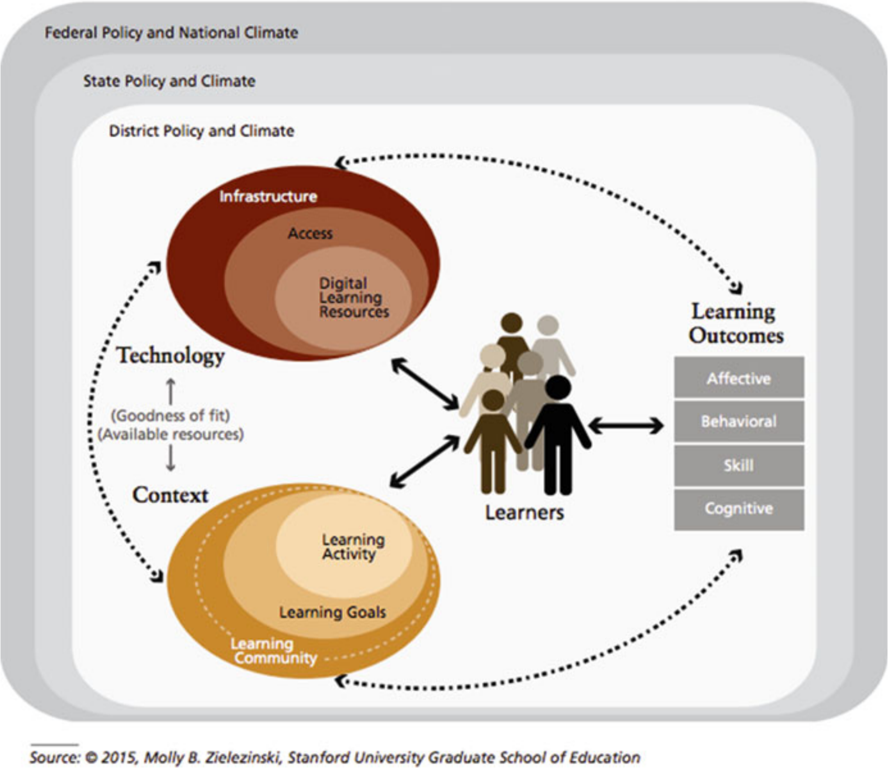


Fig. 4 The Digital Learning Ecosystem 2.0. (Source: © 2015, Molly B. Zielezinski, Stanford University Graduate School of Education)

of promising practices in the technology sphere should not be considered comprehensive or final.

The recommendations from the review related to context have slightly more staying power because the rate of change for formal learning environments is far slower than a technology evolution cycle. In the literature related to the learning context, Zielezinski and Darling-Hammond (2016) found positive outcomes for students when digital learning activities were used to support the development of higher-order thinking skills, when learning activities drew on relevant culture and community, and when students were drivers of their own learning, developing expertise and creating original content. These contextual features broadly frame the types of learning activities and learning objectives that guide all aspects of instruction, not just the moments that integrate technology. Successful long-term adoption of these kinds of objectives and activities is partially dependent on their alignment with other elements of the learning context, including but not limited to the curricular ideology and values of the school community, teachers' beliefs and experiences related to technology, classroom culture, and the time available for the activity.

Conclusion

Finally, conclusions in the review were informed by studies of specific students at a particular place, in a particular time, using a particular technology. Each study accounted for some, but certainly not all, of the factors that enabled or limited success for underserved students, and no single study provides detailed information about all of the variables in the Digital Learning Ecosystem. So, for those who seek to apply these recommendations, remember they are not an instructional manual for digital learning. Instead, they are merely guidelines intended to stimulate thinking and mobilize change. As we endeavor to use technology to support learning by underserved students, we must remember that the most immediately relevant beacons always come from within. Data about what is working and what is not working in your classroom, school, or district are more relevant and up to date than any academic article or national report. Interpreting these data within the Digital Learning Ecosystem can shed light on the multiple factors enabling or limiting student success as digital tools are utilized in new ways. There is utility in knowing what are widely considered to be promising practices, but these are only the starting point. The end point is when you find what works for the students who you work with and the technology available to them – especially if what is working today is preparing these students for the world they will encounter tomorrow and the one they will inherit in the years to come.

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Section XII

Paradigms for Researching Information Technology in Education

Section Introduction: Paradigms for Researching Information Technology in Education

73

Margaret J. Cox and Joke Voogt

Abstract

Research and development of IT in educational settings is intertwined with the design of the IT tools themselves and influenced by policy makers and other stakeholders. This section presents the key paradigms for researching information technology (IT) in education, taking account of the challenges which need to be addressed while the teaching and learning environment is forever evolving and expanding because of the increasingly diverse IT tools and resources. Each chapter addresses different research methods and approaches, all of which have implications for designing effective research investigations, which will help to inform and shape the policies and practices of stakeholders in education.

Keywords

Researching IT · Emerging technologies · Knowledge representations

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This section presents the key paradigms for researching information technology (IT) in education building on the evidence from the previous edition of the Handbook in 2008 (Cox 2008). Current research challenges now include the varying access to IT beyond the school boundaries, the changing sensory perceptions of the learners, the diversification of human computer interfaces, the mobility of the learner, and the effects of IT tools on teachers' and learners' expectations. The last Edusummit (Lai et al. 2017) identified the importance of the control of the individual learner in adapting to the digital world and the relationship between formal and informal learning. All of these have implications for designing effective research investigations which will help to inform and shape the policies and practices of stakeholders in education.

In this chapter (▶ Chap. 74, "Researching Information Technology in Education: Meeting the Challenges of an Ever-Changing Environment"), Cox considers the research challenges to take account of the new knowledge and knowledge representations which are accessible through dynamic, mobile, and diverse computing technologies. Evidence from this chapter shows a shift from research involving using IT resources in formal classroom settings to research across contexts between school and home and learning with personalized mobile devices. Based on the roles and interactions among researchers, policy makers, and practitioners, the chapter concludes with considering the scalability and sustainability of research methods and outcomes through recommending strategies which will consolidate research outcomes and underpin future policy and research decisions.

An important approach to researching IT in education is the use of meta-analyses which occur in many subjects ranging from medicine, law, and science to education. Extensive previous studies, reviewed by Liao and Lai in ▶ Chap. 75, "Meta-analyses of Large Scale Datasets: A Tool for Assessing the Impact of Information and Communication Technology in Education," provide a brief description of the meta-analysis research method, a synthesis of meta-analysis studies of the impact of IT in education, and an identification of what kinds of evidence outcomes can be achieved through meta-analysis. They conclude that meta-analyses enable educational researchers to deliver generalizable answers to basic questions of policy and therefore practice and the consequent effective uptake of IT.

In ▶ Chap. 76, "Researching the Design and Evaluation of Information Technology Tools for Education," Bruillard and Baron, investigating IT tools for education, distinguish three genres: (1) software tools for learning specific subjects, (2) learning platforms such as MOOCs for distance learning, and (3) digital resources. Behind all these tools, they observe a strong tension between individualized instruction and the intention of offering collaborative usage of general tools and individualized instruction and collaborative usage of general tools, where users have a certain margin of freedom. They conclude that evaluating education software, resources, and platforms supports an extreme diversity of approaches. To be effective, it should include different criteria: functional compliance, interactional conformity, and hedonic quality. Finally, it is important to reaffirm the key role of teachers, helping them to develop their agency in the field of educational resources, empowering them, and accepting them as collaborative partners.

In ► Chap. 77, "International Large-Scale Computer-Based Studies on Information Technology Literacy in Education," Fraillon discusses recent developments in international large-scale studies of IT literacy-related achievement with a focus on their shared necessary attributes and the associated challenges with operationalizing these attributes in the test instruments. Two key attributes addressed are (i) that the test contents reflect real-world use of IT and (ii) that the tests make use of the dynamic functionality and multimodal opportunities afforded by the computer-based environment. The chapter concludes with recommendations of possible future directions in large-scale international studies related to IT literacy.

An important challenge for researching IT is how to measure the impact of emerging technologies and their integration into learning and teaching. This is addressed in ► Chap. 78, "Measuring the Impact of Emerging Technologies in Education: A Pragmatic Approach" by Cukurova and Luckin. They argue that traditional impact evaluations in education have to be reconsidered within these more diverse contexts. They present a pragmatic approach which focuses on the suitability of the proposed evaluation methods and the types of evidence rather than on the hierarchy of these methods and evidence types. They conclude that all types of evidence during impact evaluations of emerging technologies should be generated from intervention trials and case studies and existing literature should be leveraged at different innovation stages of emerging technologies.

In ► Chap. 79, "Looking Back, Moving Forward: Impact and Measurability of the Use of Educational Technology," Pachler and Turvey present a critical review of the various historical analyses of the impact of technological interventions in education in order to identify the gaps in educational research and the challenges posed for researchers. These include teachers' often limited knowledge of IT affordances and therefore the vagueness of teachers' actual uses of IT resources in their teaching and often a failure to understand how learners think. They conclude with a call for methodological perspectives that are not confined by paradigm but that are able to bridge and integrate research paradigms in order to respond to the complex sociocultural ecologies within which digital technologies are implicated.

These anomalies and misunderstandings about research results imply that there needs to be a much clearer identification and classification of what constitutes researching IT in education and what can be relied upon to inform other researchers, practitioners, and policy makers. Hence the justification for this section of the Handbook aims to enlighten the reader on these challenges.

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74 Researching Information Technology in Education: Meeting the Challenges of an Ever-Changing Environment

Margaret J. Cox

Contents

Abstract

This chapter considers the challenges which need to be addressed by those researching IT in education. Evidence from the first Edition of the handbook and many meta and individual studies published since 2008 reveal changing methodological approaches to address the increasing diversity of IT in continuously changing educational contexts. These include research methods to take account of the new knowledge and knowledge representations which are accessible through dynamic, mobile, and diverse computing technologies. The discourse uses Entwistle's evaluation framework to help researchers identify the range of factors which have an impact on the quality of learning consequent to the use of educational innovations in formal and informal settings. Evidence from this review shows a shift from research involving using IT resources in formal classroom settings to research across contexts between school and home, computer-based learning devices to learning with personalized mobile devices.

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Based on the roles and interactions among researchers, policy makers, and practitioners, the chapter concludes with considering the scalability and sustainability of research methods and outcomes through recommending strategies which will consolidate research outcomes and underpin future policy and research decisions.

Keywords
Researching IT · Educational evaluation · Informal learning · Knowledge representations · Research methods · Research informed policy

Introduction

This chapter reviews the evidence to date reported in the literature about researching IT in education. Building on this evidence, it identifies the challenges of researching the new knowledge and knowledge representations which are accessible through dynamic, mobile, and diverse computing technologies. Comparing the evidence with the previous version of a similar review published in the first edition of the handbook in 2008 (Cox 2008), 10 years on, there are still many of the same limitations and challenges facing those involved in educational research in this field (▶ Chap. 79, "Looking Back, Moving Forward: Impact and Measurability of the Use of Educational Technology" by Pachler and Turvey in this volume). However, more recent research shows that there is a better and growing understanding of the complexity of conducting research in technology enhanced learning (TEL) (e.g., see San Diego et al. 2012; Cox et al. 2013; Huber et al. 2016; and Herodotou 2018), whose studies are discussed in more detail later in this chapter.

Rather than give a definition of the meaning of IT in this chapter, it is probably, I would argue, more helpful to show what affordances are and have been provided by IT resources for teaching, learning, and understanding over many decades and how these have influenced research agendas (see Table 1). In many countries and across eras, the IT resources made available in schools have been determined by government priorities and initiatives and what has been produced for society as a whole rather than led by the teachers' perceptions of the potential to enhance learning or by teachers' choices (Webb and Cox 2004; Cox et al. 2013; Brinda et al. 2016). As a consequence, the research methods and approaches have often been influenced by key outcomes wanted by policy makers rather than investigating the actual learning potential of a new IT resource.

As was shown in the previous edition (Cox 2008), the early research and development of IT in educational settings was intertwined with the design of the IT tools themselves and the research focus was on measuring the impact which these had on students' learning leading to a consequent improvement of the design (Reeves 2008). There was little awareness and realization of the impact on learning which such additional influences might have, such as teacher intervention, student

Table 1 Technological developments for education and the focus of research into teaching and learning (Cox 2013a)

Dates/era	Technological developments	Development of IT in education and focus of *research*
1950–1967	Large scale main-frame valve-based analogue computers. Miniaturization of electronic components (transistors and diodes) and circuitry leading to the large scale digital computer. Increase in memory/processing capacity.	Subject based drill and practice programs for use with small groups of pupils. *The impact on pupils' learning and evaluating educational software.*
1968–1970	The introduction of the Internet – ARPANET[a] seeding the international networks of computers and subsequent online learning, social media 20 years or so further on.	Remote access to schools and universities to widen the use of subject specific software, *comparing learning with subject specific software to learning with traditional resources.*
1971–1974	Creation of JANET[b] – UK network of computers, and real-time interactive computers. User graphics on-line computer terminals. Internet connections for some schools. Remote access to computers from different locations. Forerunners of desk-top computers: e.g. Hewlett Packard, Horizon.	Remote access to educational software programs from universities to schools. Individual computer work-stations. *The impact on learning and evaluating educational software.*
1975–1979	Miniaturization of computers. Production of small desk-top computers with 32k of memory and graphics. Move from tape-based storage to disk based storage of large computer programs. Prestel/Teletext: commercial and educational information provided on-line.	Educational graphic simulations, expanding range of educational software. Changes in the IT subject curricula. *The impact on learning and the requirements for teacher training.*
1980–1984	Fibre optics facilitating fast and large-scale communication Modems in schools providing wider remote access. Range of input and output devices for education, e.g. concept keyboard/ graphics tablets, touch screens, speech input and output	Large range of drill and practice and simulation software available to schools. *The impact on pupils' learning, attitudes and uptake by teachers and schools. Effectiveness of teacher training.*
1985–1989	Microsoft windows launched. More powerful cheaper personal microcomputers. Invention of the World Wide Web by Tim Berners-Lee (http://en.wikipedia.org/wiki/Tim _Berners-Lee). New external storage devices: CD-ROM: Interactive video; plug-in memory cards.	More diverse range of educational software, including modelling software and some access to the Internet and WWW. International school collaborations. *The impact on learning, uptake by teachers and schools, and collaboration amongst learners. International comparisons.*

(*continued*)

Table 1 (continued)

Dates/era	Technological developments	Development of IT in education and focus of *research*
1990–1999	Lap-top computers. Spread of wireless computer technologies: networks; air-mouse; video-conferencing. Mobile phones. Interactive whiteboards. Personal Digital Assistants (PDAs).	School/home uses of IT. Pressure on IT resources for teaching IT as a subject and teaching with IT. Whole class teaching with IT. Organisation of learning with IT and online. Individualised learning. Informal education. School priorities and level of integration. *Theories underpinning educational change.*
2000–1904	Further increases in processing and storage of personal computers. Wide cheap access to the Internet and the World Wide Web. Virtual learning environments (VLEs).	More powerful educational software. Curriculum dilemma for teachers in schools between using office software (word-processing etc.) and educational bespoke software. *Researching online courses and assessment. Networked learning.*
2005–1909	Web2, Wikis, VLEs. Thin clients. Thin client technologies in schools. Haptic devices for use in education. Development of molecular computing technology. Widespread access to wireless networks. Web2 technology - Social software environments: e.g. Wikipedia, Second Life	Digital literacies and agendas, relative benefits of different IT resources in school and home. New representations. Changing focus of human computer interactions. *Impact on formal/informal learning. Changing teacher-learner-external expert relationships.*
2010–2012	Graphics portable devices: I-phone; Blackberry; I-pad; Satnav; MP3-players; E-books; Social software: Facebook, Blogs; Twitter; social bookmarking; One World TV. Integration of mobile technologies with social software.	Mobile learning, Blended learning, *Research to understand the levels of immersion in technologies. Impact of social software on learning scope and agendas.*
2012–2018	Touch technologies; haptic devices; Integration of different HCI interfaces.	Learning with touch devices. *Researching sensory perceptions; interface between different learning modes and experiences.*

[a]ARPANET – Advanced Research Projects Agency Network created in 1969
[b]JANET – Joint Academic Network

cooperation; students' digital literacy skills, new ways of interacting with learning resources and so on which could be happening within any IT learning experience. Alongside these earlier developments were evaluations of the effects of using IT on students' IT skills and abilities. It was decades before the majority of the research community became aware that researching IT in education needed to acknowledge the ways in which IT is used in and out of schools, online, and in many different contexts.

Table 1, modified from previous similar tables (e.g., Cox 2008, 2013a) shows the types of IT resources which were available to educators and therefrom the focus of past research studies. As a result of the previous review of the effectiveness of research designs and methods across different educational contexts, the recommendations identified in the previous edition of this chapter (Cox 2008, p. 959) were:

1. "Any investigation should be clear about what types of IT are going to be used and design measures to match the specific IT type to the teaching and learning outcomes.
2. Research studies should take account of the nature of the knowledge representations likely to be experienced and not limit the research to assumptions about traditional subject material knowledge representation.
3. Research into the impact of IT resource types on learning needs to take account of the pedagogical beliefs and practices of the teachers involved.
4. In-depth case study investigations are required to measure the quality and extent of the teaching and learning experience.
5. The ways of measuring the impact of IT on education need to take account of the different factors which may need measuring in addition to attainment and learning gains.
6. Large-scale national and international studies should include case studies to find out the level and depth of IT use and experience to inform the quantitative data."

As is now well known, investigating the impact of IT on students' learning therefore involves measuring the effects of IT on generic and specific skills and knowledge, the effects of group and collaborative learning, taking account of human computer interfaces and the changing nature of knowledge presented and the role of the teacher. The remainder of the chapter addresses new challenges which, although researched by several in the last few decades, have become more prominent now because of the ever-changing IT environment in society permeating what was once a fairly controlled and understood formal educational system.

Complexity of the Learning Experience

Following from the earlier research discussed in the previous edition of the handbook "An important word of warning for teachers and researchers which came from many of the earlier studies between 1975 and 1995 is that *what* the students learnt was often not *what* the teachers and researchers had anticipated them learning" (Cox 2013a, p. 24.). There are many reasons for this which have become more significant as IT continues to pervade all aspects of society. A useful framework developed by Entwistle (1987) for teaching and learning at university level is still applicable today and is also relevant to primary and secondary schools. This framework, although developed 30 years ago, has been used by many researchers to construct a comprehensive and inclusive research strategy. It shows the more obvious factors which influence students' learning as well as those at an institutional level. This framework,

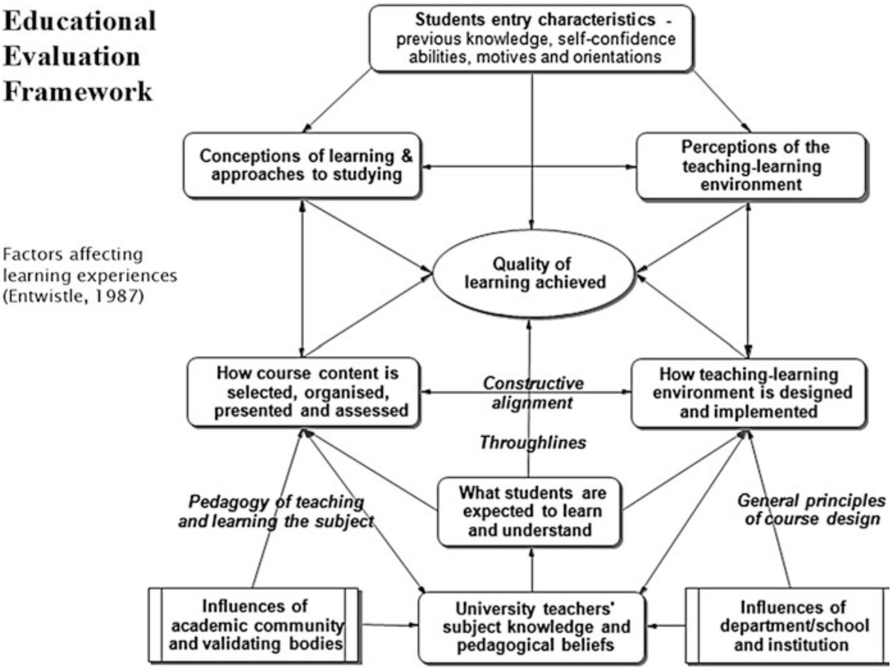

Fig. 1 Evaluation framework showing key influences on students' learning within a formal institution (Entwistle 1987)

shown in Fig. 1, was developed from a meta-analysis of over 250 research studies of the quality of the student learning based on a range of measures and the different variables which will influence the actual learning achieved.

Many of the variables shown in this framework are also relevant to researching any educational innovation but have added complexity and significance when considering the digital environment and the teachers' and learners' own expertise and familiarity with it. If we consider each of these in turn related to past research, it helps us to identify the methodological approach which might best fit researching IT in complex learning environments.

1. *Student entry characteristics.* When measuring the impact of using an IT resource on students' learning in a formal setting such as a school, research which additionally measures the students' previous knowledge, not only acknowledges the need to measure subject or topic conceptual understanding but now more than ever needs to know about the students' IT literacy skills. These might include how to interpret knowledge presented in new formats through the use of computer screens, diverse IT applications, e.g., spreadsheets, simulations, skills at using personal devices such as social networking tools, instant messaging, taking pictures with cameras to access relevant information (Looi et al. 2014a), and motives and orientations (Romero-Hall et al. 2016).

2. *Conceptions of learning and approaches to studying.* According to Entwistle's Framework, the quality of the learning achieved will also depend upon the students' conceptions of learning and approaches to studying. In a recent study by Iten and Petko (2016) of 74 children from five primary schools playing the learning game AWWWARE, the authors measured the anticipation of the pupils towards the learning activity (serious game). The results of pre- and post-tests were analyzed using multiple linear regressions. The results showed that "anticipated enjoyment played only a minor part in students' willingness to learn with serious games. Of greater importance was the students' expectation that the learning game would be easy and instructive." (p. 151.). However, this study like many others measured the children's attitudes towards the learning activity through online questionnaires using Likert scales for such statements as "Ease of use," "simplicity to use," "fear of use." Many earlier research studies (e.g., see Cox and Marshall 2007) have shown, however, that such constructs eliciting the pupil's opinions often do not measure the deeper attitude of learner's conceptual understanding and approaches to studying which we need to know to determine these effects on the quality of learning.
3. *Perceptions of the teaching and learning Environment.* It is already well established that how teachers perceive the IT resource's contribution to learning is dependent upon the teachers' IT literacy, their pedagogical content knowledge and their perceptions of the students' responses to the learning activity and so on. (Webb and Cox 2004). These factors are becoming even more complex now with students able to use their own devices to study subjects being taught in school with very limited control by the teacher. The consequences of this eclectic mix of learning resources is that the teacher's perception of the learning environment may differ from that of the actual learning environment and therefore be more evasive to the researcher attempting to measure its impact.
4. *How course content is selected, organized, presented, and assessed.* Although recent research shows that there is a growth in the use of IT resources in formal learning settings, there is still a large variation in the way in which the same resources might be selected by different teachers, different integration within the curriculum, and how the learning may be assessed (Voogt 2008). A recent study by Wang (2017) investigated the learning effects of different instructional methods by two teachers who were using the Interactive Response System (IRS) with two different teaching methods: learner as leader, and teacher as leader. They found that the students' learning resulting from both organized learning strategies supported previous research which showed that IRS improved learner's engagement. In the majority of educational settings, it is still the case that for formal education, the course content is often preselected for a body of students while the IT resources are an additional extra. (e.g., see Passey 2015; Cox et al. 2013). This provides a significant challenge for researchers investigating the effects of an IT resource on students' learning across several classes or schools, because the same resource may be used differently by each teacher being studied.

5. *How teaching-learning environment is designed and implemented.* With the growing use of personal mobile devices (tablets, laptops, mobile phones, etc.) and online learning, it has been argued that the control of the prepared curriculum and standardized content is in many countries and schools a passing phase (Sakamoto 2002; Cox and Niederhauser 2013). The actual use of the teaching-learning environment is becoming fluid, more determined by the scope and extent of IT use than by an accepted set of materials chosen by the teacher/course leader. A review of just one issue of the Journal of Computer Assisted Learning for example (Journal of Computer Assisted Learning 2017) includes research articles on the use of tablets, blended learning environments, Web activities, automated learning, video instruction, and computer simulations. This diverse range of research foci shows a trend in what kinds of IT resources are now being used in schools.
6. *What students are expected to learn and understand* – In the previous handbook edition, decades of evidence (Cox 2008) showed a potential mismatch between the teacher's expectation of the concepts and processes their students would be learning (through the use of an IT environment) and the actual learning which might occur. This is because, frequently, the teachers are mostly accustomed to using more traditional teaching resources and methods and are unfamiliar with the different interactions and educational challenges offered by an IT environment. As said previously, "*what* the students learnt was often not *what* the teachers and researchers had anticipated them learning" (Cox 2013a). Even a decade later, it is still difficult for researchers to measure the impact of IT use on students' learning because as Entwistle (1987) has shown over 30 years ago, not only is what is learnt affected by what each student expects to learn but what the IT resource affordances provide.

The remaining three variables identified by Entwistle in his framework: *Influence of the academic community* (in the case of this handbook would be confined to the formal settings); *teachers' subject knowledge and pedagogical beliefs; and influences of the department/school and institution* have been extensively addressed in the previous handbook edition (Voogt and Knezek 2008). Previous reviews of large-scale international studies, e.g., Plomp et al. (2009) include evidence of the effects of policies on practices in over 30 different countries. These previous studies support Entwistle's claim that the quality of students' learning will also be influenced by the ethos, emphasis and facilitation of the educational communities within which their learning is taking place.

Numerous studies previously reported confirm the significant influence of teachers' subject knowledge and pedagogical beliefs on the quality of students' learning (e.g., see Webb and Cox 2004). Even more than a decade on it is still difficult to measure this when trying to evaluate the contribution of IT to students' learning. In conclusion, the previous substantial published research literature into the influence of the school on students' access to appropriate, relevant, and beneficial IT resources (e.g., see Voogt and Knezek 2008) and teachers' professional development (Desforges 1995; Cox 2013a) and those discussed above confirm the importance of the range of variables identified by Entwistle (1987), and the significance for researchers in considering these influences when planning research in IT in education. The remaining sections of this chapter address the most recent challenges we have to face in achieving research designs and outcomes which will be scalable and sustainable across different contexts and communities.

Evolution and Diversification of IT Resources – Shifting Sands

In spite of the limitations caused by not enough account being taken of Entwistle's factors in many previous studies, there are those reported in the literature which have addressed many of these influences and shown that the impact of diverse types of IT resources on students' learning can have a positive impact on learning gains within formal and informal settings (Cox 2008, 2013a; Huber et al. 2016); on students' motivation (cf. Gardner et al. 1993); attitudes and perceptions (Christensen and Knezek 2008; Romero-Hall et al. 2016). However, each study has often involved different research methods, different types of IT resources, and different educational settings. These differences present various research challenges when attempting to measure the precise nature of students' learning as a consequence of the affordances of the specific IT resources being used. Furthermore, these diverse approaches often make it difficult to generalize and apply these findings on a larger scale (see the section below on Scalability and Sustainability of Research Methods and Outcomes).

As discussed in the previous section and shown in Table 1 above, the IT resources used in educational settings (formal and informal) are often driven by those used in society as a whole and the last 50 decades show that these continue to diversify and become more individualized. Not only can all pupils in a school in a developed country bring their own devices (BYOD, e.g., mobile phones) to school and be encouraged to use them in their lessons, but such mobile devices can complement traditional learning resources and other IT resources (e.g., searching for information online) (e.g., see Mehdipour and Zerehkafi 2013). These opportunities have been researched in settings ranging from traditional science field work to changing the curriculum to an enquiry-based curriculum which would need mobile devices such as phones to collect data in the field. Wu et al. (2012) conducted a meta-analysis of 164 studies (most of which were in higher education) of mobile learning from 2003 to 2010 with an increasing number being found in 2010. The primary research method to measure effectiveness of these 164 studies was through survey methods followed by experimental research. However, evidence from the first edition of this handbook (Marshall and Cox 2008) have shown that surveys do not reliably measure the learning effectiveness because as is shown in Fig. 1, many of the variables which influence the quality of learning have not been accounted for. This is especially true for mobile learning studies which involve learners in different settings. For an extensive review of mobile learning in this handbook see Soloway and Norris (▶ Chap. 53, "Section introduction: Mobile learning").

One of the conclusions from Looi et al.'s study, referred to earlier, was that "With mobile technology, science inquiry can be extended into more authentic contexts, such as field trips to a park, woodlands, and a museum, and other home-based activities" (p. 102). The challenge posed for researchers in this ever-changing IT environment is not only investigating the level of use and integration within the curriculum but the personal individual skills of each pupil using such devices.

A further complication for researchers especially when consolidating previous international evidence and comparing new results with those published by others is that the actual curricula in which such innovative uses might take place will differ by content and approach from one country to another. It is therefore difficult to generalize and scale up the results for wider implications. For example, in the extensive research into Mobile learning reported by Looi et al. (2014b) and the earlier review of trends in mobile learning reported by Wu et al. (2012), they advocated being able to scale up an innovation by transforming their national science curriculum in Taiwan into an enquiry-based science curriculum. Although this is an obvious appropriate use for mobile technologies for measuring and controlling science data in schools in the laboratory and in the field, it is hardly new in many Western countries. The importance of such field work was concluded by Woolnough (1994) more than 20 years ago from the results of a survey of over 6000 students (16–18) and science teachers of their attitudes towards studying science in schools. He found that learning activities which involved collecting scientific data in the field encouraged students both to study science at school and to pursue it in a career. These results reveal another challenge for researchers which is that, when reviewing previous research published internationally, in order not to repeat unnecessary investigations, a proposed research study needs to be founded on extensive knowledge of the evidence to date of the context and national curricula as well as the research objectives identified by the affordances of the IT environment itself.

Researching Across Boundless Contexts: Informal and Formal Learning.

If we refer back to Table 1 above and the previous discussions, we can see that even in the 1970s, some people in mainly developing countries had access to personal desk-top computers in the home and Internet access in the later 1970s. Mobile phones were coming into use in the 1980s. There were early research studies into the personalized informal use of computers for learning with the focus mostly on learning specific science or mathematics concepts using dedicated educational software. Later reviews reported an increasing use of informal learning for homework (Hallam 2004) and in more recent years linking school and home IT use for learning (Pachler and Redondo 2005; Cox 2013b). Much of this earlier research was reporting on the uses of IT in the home by learners rather than finding out the impact on the quality of their learning.

From the plethora of research reports already published (e.g., see Badri et al. 2017), the range of technologies available in society will continue to change and the use of these outside formal settings is very difficult to measure accurately. An earlier review of informal learning with technology outside school by Sefton-Green (2004) identified these challenges for researchers: it “is conceptually difficult because there is no one simple science of learning, no one set of shared rules to which all researchers in the field would point to begin to describe how informal learning might take place. At the present time, for example, researchers in ‘education’ continue to struggle with the challenges of combining psychological and sociological approaches to an understanding of learning. The conceptual challenge of defining children’s learning outside schools is also particularly problematic as most literature in this field is oriented towards the implications of informal learning for the formal sphere.” (Sefton-Green 2004, p. 8). Over a decade later a more recent review by Lai et al. (2013, p. 422) of blending student technology experiences in formal and informal learning with more diverse and powerful personal learning devices confirmed the earlier review concluding that “we know very little about how it (informal learning) can best be supported by mobile technologies and applications.”

Although, for many decades the main research objectives for funded research has been linked to formal educational settings which in the majority of countries would be schools mostly funded by national governments, the widespread use of technologies outside schools can no longer be ignored. It is necessary to accommodate the greater granularity across the increasingly leaky formal and informal boundaries which educational technologies encompass. A recent review conducted by Working Group 2 of Edusummit2017 (Lai et al. 2017) provided four key strategies for researching the impact of informal learning using technologies:

- Develop technologies to enable learners to capture and reuse their learning experiences (e.g., the SCROLL system in the context of language learning)
- Develop technologies to support critical thinking
- Conduct more evidence-based studies to understand the relationship between formal and informal learning
- Design studies that capture rich data on student use of technology outside formal institutions (e.g., ethnographic, walkthroughs). (ibid. p. 30).

In order to identify approaches that can be adopted by researchers investigating the impact of informal uses of technology on learners, the first stage is, as it has always been with traditional learning, to identify the research objectives. However, for research objectives which include trying to measure the impact of IT on the quality of learning specific to informal learning, there are three main considerations which need to be addressed:

1. The loss of control of how learners in schools are using IT beyond the school (Cox et al. 2013).
2. The changing sensory modes of learning and thereby perceptions due to the IT interfaces leading to changes in use of our anatomical sensory organs: (sight, sound, smell, touch, and taste: see the following section).
3. The changing IT literacies of the learners brought about by knowledge being learnt in new forms of representation: new ways of learning (see the following section).

2 and 3 above apply equally to formal and informal settings although the increasing use of various devices by learners will impact upon how they learn and conduct their learning beyond the experiences they used to have when their learning was once mostly controlled by teachers.

New Knowledge; New Representations; New Modes of Learning

Prior to the 1960s, the dominant way of learning for over a century was through reading books and other texts and listening to teachers. This mostly involved students applying visual reading and listening skills. For science subjects, other sensory modes of learning have also been used for experimentation, such as smelling, listening (to various sounds), and touch (haptics) (e.g., see Perkins et al. 1995). Haptics and its application have become more dominant in the last decade and is widespread across mobile devices such as touch-phones and tablets. Other specific haptics simulators have long been the norm for pilot training and other professional skills but are now expanding in use in formal sectors of education at school level (e.g., Webb et al. (2017) and in many health care courses in higher education (e.g., see Quinn et al. (2015).

Herodotou (2018) conducted a literature review of the use of tablets with children, the main focus of the 19 studies being to measure the effects of the use of mobile technologies on learning. "The great majority of the 19 studies included in this review examined cognitive effects of mobile devices on young children, relevant to mainly literacy, science and Math, and reporting positive outcomes. There is a lack of studies examining possible impact of mobile devices on children's social and emotional development and a need for gaining a fine-grated understanding as to why observed effects have been identified" (Herodotou 2018, p. 8). A small number (4) of these studies considered the changes in the new and different ways the children might be learning due to the haptic interface with the tablets they were using by also measuring changes in their fine motor skills.

Another review of the use of tablets in schools by Haßler et al. (2016) of 33 studies showed that the main affordances investigated were related to the multiple features of the resources, such as the camera, microphones, and easy access to dictionaries and screen readers and the benefits of their portability. However, they found that few of these studies investigated the effects of these affordances on learning outcomes but only on learners' uses of the technologies. They concluded that "Researchers investigating what it is about tablets that supports students to learn should seek to establish ways in which the technology can be used more effectively than other similar devices to promote learning in the classroom" (Haßler et al. 2016, p. 23).

From the results of these reviews and many other studies, it is clear that there is still a lot of uncertainty about the interaction between the different senses which learners may be using and how this will affect the learning outcomes. For more than a decade, as was also discussed in the first edition (Cox 2008), researchers have been aware of the need to improve our understanding of the relationship between knowledge and how it is conveyed and experienced by the learner through interfacing with the technology (Hindmarsh et al. 2014). Before haptics began to pervade IT technologies, it was already a significant challenge. For example, if we consider touch screens used by children (see Herodotou's meta-analysis summarized above), the research methods used to measure their learning need to include measuring the changes to the learners' fine motor skills as reported in some of the studies out of the 19 reviewed. Furthermore, "The interactive and social features of touch screen media suggest new forms of prosocial behaviour that merit examination including understanding what characteristics of the media or of certain applications might affect emotional competences, how children might relate to application characters and exhibit empathy or accepting or rejecting others. Moreover, given the play-like character of mobile applications in early years, it might be fruitful to examine how interaction with such technologies relates to children's imaginary play, their understanding of the distinction between fantasy and reality, and the extent to which interaction with this new media enriches their imaginative and creative capacities" (ibid. p. 9).

A recent study on the use of touch screens by children conducted by Piotrowski and Krcmar (2017) measured the effects of hot spots on children's haptic uses of the tablet, their verbal responses, attention, and story comprehension. They found that the children showed less attention to the story being told with the use of hot spots, yet recorded similar content afterwards as the control group who read the story without the use of the tablets. From the range of results obtained, the researchers concluded that "Given the full-scale adoption of tablet computers into many schools it is crucial to consider how children use and respond verbally and haptically to tablets when educational information is presented to them. Furthermore, a better understanding of how the timing of hotspot use influences comprehension may allow digital storybook creators to tailor more to children's comprehension needs" (Piotrowski and Krcmar 2017, p. 333).

Evidence from these recent studies and those previously reported in the first Edition show that there has been some progress made by researchers from the Human Behaviour and Human Computer Interface domains in recognizing the need to take account of the learners' gross and fine motor skills which will affect their interactions with haptic devices and consequent learning. However, there is still no common agreement on taxonomy of touch or on the effects of immersion within the IT medium and transfer of knowledge to other domains. The most promising approach to take account of new representations and interfaces is to incorporate the body of knowledge from the psychology field when identifying the objectives of a research study and the expertise of haptic cyberneticists to help in the identification of the affordances of these complex learning environments (e.g., see San Diego et al. 2012; Hindmarsh et al. 2014).

International Significance and Applicability

As can be seen in Table 1, access to IT resources has expanded with the reductions in cost and the diversification of types of IT technologies. As a result of national government IT in education policies, there have been many national and international large-scale studies investigating and comparing the uptake of IT in education (mostly at the school level) (Kozma 2003, Law et al. 2008; Plomp et al. 2009, Voogt and Knezek 2008, Fraillon et al. 2014), which have provided evidence of the factors which promote or inhibit the uses of IT in education.

The methods used in these large-scale studies include school and teacher questionnaire surveys across countries, specialized IT tests and standardized tools for analyzing the results (▶ Chap. 77, "International Large-Scale Computer-Based Studies on Information Technology Literacy in Education" by Fraillon). However, the data provided by each country will be influenced by the national interpretations, the political priorities, and the local methods for collecting the data. Furthermore, many of these large-scale studies do not always specify what is meant by IT and what is understood nationally. Although great care may be taken in the design of questionnaires for example to cover this diversity of IT resources, schools and teachers themselves have been seen to differ significantly in their interpretation of the meaning of IT which therefore influences their responses to such questionnaire surveys. There still remain ambiguities across such results because of these factors and more work needs to be done to identify which data collection methods can provide the most reliable and robust results.

Scalability and Sustainability of Research Methods and Outcomes

In the 1960s, research into IT in education was initially focused on the effects on students' learning because the main purpose for using IT was to enhance existing teaching and learning practices or to present the existing curriculum in different ways. It was assumed that results which showed evidence of a positive impact on students' learning would gradually be adopted by other teachers and educational establishments. However, 50 years on, we have seen many promising technological applications in education decline in use (see Table 1 and Cox and Marshall 2007), e.g., the QUERTY keyboard, the use of LOGO in primary schools, the use of integrated learning systems, simulations in science teaching, and many others. One of the main reasons for the lack of sustainability of use of specific technologies in education has been due to teachers being persuaded by policy makers to adopt it initially and they have therefore never claimed ownership for their own teaching innovation. The factors shown in Fig. 1 and the body of research into the pedagogies and roles of teachers (e.g., Desforges 1995, Law 2008) has for many decades found that innovations particularly IT are often only used by innovative teachers in schools where the Head-teacher/principal has a strong policy for professional development and innovations in the curriculum.

Earlier large-scale international studies and meta-studies conducted in a time when the range of IT resources in schools was more limited and much less mobile have provided results which still could be generalized and thereby scalable. However, such studies did not always take account of the learning contexts and the effects of stakeholders on the uptake of new technologies which influences the interpretation of the results in relation to specific local, national, and cross-national contexts. In conclusion, 10 years on, there continues to be evidence that, in order for IT innovations in education to be sustainable, teachers need to feel ownership of the technology and require detailed knowledge of the nature of IT tools, their different representations, and the ways in which they may contribute to learning and knowledge. These factors therefore need to be taken into account by educational researchers in order for them to be able to design appropriate research methods to measure their impact and the relationship between learning and the types of IT media being used by the learner (Khenissi et al. 2016).

The review conducted by one of the working groups of Edusummit2017 (Lai et al. 2017, pp. 71–76) focussing on the sustainability and scalability of educational research, identified three challenges for researchers, practitioners and policy makers (p. 73–74) which need to be adopted if we are to build on research in the past and present to *sustain* an innovation over time and *scale* up the use of an innovation into other contexts, domains, cultures and across nations. Challenge 1 recommends that productive partnerships need to be established among all stakeholders to build capacity of IT use in schools. Research programs need to be co-designed so that policy makers need to claim ownership of the research results and thereby take responsibility for policies based on research outcomes. Challenge 2 is that research approaches should be identified that are sustainable and scalable and where relevant support sustainability and scalability. Challenge 3 is that successful integration of technology should be founded on evidence from the research literature rather than on isolated policy driven initiatives.

Challenges to Researching IT and Solutions

In this chapter, I have identified the key challenges which researchers face in an ever-changing IT environment. These include having a prior understanding of the following:

- The affordances and reach of the IT learning environment be it a specifically designed educational resource used within the formal classroom or a personal device being used outside of the classroom in an informal setting
- Organization of courses, curriculum, in which IT resources might have a central or peripheral role, and interactions in learning between formal and informal education
- Student and teachers' digital literacy skills and how these encompass new knowledge: new representations and new modes of learning when IT resources are being used
- Evolution and diversification of IT resources and the effects on the complexity of the learning experiences and the loss of control of the teacher
- Scalability and sustainability of research methods and outcomes at a local, national, and international level

Figure 2 below shows how these challenges and associated factors and influences are related, complementing the earlier educational framework shown in Fig. 1 developed by Entwistle (1987). It takes into account the innovation being IT

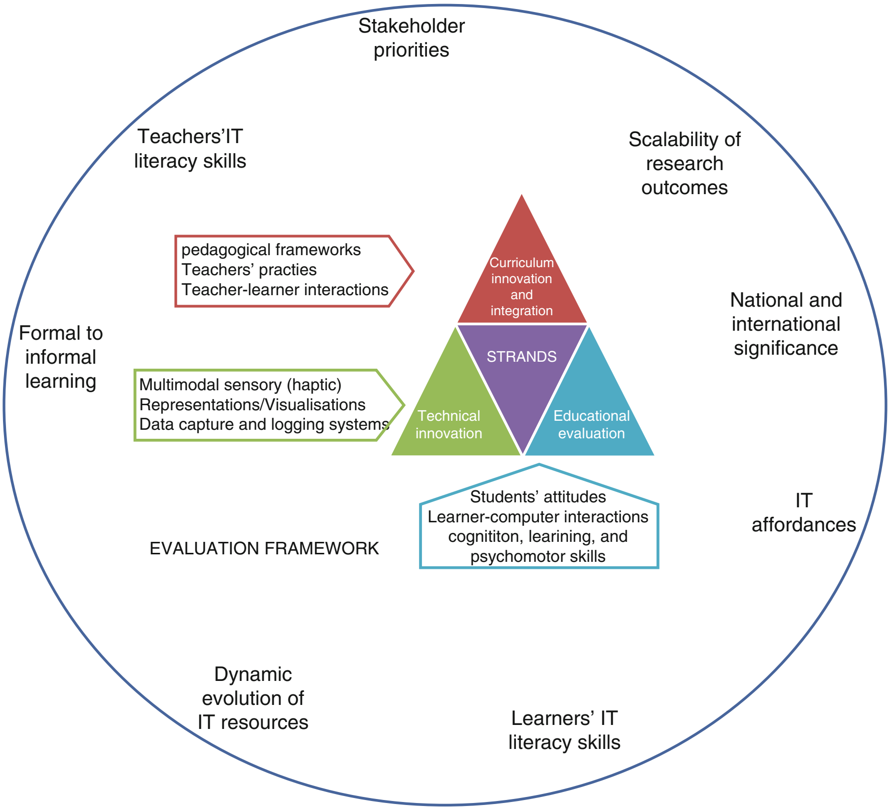

Fig. 2 Evaluation framework for researching IT in education

resources (E-learning) and the consequent integrated and multi-methods research approach which is needed.

In considering the long-term strategies and effects of researching IT in education, Pachler and Turvey (▶ Chap. 79, "Looking Back, Moving Forward: Impact and Measurability of the Use of Educational Technology" in this volume) identify research principles (p. xx) which they believe will "act as a catalyst for sustainable methodological innovation that progresses the field of educational technology research." They recommend that there should be a "call for far-sighted innovation that resists becoming confined by methodological or pedagogical paradigms."

In the 10 years since the publication of the first edition, there have also been calls from research teams to devise strategies which will ensure appropriate methodologies and a sustained body of experts interacting with policy makers and practitioners to ensure that the challenges we face identified in this chapter can be adequately addressed and can achieve sustainability and scalability. Figure 3 shows a framework initially produced by Cox and Niederhauser (2013) and further developed by Cox et al. (2013) which identifies the wide range of roles and interactions among

Fig. 3 Roles and interactions among researchers, policy makers, and practitioners (Cox et al. 2013: p. 482)

researchers, policy makers, and practitioners which need consideration when researching IT in education. As has been discussed in this chapter, in order for the field of researching IT to have the most effective and long-term impact on innovation adoption in education, research studies need to have relevance and meaning for practitioners and policy makers. Otherwise, the outcomes often fall on deaf ears of policy makers and teachers or wither on the vine of disinterestedness and stagnation.

Technology changes society and thereby changes the goals of education. Therefore, important considerations for policymakers include: how technology is changing the ways we learn, and the educational institutions that support that learning, how research practices can be intertwined with cultural differences, national priorities and global agendas; and what is the nature of technology use that improves education and will be likely to support its transformation? Success (for researching IT) will require cooperation, collaboration and a shared vision with all stakeholders contributing to the greater effort (Cox et al. 2013, p. 485).

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75 Meta-analyses of Large-Scale Datasets: A Tool for Assessing the Impact of Information and Communication Technology in Education

Yuen-Kuang Cliff Liao and Wan-Ching Lai

Contents

Abstract

This chapter focuses on the types of research questions that might be answered by using meta-analysis in the area of information communication technology (ICT) in education and the strengths and weaknesses of such meta-analyses. The chapter is divided into four parts: (a) brief description of the meta-analysis research method, (b) synthesis of meta-analysis studies of the impact of ICT in education from 1988 to 2017, particularly focusing on 2007–2017, (c) identifying what kinds of evidence outcomes can be achieved through meta-analysis, and (d) discussion of the strengths and weaknesses of meta-analysis in ICT in education and what are the most reliable methods to obtain accurate evidence about the impact of ICT in education.

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The Meta-analysis Research Method

In the first edition of the *International Handbook of Information Technology in Primary and Secondary Education*, Liao and Hao (2008) showed that meta-analysis is a useful research method to synthesize research outcomes in the field of technology in education. Meta-analyses apply statistical methods to the treatment of quantitative representations of study outcomes. In this respect they differ from more qualitative reviews of research findings (e.g., literature reviews) or informal reviews (e.g., "vote counting"). For a definition of Meta-analysis and an extended discussion of the advantages and criticisms of meta-analysis as a research method, we refer to the first edition of this Handbook (Liao and Hao 2008).

The present synthesis focuses on two eras, from 1988 to 2017 because prior to 1988 Walberg (1983) and Roblyer et al. (1988) had done a wonderful job to synthesize studies in computer-based instruction (CBI) before 1988. There is no reason to repeat their works. However, since 1988 new instructional technologies such as e-learning, web-based learning, and m-learning have continually developed. In addition, new approaches to synthesize large-scale datasets advanced. It is important to see the impact of these new approaches to students' learning. We first summarize two periods which are also covered in the first edition of the Handbook (see also Liao and Hao 2008): 1972–1986 – the early days of technology in education – and 1988–2006 when the Internet became widely available for education. Then we extensively present and discuss the meta-analyses published in the 2007–2017 timeframe when mobile learning became widely available in schools. The chapter concludes with a discussion of the final period up to the present day and the changes since 1988.

Review of Studies of Meta-analysis on Information Technology in Education

According to Anderson et al. (2001), the revision of Bloom's taxonomy of learning domains can be categorized in three domains: cognitive, affective, and psychomotor domains. The learning outcomes of studies in the field of information technology (IT) can also be characterized within this framework. Most meta-analyses in IT focused on students' cognitive outcomes (e.g., academic achievement, or problem-solving ability); some meta-analyses assessed students' affective outcomes (e.g., attitudes toward learning, or interest in specific domain); and a few meta-analyses evaluated students' psychomotor outcomes (e.g., social skills). In the present review, we used this framework and grouped the overall effect size of collected meta-analyses into cognitive, affective, and social skills aspects.

The Period from 1972 to 1986

Many studies regarding the impact of IT in education have been published since the 1970s. These large numbers of published studies enabled educational researchers to conduct studies of the meta-analysis method itself. Walberg (1983), for example, introduced and illustrated the methods of research synthesis and summarized the substantive findings regarding teaching and areas of instructional technology (IT in education). On the other hand, Roblyer et al. (1988) reviewed 26 research studies between 1972 and 1986 to assess the impact of computer-based instruction (CBI) on students' learning. However, the reviews from this period did not reach similar conclusions, and only a few clear agreements were found among the findings of these various reviews. Nearly all the reviews during this period seemed to yield evidence that computer-based treatments offered some benefits over other instructional methods (Roblyer et al. 1988).

The Period from 1988 to 2006

In the first edition of the *International Handbook of Information technology in Primary and Secondary Education* Liao and Hao (2008) presented a review of meta-analyses published between 1988 and 2006. Their review included 44 meta-analyses and were grouped into two categories: 30 meta-analyses for computer-assisted instruction (CAI) and 14 meta-analyses for distance education (DE). The results showed that when combining the effect sizes (ESs) of both CAI and DE together, the overall ESs were 0.29 and 0.06 for the cognitive aspect and affective aspect, respectively.

The further analysis was to compare the different effects between K-12 and other students (college and higher education) for both CAI and DE meta-analyses. For CAI, the ESs were almost identical for K-12 and non-K-12 students on every aspect (0.41, 0.15, and −0.02 for the cognitive, affective, and social skill aspects, respectively). However, for DE, the results showed that the ESs of non-K-12 were higher than those of K-12 for the cognitive (0.06 for K-12 and 0.19 for non-K-12) and a bit higher for the affective aspects (−0.09 for K-12 and −0.03 for non-K-12) of DE. This can probably be explained by the fact that at the time DE in this period was much more used in higher education than in K-12 education (see also ▶ Chap. 49, "Virtual Schools: A Global Perspective" by Davis and Ferdig, this volume).

In sum, there were 30 meta-analyses comparing CAI with conventional instruction in terms of students' cognitive achievement. About 90% (27) of the meta-analyses indicated that students whose teaching was supplemented with CAI performed better than students without CAI. Five meta-analyses investigated the affective variable, attitude. Two of them indicated that students using CAI had a better attitude toward learning than did students without CAI, and two studies indicated that there was no significant difference between the two modes. Only one meta-analysis compared students' social skills when using computerized testing with those when using paper-and-pencil tests. The results indicated that a slight reduction in impression management happened because of computerized testing and a slight increase in self-deceptive enhancement happened because of computerized testing, when comparing computerized testing with paper-and-pencil or face-to-face administration (see details in Liao and Hao 2008, pp. 1023–1027).

For the 14 meta-analyses comparing DE with traditional face-to-face instruction, 57% (8) of the meta-analyses indicated that DE students slightly outperformed traditional students on examinations. Thirty-six percent (5) of the meta-analyses concluded that there was no significant difference between the two modes, and 7% (1) of the studies summarized that traditional students had better achievement than remote distance learning students. In addition, three meta-analyses investigated the affective variable, attitude, and concluded that either traditional students had better attitude toward instruction than did remote students (67%) or students had no significant preference to any mode of instruction (33%) (see details in Liao and Hao 2008, pp. 1023–1027). However, the ages and therefore maturity of the students differed among those k-12 students compared with adult students in higher education, one of several variable differences not addressed in these comparisons.

The Period from 2007 to 2017

The meta-analysis presented in the remaining part of this chapter includes 45 studies published between 2007 and 2017. These studies were grouped into five categories: (1) Computer-assisted instruction (CAI): CBI, CAI, information and ICT, and teaching or learning with Intelligent Tutoring Systems (ITS); CAI is used as a general term here. (2) Distance education (DE) and Internet technologies: Tele-courses, online learning (synchronous or asynchronous), and courses utilizing the media of online computer-mediated communication belong to this category; DE is used as a general term here. (3) Multiple technology (MT): meta-analysis might include studies utilizing all kinds of tools related to educational technology. (4) Game-based learning (GBL): digital game-based learning and computer-based simulation; GBL is used as a general term here. (5) Mobile-learning (ML): mobile learning, and ubiquitous learning; ML is used as a general term here.

The overall ES for CAI were 1.06 for the cognitive aspects, while most meta-analyses did not report affective outcomes and psychomotor skills. Table 1 lists the meta-analyses included in the present period reviewed in this chapter. The overall ES are given as a footnote to the table. The fact that the overall ES of 1.06 is much higher than the ES in the period of 1988–2006, which is 0.41, is because the 5 meta-analyses conducted in Turkey (Camnalbur and Erdogan 2008; Demir and Basol 2014; Dýnçer 2015; Tekbiyik and Akdeniz 2010; Yesilyurt 2010) all reported high ESs. That raises a question whether the effect of CAI may differ for students in different countries.

Further analyses were completed to compare the different effects between K-12 and other students for CAI meta-analyses. Seven out of 11 studies displayed overall ESs for students in all grade levels, three studies presented overall ESs for postsecondary students, and two studies (Liao 2007; Tekbiyik and Akdeniz

Table 1 Overall effect sizes for 11 meta-analyses of CAI versus non-CAI instruction

Author(s)	Number of studies	Effect size	Subject matter	Grade level
Abraham (2008)	11	C = 0.73	Language (L2)	Postsecondary
Camnalbur and Erdogan (2008)	78	C = 1.05	NA	All
Chiu (2013)	16	C = 0.75	Language (L2)	All
Demir and Basol (2014)	40	C = 0.9	Math	All
Dýnçer (2015)	26	C = 1.21	Math and science	All
Larwin and Larwin (2011)	70	C = 0.57	Statistics	Postsecondary
Liao (2007)	52	C = 0.55 Elem. = 0.41 Juni. = 0.85 High. = 0.23 Univ. = 0.82	All	All
Kulik and Fletcher (2015)	50	C = 0.66	All	All
Sosa et al. (2011)	45	C = 0.33	Statistics	Postsecondary
Tekbiyik and Akdeniz (2010)	52	C = 1.12, Elem. = 1.43 Seco. = 0.79 Univ. = 1.06	Science	All
Yesilyurt (2010)	25	C = 3.84	Math and science	All

Note. The overall effect size of the cognitive aspect is 1.06 (K-12 = 0.74; postsecondary = 0.61)
NA data not available, *C* cognitive achievement.

2010) specifically reported ES for each grade level. The overall ESs for K-12 and postsecondary students are 0.74 and 0.61, respectively. The overall ES for K-12 was mildly higher than those of postsecondary students. Regarding the subject matter, 8 of 11 studies focused on specific subject matters: two studies on L2 language, four studies on mathematics, science, or both, and two studies on statistics. In total, there were 11 studies comparing CAI with conventional instruction in terms of students' cognitive achievement. All studies indicated that students who learned with CAI performed better than students without CAI.

Nine meta-analyses categorized in DE were included in this period. The overall ES for DE was 1.07 for the cognitive aspects while most meta-analyses did not report affective outcomes and psychomotor skills. Table 2 lists the meta-analyses included in the present period. The overall ES are given as a footnote to the table. Three studies (Kim and Kim 2013; Mothibi 2015; Voutilainen et al. 2017) utilized e-learning as instructional tools, while 2 studies (Lin et al. 2013; Lin 2014) applied CMC in learning L2 language. The fact that the overall ES of 0.92 is much higher than the ES in the period of 1988–2006, which is 0.17, is because that one meta-analysis (Voutilainen et al. 2017) reported a very high ES of 5.24.

Table 2 Overall effect sizes for 9 meta-analyses of distance education and Internet technologies versus non-Internet-based instruction

Author(s)	Number of studies	Effect size	Subject matter	Grade level
Jahng et al. (2007)	20	C = 0.023	All	Postsecondary
Kim and Kim (2013)	8	C = 0.301	NA	All
Lin et al. (2013)	10	C = 0.33	Language (L2)	NA
Lin (2014)	59	C = 0.44	Language (L2)	All
Means et al. (2009)	45	C = 0.2 K-12 C = 0.17 Non-K-12 C = 0.204	All	All
Mothibi (2015)	15	C = 0.712	NA	Postsecondary
Roberts (2011)	59	C = 0.777	All	Postsecondary
Shachar and Neumann (2010)	125	C = 0.257	All	Postsecondary
Voutilainen et al. (2017)	10	C = 5.24	Nursing education	Postsecondary

Note. The overall effect size of the cognitive aspect is 0.92 (K-12 = 0.17; postsecondary = 1.40)
NA data not available, *C* cognitive achievement

Further analysis was to compare the different effects between K-12 and other students for DE meta-analyses. Five of nine studies presented overall ESs for postsecondary students, and only one study (Means et al. 2009) reported ES for each grade level. The overall ESs for K-12 and postsecondary students were 0.17 and 1.4, respectively. The overall ES for postsecondary students was much higher than those of k-12. Overall, there were nine studies comparing DE with non-Internet-based instruction in terms of students' cognitive achievement. All studies indicated that students who utilized DE as learning technology performed better than students without DE.

Multitechnology (MT) includes all types of computer-based tools (Schmid et al. 2014), ranging from early computer-assisted instruction (CAI) or computer-based instruction (CBI), to simulations, or computer-mediated communication, to the Internet or Logo (Li and Ma 2010). Meta-analyses gathering studies utilized more than one instructional technology were categorized into MT.

The overall ESs for MT were 0.36 and 0.19 for the cognitive and affective aspects, respectively. Table 3 lists the meta-analyses included in the present period. The overall ES are given as a footnote to each table. Further analysis was to compare the different effects between K-12 and postsecondary students for MT meta-analyses on both aspects. Four of nine studies presented overall ESs for K-12 students, two studies presented overall ESs for every grade level, and three studies reported ES for postsecondary students. The overall ES for K-12 (0.42) was slightly higher than those of postsecondary (0.32) on cognitive aspect, but both achieved small to moderate ES. However, for affective aspect, the overall ESs for K-12 (0.18) and postsecondary (0.2) were almost identical and reached small but positive ES. On the

Table 3 Overall effect sizes for nine meta-analyses of multitechnology versus conventional instruction

Author(s)	Number of studies	Effect size	Subject matter	Grade level
Bernard et al. (2014)	117	C = 0.33	All	Postsecondary
Borokhovski et al. (2016)	45	C = 0.35	All	Postsecondary
Chauhan (2017)	122	C = 0.55	All	Elementary
Grgurović et al. (2013)	37	C = 0.26	Language	All
Lee et al. (2013)	58	C = 0.42, A = 0.18	All	K-12
Li & Ma (2010)	46	C = 0.28	Math	K-12
Liao et al. (2007)	48	C = 0.45	All	Elementary
Schmid et al. (2014)	1105	C = 0.27, A = 0.2	All	Postsecondary
Tamim et al. (2011)	25	C = 0.35	All	All

Note. The overall effect size of the cognitive aspect is 0.36 (K-12 = 0.42; postsecondary = 0.32)
The overall effect size of the affective aspect is 0.19 (K-12 = 0.18; postsecondary = 0.2)
NA data not available, *C* cognitive achievement, affective achievement

subject matter, only two studies (Grgurović et al. 2013; Li and Ma 2010) focused on language and mathematics. In summary, there were nine meta-analyses comparing MT with conventional instruction. All studies indicated that students who learned with MT performed better than students without technology on cognitive aspect; two studies (Lee et al. 2013; Schmid et al. 2014) examined the affective outcome and concluded that K-12 ES was trivially lower than those of postsecondary students.

Computer games are designed under a set of agreed rules and constraints (Garris et al. 2002). The purpose of game-based learning (GBL) is not to entertain the player but to use the entertaining quality for training, education, health, public policy, and strategic communication objectives (Wouters et al. 2013; Wouters and van Oostendorp 2013). On the other hand, in general, a simulation is defined as a computer program which relates cause and effect together. When it comes to an instructional purpose, it enables students to bridge the gap between reality and abstract knowledge (Lee 1999). Although GBL and instructional simulation have slight differences in terms of goals, rules, and design features, they all share the idea of providing users with an enjoyable virtual environment to enhance learning motivation. Meta-analyses investigating the effect of GBL or simulation were categorized into GBL.

The overall ESs for GBL were 0.45, 0.44, and 0.35 for the cognitive, affective, and social skill aspects, respectively. Table 4 lists the meta-analyses included in the present period. The overall ESs are given as a footnote to each table. Further analysis was to compare the different effects between K-12 and postsecondary students for GBL meta-analyses on three aspects. Ten of 13 studies reported overall ESs for every grade level, two studies presented overall ESs for postsecondary students, and only one study (D'Angelo et al. 2014) reported ES for K-12 students. The overall ES for

Table 4 Overall effect sizes for 13 meta-analyses of game-based learning versus conventional instruction

Author(s)	Number of studies	Effect size	Subject matter	Grade level
Brydges et al. (2015)	8	Immediate C = 0.23, delayed C = 0.44	Health profession	Postsecondary
Clark et al. (2016)	55	C = 0.35 S = 0.35	NA	All
Cook (2014)	592	C = 1.1	Health profession	Postsecondary
D'Angelo et al. (2014)	40	C = 0.67	All	K-12
Gegenfurtner et al. (2014)	13	A = 0.82	NA	All
Lee (1999)	19	C = 0.41 A = −0.4	All	All
[a]Merchant et al. (2014)	13	C = 0.51	All	All
[a]Merchant et al. (2014)	29	C = 0.41	All	All
Sitzmann (2011)	55	C = 0.29 A = 0.52	All	All
Vogel et al. (2006)	32	C = 0.13 A = 0.59	NA	All
Wang and Tseng (2011)	21	C = 0.58	NA	NA
Wouters and van Oostendorp (2013)	29	C = 0.34	All	All
Wouters et al. (2013)	39	C = 0.29 A = 0.26	All	All

Note. [a]two meta-analyses reported in an article
The overall effect size of the cognitive aspect is 0.45 (K-12 = 0.67; postsecondary = 0.59)
The overall effect size of the affective aspect is 0.44 (K-12, NA; postsecondary, NA)
The overall effect size of the social skill aspect is 0.35 (K-12, NA; postsecondary, NA)
A affective achievement, *C* cognitive achievement, *S* social skill, *NA* data not available

K-12 (0.67) was mildly higher than those of postsecondary students (0.59) on cognitive aspect, but both achieved moderate ES. However, for the affective and social skill aspects, the overall ESs for both K-12 and postsecondary were not available. Regarding the subject matter, two studies (Brydges et al. 2015; Cook 2014) specifically focused on the health profession. In summary, there were 13 meta-analyses comparing GBL with conventional instruction. All studies indicated that students who learned with GBL performed better than students without GBL for the cognitive aspect. Five studies investigated the affective outcome and one study analyzed the students' social skills (Clark et al. 2016). The GBL forms of instruction all showed positive and moderate effects over conventional instruction.

Mobile devices such as Personal Digital Assistants (PDAs), tablet PCs, mobile phones, and e-book readers offer features of portability, social connectivity, context sensitivity, and individuality, which desktop computers might not offer (Chinnery 2006). Mobile learning (ML) integrates electronic learning (e-learning) materials

Table 5 Overall effect sizes for three meta-analyses of mobile-learning versus non-ML instruction

Author(s)	Number of studies	Effect size	Subject matter	Grade level
Lee et al. (2014)	44	C = 0.54	Languages	NA
Sung et al. (2015)	45	C = 0.53 A = 0.55	Language	All
Sung et al. (2016)	110	C = 0.52 Kinder = 0.1 Elem = 0.66 Middle = 0.51 High = 0.39 College = 0.6 Adults = 2.47 Mixed = 0.08	All	All

Note. The overall effect size of the cognitive aspect is 0.53 (K-12 = 0.42; postsecondary = 1.54)
The overall effect size of the affective aspect is 0.55 (K-12, NA; postsecondary, NA)
A affective achievement, *C* cognitive achievement, *NA* data not available

with mobile devices (Lee et al. 2014; Sung et al. 2016). Meta-analyses investigating the effect of ML on students learning were categorized into ML.

The overall ESs for ML were 0.53 and 0.55 for the cognitive and affective aspects, respectively. Table 5 lists the meta-analyses included in the present period. The overall ESs are given as a footnote to each table. Further analysis was to compare the different effects between K-12 and postsecondary students for ML meta-analyses on both aspects. The overall ES for K-12 (0.42) was much lower than those of postsecondary students (1.54) on cognitive aspect, but both achieved moderate to very high ES. However, for the affective aspect, the overall ESs for both K-12 and postsecondary students were not available. In total, there were only three meta-analyses comparing ML with non-ML instruction. All studies indicated that students who learned with ML performed better than students without ML on cognitive aspect; one study (Sung et al. 2015) investigating the affective outcome also showed positive and moderate effects over non-ML instruction.

Evidence Outcomes Achieved Through Meta-analysis on Information Technology in Education

According to Cohen (1988), an effect is said to be small when ES = 0.2, medium when ES = 0.5, and large when ES = 0.8. In the period of 1988–2006, when both CAI and DE were combined, the overall mean ES for the cognitive achievement was 0.29, and 0.06 for the affective aspect. These results suggest that students with technology integrated into learning activities slightly outperformed those students without using technology for learning. With regard to the affective aspect, technology seems to have a trivial impact on student learning in the 1988–2006 time frame. In addition, in the same period, when comparing K-12 and non-K-12 settings, CAI appear to be equally effective for both K-12 and non-K-12 students' performance, but DE was more effective for postsecondary than K-12 students.

Table 6 Summary of overall ES for each category of ICT in Education in 2007–2017

Category	Cog. ES	Aff. ES	Sc. ES	Cog. ES for K-12	Cog. ES for PS	Aff. ES for K-12	Aff. ES for PS
CAI	1.06			0.74	0.61		
DE	0.92			0.17	1.4		
MT	0.36	0.19		0.42	0.31	0.18	0.2
GBL	0.45	0.44	0.35	0.67	0.59		
ML	0.53	0.55		0.42	1.54		
Overall mean ES	0.67	0.39	0.35	0.48	0.89	0.18	0.2

Note. *CAI* computer assisted instruction, *DE* distance education, *MT* multitechnology, *GBL* game-based learning, *ML* mobile learning, *Cog*. cognitive, *Aff* affective, *Sc*. social skill, *PS* postsecondary

However, in the period of 2007–2017, when combining all 5 categories of technology (i.e., CAI, DE, MT, GBL, and ML) together, the overall mean ESs for the cognitive, affective, and social skill achievement were 0.67, 0.39, and 0.35, respectively, which are much higher than those in the previous period. The results from this period point out that students learning with technology performed much better in all three aspects than those students without using technology. The summary of overall ES for each category is presented in Table 6. Furthermore, when comparing the effects of K-12 and postsecondary for the cognitive aspect, postsecondary students (overall mean ES = 0.89) seemed to benefit more from learning with technology than K-12 students (overall mean ES = 0.48). Regarding the affective aspect, the overall mean ESs were 0.18 and 0.2 for K-12 and postsecondary students, correspondingly; students in both levels were almost identical. Moreover, when comparing the effects of different technology applications in education, the overall mean ESs for cognitive aspect were CAI = 1.06, DE = 0.92, MT = 0.36, GBL = 0.45, and ML = 0.53. CAI and DE appeared to be the most effective technology for learning. For the affective outcomes, the overall mean ESs were MT = 0.19, GBL = 0.44, and ML = 0.55. ML was considered to be the best choice.

A detailed discussion about the evidence of outcomes achieved through meta-analysis on information technology in education in the period of 2007 to 2017 is given below.

There are 11 meta-analyses focused on CAI published in this period. Among them, seven studies were for all grade levels, three studies for postsecondary students, and two studies (Liao 2007; Tekbiyik and Akdeniz 2010) reported separate ESs for K-12 and postsecondary students. Liao's meta-analysis involved 52 studies (134 ESs) from Taiwan. The overall ES was 0.55 and the ESs for elementary, junior, high, and university students were 0.41, 0.85, 0.23, and 0.82, respectively. According to the earlier meta-analysis by Cohen (1988), the effects of ESs ranged from small to large, and the most effective ESs were for junior and university students, and the most ineffective ES was for high school students. Tekbiyik and Akdeniz's meta-analysis involved 52 studies (65 ESs) on students' academic achievement in science education from 2001 to 2007 in Turkey. The overall ES was 1.12, while the ESs were 1.43, 0.79, and 1.06 for elementary, secondary, and university students, respectively. These ESs are interpreted as large. The study also found significant differences in effectiveness for different grade levels; the most effective grade level was elementary (4th–8th), followed by the university level. The most unproductive effects were the high school (9th–12th) level. Based on the findings of Liao and Tekbiyik et al.'s studies, CAI do have different effects for different grade levels.

One interesting finding is that five meta-analyses conducted in Turkey (Camnalbur and Erdogan 2008; Demir and Basol 2014; Dýnçer 2015; Tekbiyik and Akdeniz 2010; Yesilyurt 2010) all reported high ESs. The study by Yesilyurt even achieved a very high ES of 3.83. The high ESs from these studies raised a question whether the effects of CAI may vary when applied to students in different countries. Studies of this question will require further clarification of the exact relationship between CAI and educational policy or culture of that specific country.

In comparing DE with traditional classroom instruction in this period, DE students have noticeably higher gains in cognitive outcomes than those who are being taught conventionally. Among nine meta-analyses, only one study analyzed by Means et al. (2009) reported separate ESs for k-12 and non-k-12 students, and the effects were all small, based on Cohen's criteria. The fact that only one out of nine meta-analyses in this period specifically examined the effects of DE on K-12 students seemed to suggests that DE is perhaps not appropriate for K-12 students and that it is not an integral part of the curriculum delivery. In addition, five meta-analyses used postsecondary students as the sample and reported quite diverse effects; the ESs ranged from 0.023 (Jahng et al. 2007) to 5.24 (Voutilainen et al. 2017). The study by Voutilainen et al. was particularly for students in a nursing school, and the other four meta-analyses did not specify any subject area. Although the ES of 5.24 is unusual in meta-analytic research, the wide range of ESs seemed to suggest that the effects of DE may differ when applied to different subjects.

In comparing multitechnology with conventional instruction, students who used multitechnology showed better gains in both cognitive and affective aspects. In K-12 setting, the benefits of multitechnology were greater among elementary students compared to secondary students (Li and Ma 2010; Lee et al. 2013), and the role of learning strategies was found to be important whether with a constructivist approach (Li and Ma 2010) or project-based learning (Lee et al. 2013). To investigate whether the use of multitechnology can help elementary students achieve better learning, Liao et al. (2007) analyzed 48 studies. They showed a positive result (ES = 0.45) and concluded that the effect of CAI may vary over different subject matter, individual learning is better than group learning, and that computer simulation had the highest ES comparing to web-based learning or CAI. Chauhan (2017) used 122 studies resulting in 215 ESs, which confirmed that the technology had a medium effect on learning effectiveness of elementary students.

In a much earlier study by Clark (1983), after reviewing several meta-analyses of CAI, his results suggested that the effects of new media on instruction were due to a novelty effect, because the ES was reduced when treatment lasted for longer periods of time. Liao and Bright (1991) also reported this novelty effect in their meta-analysis of programming on students' cognitive abilities. However, the results of

Chauhan's study, more than 25 years later, found that ESs for studies in which the duration of treatment was over 6 months or less than 1 week were equally high, indicating that novelty effects may not be a factor affecting the impact on learning, which counteracts the previous viewpoint of the novelty effect.

Three meta-analyses categorized in multitechnology and used in postsecondary all tried to answer the "big question": does technology work? Schmid et al. (2014) examined Richard Clark's claim about the nature of the relationship between technology and pedagogy, Bernard et al. (2014) focused on the blended learning, and Borokhovski et al. (2016) emphasized the impact of designed interaction treatments and contextual interaction treatments on student learning outcomes. The results of these studies are all positive in both cognitive and affective aspects.

Grgurović et al.'s (2013) meta-analysis concentrated on the effects of computer assisted language learning (CALL) in all education levels and reached some conclusions. First, research of CALL tends to use in higher education and the need for research in K-12 is urged to better understand any potential differences. Second, in comparing the various conditions of technology use, second/foreign language instruction supported by computer technology was at least as effective as instruction without technology. However, when comparisons between CALL and non-CALL groups were made in rigorous research designs, the CALL groups performed better than the non-CALL groups, as indicated by a small, but positive and statistically significant weighted mean effect size of 0.257. (Grgurović et al. 2013).

The overall ESs for GBL were 0.42 and 0.44 for the cognitive and affective aspects, respectively. All studies concluded that students learning with game-based computer resources performed better than students without game-based learning. However, the evidences show research interests diverse among different GBL studies. In an attempt to resolve the dispute of which educational technology results in the highest cognitive gain for learners, Vogel et al. (2006) investigated 32 studies and conducted a meta-analysis to decipher which teaching method, games and interactive simulations or traditional, truly dominates and under what circumstances. Their results concluded that games and interactive simulations are more dominant for cognitive outcomes. When students navigated through the programs themselves, there was a significant preference for games and interactive simulations. However, when teachers controlled the programs, no significant advantage was found and when the computer dictated the sequence of the program, results favored those in the traditional teaching method over the games and interactive simulations. Examining the relationship between two forms of simulation, pure and hybrid, and two modes of instruction, presentation and practice, Lee (1999) analyzed 19 studies and concluded within the presentation mode that the hybrid simulation is much more effective than the pure simulation. Simulations are almost equally effective for both presentation and the practice modes. If the hybrid simulation is used, specific guidance on how to use the simulation seems to help students to perform better, whereas when students learned in the presentation mode with the pure simulation, they showed a negative attitude towards simulation.

Wang and Tseng (2011) synthesized 21 studies and analyzed how media were used to support GBL. The ES of 0.58 indicated that students who learned with games can obtain better learning effects than those who learned without games. Wouters and Van Oostendorp (2013) examined 29 studies to test if instructional support enhances learning in GBL. The overall ES was 0.34, suggesting that instructional support in GBL environments improved learning. Additional analyses revealed that the learning effect became largest when learning of skills was involved and when the instructional support aimed at the selection of relevant new information.

To investigate whether serious games are more effective in terms of learning and more motivating than conventional instruction methods, Wouters et al. (2013) analyzed 39 studies and concluded that serious games were more effective in terms of learning and retention, but they were not more motivating than conventional instruction methods. D'Angelo et al. (2014) researched the effects of computer simulations on science, technology, engineering, and mathematics (STEM) and concluded, on average, that simulations had a positive effect on science achievement. Additional findings revealed that learners using serious games learned more when the game was supplemented with other instruction methods, when multiple training sessions were involved, and when players worked in groups (Wouters et al. 2013).

Examining the impact of GBL in K-12 or higher education settings, Merchant et al. (2014) concluded that an elaborate explanation type feedback is more suitable for declarative tasks, whereas knowledge of correct response is more appropriate for procedural tasks. Students' performance was found to be enhanced when they played games individually than in a group.

Theory-driven meta-analysis examines the correlation between theory and GBL. Drawing from social cognitive theory and the cognitive theory of multimedia learning, Gegenfurtner et al. (2014) examined how design characteristics in digital simulation-based learning environments moderate self-efficacy and transfer of learning. The findings indicate that high levels of user control result in higher estimates of self-efficacy and transfer and that offering assessment feedback after rather than during training led to higher efficacy beliefs and transfer. Brydges et al. (2015) evaluated the effectiveness of interventions designed to support trainees in self-regulated learning (SRL) activities in the simulation-based training context and found that interventions including SRL supports were associated with small benefits compared with interventions without supports on both immediate posttests and delayed retention tests. To find out whether interactive cognitive complexity theory claim that simulation games are more effective than other instructional methods, Sitzmann (2011) analyzed 55 studies and the result showed posttraining self-efficacy was 20% higher, declarative knowledge was 11% higher, procedural knowledge was 14% higher, and retention was 9% higher for trainees taught with simulation games, relative to a comparison group. Cook (2014) re-analyzed the results of a meta-analysis of simulation-based education (SBE) to determine the necessity of replication research studies. The result showed some replication is necessary to obtain stable estimates of effect and to explore different contexts.

The cognitive effect of ML for language learning has been shown to be effective (Sung et al. 2015; Lee et al. 2014). Adults and school children had similar beneficial effects, integrating mobiles with multiple learning strategies produced better learning achievement, using mobile devices for vocabulary or mixed language skills produced better effects, and using mobiles produced better learning achievement for L2 learning than for L1 learning (Sung et al. 2015). As for which subject matter has better effects with the integration of M-learning, Sung et al.'s (2016) meta-analysis has shown that social studies had a high ES, while professional subjects, such as science, language arts, and mathematics, had medium effect sizes.

In addition, Sung et al. (2016) found the effects of ML were varied for different grade levels. Young children achieved a high ES on learning achievement, while adults and secondary-schools had medium ESs. As for the answer of novelty effect, no conclusion is yet able to be made, since the results have not been consistent (Sung et al. 2015; Sung et al. 2016).

Meta-analysis on Information Technology in Education: Potential and Limitations

As has been shown in this chapter, meta-analysis as a research method helps to make sense of the available evidence about the impact of technology on student performance. With a carefully conducted meta-analysis, the findings of quantitative studies in the field of technology in education can be synthesized and presented in terms of effect sizes. One should keep in mind that meta-analysis has the ability to reduce sampling error by synthesizing effect sizes estimates across multiple primary studies and it cannot reduce sampling error to zero (Schmidt and Oh 2013). A second-order meta-analysis defined as the quantitative synthesis of the results of apparently similar meta-analyses may be able to reduce the sampling error from multiple meta-analyses. As such meta-analysis provides a more robust picture of the effect of technology integration on student performance compared to traditional teaching and learning methods. Such information might help policy makers and industry to decide whether their investments are worth the effort. The strength of meta-analysis is it can answer the big question of what makes learning effective; however, numbers have their limitations as has been shown, for example, in the comparisons presented in this chapter between K-12 results and students in higher education learning through DE (distance education). Therefore, meta-analysis as a research method in the field of technology in education is not the only way to get insights into the impact of technology use in education (see other chapters in this section). Meta-analysis falls short when the aim is to understand the reasons behind the numbers. Experimental designs and qualitative studies are more informative when "why" or "how" questions need to be answered and an in-depth analysis of the types and extent of IT in education being used by the teachers and learners.

A keyword search using the term "meta-analysis" performed on Proquest and set the periods from 1960 to 1988, 1988 to 2006, and 2007 to 2017 result in 686, 49,888, and 244,271 studies, respectively. The increasing number of studies across decades and various academic discipline confirms the fact that meta-analysis has become a highly accepted and focal approach for reviewing large-scale quantitative studies.

As in the first edition of the Handbook we conclude with quoting Bangert-Drowns' (1986, p. 398):

> Meta-analysis is not a fad. It is rooted in the fundamental values of the scientific enterprise: replicability, quantification, causal and correlational analysis. Valuable information is needlessly scattered in individual studies. The ability of social scientists to deliver generalizable answers to basic questions of policy is too serious a concern to allow us to treat research integration lightly. The potential benefits of meta-analysis method seem enormous.

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Researching the Design and Evaluation of Information Technology Tools for Education

76

Eric Bruillard and Georges-Louis Baron

Contents

Abstract

Concerning IT tools for education, we can distinguish (1) software tools for learning specific subject matters (e.g., simulation and discovery tools), (2) learning platforms, including MOOC platforms for distance learning but also used in hybrid contexts, and (3) digital resources (Wikipedia and Wikimedia, new interactive textbooks, video capsules, etc.). Behind all these tools, we observe strong

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tension between the desire to individualize instruction and the intention of offering collaborative usage of general tools, where users have a certain margin of freedom. If the analysis of big data appears as a new Eldorado for education, we have to be aware of incompleteness or spuriousness of data and faulty interpretation of results: number of different types of data (behavior, physiology, etc.) are collected and made accessible, interpreting them is difficult, and much research is still needed. Concerning design processes, a wide spectrum is observed: companies, start-ups, communities, and groups. An interesting link between teacher communities of practice and open educational resources can be underlined. Evaluating education software, resources, and platforms supports an extreme diversity of approaches. But it should include different criteria: functional compliance, interactional conformity, and hedonic quality. Finally, it is important to reaffirm the key role of teachers, helping them to develop their agency in the field of educational resources, empowering them, and accepting them as trusted partners.

Keywords
Software · MOOC · Secondary education · Person machine interaction · Evaluation · Community of practice

Context

In the past two decades, IT tools for education have evolved quite a lot. As was prophesied by Norman (1998), computers have tended to be replaced by *information appliances*, mobile and massively online, while digital resources have come to the fore, at least in developed countries, which have sufficient technical infrastructures and low connection costs.

In these countries, what has changed is that in society at large, virtually anyone with any specific interest can find very quickly an answer to any question, simply by asking some search engine on her mobile device. What this person will later do with the information (i.e., believe it, cross-check it, forget it, etc.) is another matter. Overall, as described many years ago (e.g., Berger 2001), online environments may be used for learning everywhere, well beyond the school and its formal organization, in an informal way (see, e.g., Cox 2013; Dabbage and Kitsantas 2012).

For many persons, computer tools are just like an extension of their body. As a consequence, the classical opposition between anthropocentric and technocentric approaches tends to disappear. For example, the Google search bar offers no real affordance, but as soon as one encounters a sort of search bar, she believes it functions exactly as she thinks Google is functioning (without really knowing how). Correlatively, there is an overall tendency to expect that tools can be directly used, without any specific learning. This is an illusion: those tools, improperly considered as intuitive, function as long as their use is directly in line with previous uses of devices having similar functions and based on the same metaphors and gestures.

Among these environments, only a fraction has been designed with the explicit aim of guiding learning toward explicit learning outcomes; a special case being Massive Online Open Courses (MOOCS) and MOOC-like environments; see section "Platforms for Distance Learning in Education, Also Used in Hybrid Contexts" below.

Furthermore, let us highlight a very important distinction: users interact with devices that are more or less secretly split between what resides within the user's information appliance and what is processed and stored on some remote platform running very sophisticated algorithms profiling the user in order to adapt its message to her.

Within the school, things have also evolved. Teachers have learned to cope with the fact that students have access to alternative sources of information and knowledge and use a wide range of software tools, few of them being directed toward learning. Many learning platforms (Claroline, Moodle, MOOC platforms, and so on) have also appeared and are used to disseminate contents. But the role of these platforms is not limited to diffusion, there are adding other features: recording and analyzing data, proposing diagnostics, and suggesting interventions.

Since educational IT tools represent much more than computer-assisted instruction, the question of designing and evaluating IT tools for education has to be reframed. We propose to distinguish three great classes of such tools.

1. *Software tools* used in the study of the different subject matter and specialized software systems prescribed or selected by teachers and acting either for monitoring students' progress or as simulation and discovery tools, providing new user experiences (e.g., virtual reality).
2. *Learning platforms*, including MOOC platforms (Coursera (https://fr.coursera.org/), EdX (https://www.edx.org/), FUN (https://www.fun-mooc.fr/), Iversity (https://iversity.org/), MiriadaX (https://miriadax.net/home/), FutureLearn (https://www.futurelearn.com/), etc.), often used in distance education.
3. *Digital resources* of various granularities that may either be directly used by teachers to illustrate their courses or be prescribed to students. This idea of resource has known a huge development in the past two decades, under an extremely wide range of forms: Wikipedia and Wikimedia, new interactive textbooks, video capsules, shared curricula designed by individual teachers or associations of activists, etc.

We shall now analyze these different current forms of IT tools for learning and teaching.

From Software Tools to Digital Resources

The three categories we have distinguished above raise similar issues. For each of them, there is a strong tension between, on the one hand, the desire to *individualize instruction*, implying the implementation of hidden devices tracking the user activity and trying to orient it, and, on the other hand, the intention of offering *collaborative usage* of general tools, where users have a certain margin of freedom, up to a certain degree.

Nowadays, the illusion to be in control is very common: tactile and audio interfaces are so user-friendly. The very old issue of the balance for initiative and control between the user and the machine, explicitly stated in the 1960s about *adaptive learning* (Pask 1966) and at the beginning of the 1970s by Carbonnell (1970), comes again to the fore. What are the respective responsibilities of the user, the teacher (or the tutor), and the system?

Software Tools for Learning

"Software tools" is a term covering a reality that has taken other names in the past 50 years. Originally, what came first in the 1970s was computer-assisted learning (CAL), with many studies about systems allowing teachers to write courseware or contribute to its development (e.g., see Bork 1972; Cox et al. 1988; Reeves 2008).

Then, developing in the 1980s was the movement of artificial intelligence and expert systems which first appeared in the beginning of the 1970s, posing difficult problems of modeling, both the domain to be studied and the student (Bruillard 1997). One of the key principles adopted then was overlay models and the implementation of expert systems having a knowledge of the field to be studied and, as far as possible, of the pedagogical issues linked with the field, including the design of buggy models, able to offer understandable explanations to learners (see Van Lehn 1990; Bruillard 1997). But it has also been found, at least in scientific subjects, that the students' conceptualizations may have nothing in common with the expert one, consequently requiring designers to take into account students' conceptions and scientists' conceptions as well (Kattmann et al. 1996; Niebert and Gropengiesser 2013).

From the beginning of this century, things have evolved. Firstly, with the dissemination of online facilities, the idea of guiding the student along an optimal path for solving problems has given way to the idea of providing her with a dashboard of information about how she was situated, both in a progression and relatively to other students.

Then, toward 2010, things changed again. After the diffusion of MOOCS and the pervasive presence of "big data," a new interest for adaptive learning has arisen. This time, software is no longer propelled by a *symbolic* artificial intelligence, operating from databases of facts and rules, but on the operation of neural networks able to perform "deep learning" and to mine huge heaps of data reflecting more or less accurately learners' activities and providing some kind of classification of their actions.

This process has been fuelled by the dissemination, at least in industrialized countries, of connected mobile tools having limited processing capacities and small screens but allowing anybody to access information and redact small messages anywhere. Once again, what users see of these devices is only one face of the system, the local one, a remote platform processing most of the data.

On the other hand, a large *panoply* of software tools is now available in most subject domains: e.g., dynamical geometry software in mathematics, GIS (geographic information system) in geography, and more generally, applications using geolocation, CAeX (experimentation assisted by computers) in natural sciences, lexicographic tools in literature, databases in history, and so on. Research (see below) has shown that these tools allow very interesting experiments, but a recurrent problem is to lure students into meaningful activities lasting long enough for them to build new knowledge.

For example, Dorey's work (Dorey et al. 2013) about the three-dimensional visualization of molecules shows the existence of a sort of *saturation* effect. Using such software in interesting ways requires an understanding of some underlying concepts, and teachers in secondary schools have not enough time to ensure that students will get acquainted with them. So, in this case, activities are mainly limited to guided tours (see also Webb and Cox 2004).

A lot of hope is currently linked to the *gamification* of learning activities, which foster the design and use of games qualified as *serious*. Although the use of role-playing games and simulations has been incorporated into educational tools for more than 40 years pioneered by, among others, SAGSET (*the Society for the Advancement of Games and Simulations in Education and Training*) *founded in 1970*, the use of these is becoming more mainstream with the more powerful IT technologies. The idea is to engage students in challenging and meaningful activities. This is not exactly a new idea, since computer games and simulations have existed for a very long time as indicated above. But it has received more recent support from theories such as those expressed by Csikszentmihályi (1990) about the interest of creating lasting states of "flow," sometimes called "optimal experience." The school context (time and space constraints) makes it however generally difficult to practice games within the school, outside of specific situations (kindergarten, sports, etc.).

Overall, as shown in the diagram (Fig. 1), the degree of guidance exerted by software environments has tended to decrease along the years, the tendency being that almost any software has been used as educational software (even if, with the revival of adaptive teaching, it could reverse the curve).

Perhaps one of the most important phenomena of the past decades has been the development of distance education, relying on specific platforms.

Platforms for Distance Learning in Education, Also Used in Hybrid Contexts

A steady development of generic learning platforms has occurred in the past 20 years, a few of them such as Moodle, currently dominant, setting a standard. Offering numerous functionalities, more than any singular teacher or academic might want, they are content independent. Therefore, they allow developers and users to perform all the tasks expected in distance education and even more since they are also currently used to support learning in secondary schools but implement a view (and even a philosophy) of what education should be.

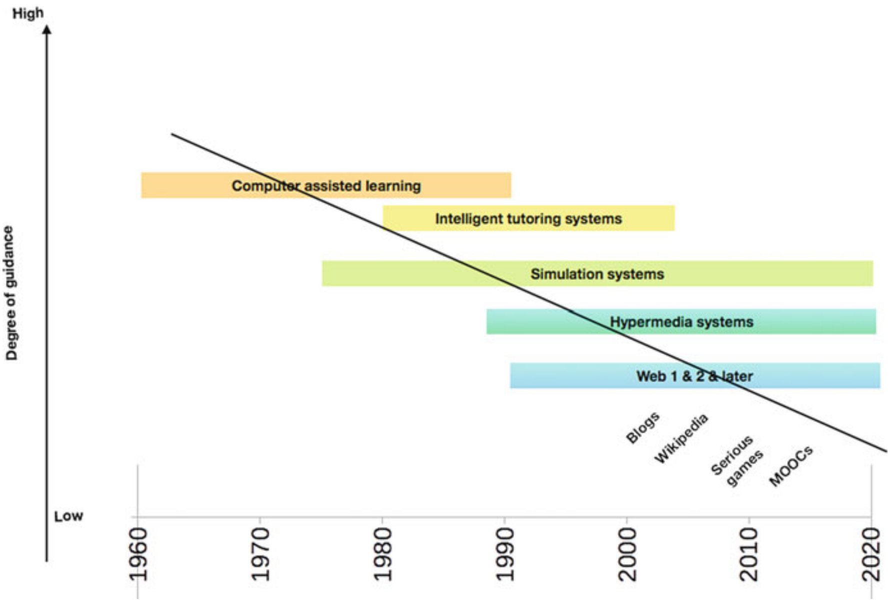

Fig. 1 A global decreasing trend over time of the guidance exerted by software

The success of MOOCS, since 2011, is changing the rules. This very notion of MOOC has evolved. In a seminal paper, Daniel (2012) analyzed an opposition between cMOOC (connectivist MOOC) and xMOOC (supposed to adopt a transmissive approach). This distinction is now less valid. In fact, three common elements, beside the generalized presence of short video capsules, may always be found in those kinds of systems: distance learning using online resources (in particular short videos), social networks, and more or less strict temporal frameworks.

The ability of being a self-directed learner has often been highlighted, and, roughly speaking, participants in MOOCS, in their majority, have had, prior to their enrollment, at least a bachelor degree, even if it is not required (Reich 2014).

Although forms of distance education are developing in secondary education, MOOCS currently have a limited role in it. However, considering them as one of the contemporary forms of books (Bruillard 2017) leads to surmise that they might gain an important place. In particular, a discernible trend exists around MOOCS with cultural aims or for helping students choosing high school itineraries, in a perspective of preparation for higher education.

An interesting observation is the relatively high proportion of teachers in the public attending MOOCS. In surveys about MOOCS hosted by the edX platform (MIT and Harvard), one-third of people say they are or have been school teachers, and 20% of them teach the same subject (Chuang and Dean 2016). This suggests that MOOCS might become a significant vector for teacher development.

Most of all, MOOCS have forced researchers to cope with big data (number of registered students, number of clicks, log files, etc.). Along with a surge in interest for “deep learning” and other applications of neural networks, a new perspective is emerging, sounding like an oxymoron: *adaptive massive personalized learning*, based on the alliance of brute force and sophisticated algorithms applied to big data.

Digital Resources

Using resources for learning is not exactly something new, since J. Dewey himself introduced as early as the beginning of the twentieth century (1916) the idea that learning was related to the presence of resources.

Among those resources, textbooks have traditionally occupied an eminent place. The huge spread of the Internet is considerably changing the landscape. Many high-quality resources, up-to-date, precise, aesthetic, well-designed, and so on may be found on the Internet, the problem being for users to recognize which resources have a high quality.

Furthermore, with the growing obsolescence of the classical truth regime in schools (postmodernist view) and the need of proposing quantities of activities to students, the teacher’s role is more complex, requiring more and more resources. These are of very different formats: texts, pictures, videos, animations, and so on. These resources may be considered as educational by opportunity (not created for educational purposes, but used in educational context) or by destination (specifically designed for education).

The action of teachers working with resources depends upon their degree of pedagogical freedom. Teachers collect resources and, most of the time, rearrange them for their students, composing something new from several sources, according to their choices and priorities. Investigations have shown that their sources may be very different. It may be other colleagues, who sell online their previous preparations (Abramovich and Schunn 2012), or free resources, either from the public sector or from some association or institution (including Wikipedia). They may also come from the market, even if teachers are rarely the clients (Baron and Zablot 2017). In a context of abundance, curation (Bhaskar 2016) becomes a key process that is very time-consuming.

In a current research project aiming at documenting the way teachers design, search, select, edit, and reconstruct educational resources (ReVEA (see http://www.agence-nationale-recherche.fr/?Project=ANR-13-APPR-0006) – teaching and learning with lively resources), we have identified four key processes:

1. Inheritance and transmission (getting resources from university preservice training or from colleagues)
2. Participation (sharing and codesigning resources)
3. Collection (storing and organizing educational materials)
4. Establishing trusted networks (persons and places, as websites) (see Bruillard 2016)

Big Data, at the Risk of Mirages and Spurious Interpretations

A series of discreet changes has been accumulating in the past 20 years and has finally produced a dramatic evolution that obliges us to reconsider the issues of designing and evaluating software. Most IT environments now collect lots of data linked to the user's activity. Much hope has been invested in the possibility of mining those data in order to produce interesting results that might help designing software and evaluating its effect on learners.

The diversity of these data is huge: log files, written interaction between students on platforms (in particular on forums), performances on tests, data from eye-tracking devices, and so on. The challenge is to extract automatically information from these data in order to inform humans (designers, teachers, students) to take pertinent decisions. The only way to do this is to apply algorithms reducing the complexity and providing a profile. There are no technical problems to obtain results in real time since broadband allows one to divide the tasks between networks of computers in the cloud that have the ability to treat really large sets of data.

The results are flabbergasting, as anyone, having used platforms like Google, Amazon, Facebook, Twitter, and the like, has realized.

The most known domain of application is marketing, where profiles allow, for example, to target advertisements and to propose purchases adapted to the clients' needs (as they have been guessed by the system). However, in other sectors such as the government, relying on statistically based predictions raises many issues (see Rouvroy 2009 for a political analysis).

We are going to focus here on educational issues and will not analyze the general case of risks toward privacy; i.e., the fact that in such algorithmic intermediations, the person tends to disappear behind the profile, the phenomenon of "vendor lock-in," nor the fact that many dangers exist (OECD 2016).

In education, the main problems encountered in basing decisions on the results of algorithms are twofold: (1) incompleteness or inaccuracy of the data and (2) faulty interpretation of the results.

We assume that the algorithms themselves are classical (pertaining to well-documented classes like computation of similarities between nodes in a graph and the like). But it may be that other computational engines be employed, with the ongoing surge of new forms of artificial intelligence.

Incompleteness or Spuriousness of Data

If data are numerous, how can one be sure they are complete and that their quantity is a guarantee of their quality? What they generally reflect is behavior or rather a small part of behavior. To what extent does this behavior correctly reflect learning activities? To what extent does it reflect the activity of one person? For example, it is well-known that, due to material problems or to a pedagogical will, some activities are led in groups of students. How then, to distinguish between the different actors?

On the other hand, it has been remarked for a very long time that the duration between different user's actions is hardly a time on task. In most cases, also, data will ignore teachers' interventions, which always are to be considered when one intends to understand the effect of an instrument. In some cases, data may therefore be spurious.

These issues have massive consequences: algorithms will always reduce the data they ingest to a smaller set, and they will classify them and highlight some results. But the final quality will fundamentally depend upon the relevance of the input they receive.

There is also another very deep problem. Often, results are based on the computation of correlations. This may be useful but correlation is by no means the same as causality and correlations are likely to be spurious. As Calude and Longo (2016) explain, basing themselves on research from the world of mathematics: "the bigger the database which one mines for correlations, the higher is the chance to find recurrent regularities and the higher is the risk of committing such fallacies" (p. 15).

Faulty Interpretation of Results

Once data are classified and profiles established, and supposing that results correspond to something real, how to interpret them? And what do they actually represent? What can be analyzed from them: learning processes or user's behavior?

The situation here is not quite the same if interpretations are to be made by humans or by software. The first case generally poses no problem except when the finality of processing the data is questionable. Take the case of text processing software or spreadsheets. For many years, when installing this kind of software, network managers could tick a box, allowing the software to transmit the data to the enterprise. Has this permitted the improvement of users' experiences and progress in their appropriation of the software? Or rather has it allowed the enterprise to adapt its offer to users' behaviors?

Human decision is crucial. To give an example mainly concerning higher education, popular software chasing plagiarism in students' work (that function very well on the average) often return for each submitted text a flag (green, orange, or red) and a score of plagiarism. Everyone having had to mark copies knows that caution is in order and that a careful inspection may reveal situations where there is in fact no plagiarism. This problem also exists in secondary education, but in this case class sizes are sufficiently small for teachers to control individual productions, and this provides them with a good opportunity to intervene in work processes rather than judge only one outcome.

The case of MOOCS is illuminating. An important literature has explored the massive data retrieved from learner traces (Reich 2014). The initial intention was to try to understand the phenomenon of dropout rates and to find mechanisms to encourage persistence, that is, to keep participants as long as possible, which is more a marketing perspective than a learning one. It was found that the best dropout prediction was registration behavior (Cisel 2016) and the kind of participation in discussion forums (strong participation is a good indicator of persistence). A/B testing was also used, good opportunity in massive courses (see, e.g., Kizilcec et al. 2014), but the results are always difficult to interpret without a thorough knowledge of the participants, as in most large-scale quantitative surveys.

It should be noted that new instruments can be used to capture data of a new type: eye movement and attachment points, pulse, blood pressure, cerebral activity, etc., but this requires special conditions. This constrains the activity of the learners, making interpretation of the collected data sometimes problematic.

For investigating complex visual displays, eye-tracking certainly is a very important technique (see Van Der Schoot et al. 2008). Research opens up complementary perspectives, allowing, for example, to study the differences between experts and novices in reading behaviors (Knight et al. 2014). But it is still hard to use.

To summarize our previous remarks, even though we are entering a new era in which a large number of different types of data (behavior, physiology, etc.) are collected and made accessible, interpreting them is difficult, and much research is still needed. The classical techniques of the human sciences remain still topical in order to understand the actors and their activities.

A Wide Spectrum of Design Processes: Companies, Start-Ups, Communities, and Groups

About Design Principles

Analyzing design processes is difficult. Which design process? Designing a textbook or computer software follows very different paths, and according to the large spectrum of resources, software, and so on as elaborated above, it is impossible to pick a typical design process.

Therefore, studying the methods and data for designing IT tools is not an easy task. The classical chain of design for new products has been profoundly modified these last years. Successive stages of production, starting from initial ideas and leading, after engineer work, to a final product sold on the market, are no longer the norm. There is not one norm, one standard and situations vary: what is common between, let us say: (1) a large company aiming at selling a serious game targeting a large audience, which gathers a large team of computer scientists, 3D designers, and content specialists; (2) a small team in a medium-sized enterprise in charge of delivering an upgrade of an e-learning resource about selling a new product; and (3) a small group of teachers preparing a course on some topic by assembling resources they have collected in different places?

While a few large companies have for decades dominated the textbook market, the explosion of educational resources has brought in new players: companies specializing in educational software, young start-ups in the Edtech field, but also teachers' associations. Now, traditional school publishers have to deal with IT companies and invent new common processes. The financial rules are also new. In the textbook market, authors' fees are paid after first sales or first purchases. Now, they have to take more risk at the beginning or let small companies take risks until a new product seems likely to have some commercial success. In this market, the users are not always the buyers and this poses specific problems. At least two levels have to be considered: the teachers are not always the final users but have a role of both prescribers and assistants (choosing parameters, choosing or developing examples, helping students). The students are generally "captive" end users.

In the IT business, users have traditionally been associated with designers from the early stages of design. But there is a new tendency to distribute products that have not been completely finalized, which are quickly brought to market with the aim of obtaining rapid returns of use in order to direct the rest of the process. Ascending design, crowdsourcing, loop between design and use, continuation of design in use, etc., are key processes. Agile software development is now a current way of producing apps (applications) for different platforms. The methods of contextual design, based upon contextual inquiry (Beyer and Holtzblatt 1998), now take into account a much richer and more complex context of use, inviting designers to immerse in the user context (Holtzblatt and Beyer 2015, p. 74).

Probably, only a fraction of the digital environments is produced by companies using a kind of industrialized approach, at least at this moment. Outside the professional publishing sector, much is improvised. People design in an incremental way without following strict rules; teachers bring their own touch and keep on refining their resources. Resources are also directly assembled by teachers, starting from elements they borrow (and sometimes buy) from a variety of sources.

The design process is therefore manifold. Many teachers redistribute the resources they have produced, either in a market (Abramovich and Schunn 2012) or freely. In France, Quentin and Bruillard (2009) have analyzed the activities of communities of activist teachers. For example, Sesamath, a small teacher association (around 80 members), has been able to create a lot of software tools and free textbooks for Grade 6–10 (http://www.sesamath.net/). Compared to traditional publishers, this small association was able to distribute drill and practice tools which can be freely used by teachers and students at school or outside schools, providing teachers with student learning data collected during their activities, even outside the school. In 2012, more than one million lower secondary school students were registered by their teachers, according to Sebastien Hache, one of Sesamath co-founders (http://www.vousnousils.fr/2012/01/16/sebastien-hache-un-collegien-sur-quatre-est-inscrit-a-notre-dispositif-labomep-519918). Sesamath products were used by a majority of mathematical secondary school teachers.

Communities of Practice and Open Resources on the Rise

This is typical of a rise of new IT resources based on non-capitalistic values: free software, open educational resources, copyleft and creative commons, etc. The idea is to support an education that may be freely accessed, reused, modified, and shared. This movement is developing in higher education (Unesco 2015; Downes 2007; OECD 2007). It seems also to gain impetus in primary and secondary education.

In a country like France and most probably in other countries where teachers are well organized, many teachers have a mentality of hackers, with strong values concerning education, considering that the necessities to adapt their teaching to their student needs are more important than copyright laws. The profession of faith of the Sesamath association is quite explicit (http://www.sesamath.net/blog/index.php/2013/04/20/quelle-est-la-philosophie-de) and illustrated below.

> The profession of faith of Sesamath sheds light on the philosophy of association. In particular, Sesamath defends a number of values: solidarity, respect, openness (Sesamath comes from Sesame Math), and sharing. The provision of free and modifiable content on the Internet (under a free license) and also the collaborative work between teachers (including different cycles or countries) are means to serve these values. Sesamath places its action in a public service perspective and considers the educational resources it generates as common goods that can be used by all.
>
> In order to develop its activities, Sesamath sets up partnerships (e.g., with publishers) that extend its activities, but seeks to remain as independent as possible, and as close as possible to the users of its resources, who can participate at any time in the improvement of these commons.

Quentin and Bruillard (2013) have described the functioning of some online teacher networks: between personal interest and depersonalized collective production and between the sandbox and the hive. The hive, which characterizes highly productive collectives underpinned by strong shared values, has very binding and explicit rules that do not allow the user to see their production processes. The sandbox, on the other hand, has collectives with flexible and implicit rules and publishes all their interactions, allowing the diffusion and legitimation of teaching practices.

The model of the commons is therefore a very good framework to analyze what is going on here. Beyond the so-called tragedy of the commons – misuse, purposeful, or not – that might diminish or destroy the common benefits shared by all users, open governance practices, meeting the openness criteria recommended by Elinor Ostrom and her colleagues, could be interestingly developed (Ostrom and Basurto 2011). One can imagine a more collective teaching profession, able to manage educational resources as “commons” in the sense of common goods (Buck 1985). Innovation commons (Allen and Potts 2016) will perhaps develop as a new way of implementing innovations, in a bottom-up vision.

Evaluating Educational Software, Resources, and Platforms

The same complexity is encountered about evaluation. Evaluation of what: Learners’ outcomes? Acceptability? Parents’ advice? Market evolution? Evaluation for what purpose? Evaluation based on which data? There is an extreme diversity of approaches. But it is possible to describe briefly some general elements and focus on exemplary cases.

Often, research results are obtained by comparing the performance between pre- and posttests for different groups studying under different conditions (Cox and Marshall 2007). From this point of view, there is an abundance of research results, which are often indecisive or not on agreement between them, suggesting that hidden variables play an important part in the results. We would like to quote here a reflection we made 10 years ago: There are many examples of systems that had worked well in an experimental context and that did not work later, in ordinary classroom practice. “What is worse, history shows that examples of ‘best’ or even ‘good’ educational practice, which are indeed absolutely necessary, are seldom infectious by their own virtue” (Baron and Bruillard 2003, 2007). Reeves (2008) showed the importance of evaluating software in real schools with actual teachers. In sum, the context plays a crucial part and several planes intervene: technical and usability. So the analysis may be carried in terms of several forms of compliance.

As previously explained by Reeves (2008), whatever the products, the first level is technical evaluation: does the product do what it is supposed to do, without error? Then, as products are essentially interactive, a set of criteria released by ergonomists specify the expectations. Coutaz (2013) analyzes these criteria in terms of compliance. The first is *utility* or *functional compliance*. The second, *usability*, is characterized by its *interactional conformity*. The third is the *hedonic quality* often named *user experience*, to designate a subjective experience, the meaning and the value that an individual attributes to a system, but also its perceived utility and usability. Coutaz adds contextual conformity (compliance), the importance of the context of use being recognized for a long time in interactive systems design.

Concerning productions such as *serious games or simulations*, other forms of compliance need to be considered. Firstly, fidelity or conformity to the functioning of objects of the real world is essential. But even low-fidelity systems may be efficient (Toups et al. 2011). In fact, the impact of instruments can be only evaluated contextually, depending on educators’ choices.

Secondly, compliance with educational objectives must be verified. For example, in order to succeed in the game, is it the targeted knowledge that is implemented? If another path is possible than the one expected, what does it help to learn? For sure, teachers can do an interesting job even with poor software, provided they devise a way to illustrate pedagogical aims. But an issue exists and caution is in order since, among existing games, some have a dark side, with questionable and unethical features. For example, Zagal et al. (2013) pinpoint some debatable issues found in common games, such as “playing by appointment” (being obliged to follow the game time schedule), “paying to skip,” “paying to win,” “impersonation” (when the software pretends somebody else sending you a message), encouraging antisocial behavior, and even games with a purpose, where the software traps users in pursuing another goals. As they put it: “It is one thing to invite someone to play a game and tell them that they may learn something in the process and another to try to trick them into learning something” (p. 6).

Beyond these characteristics, it is essential to have access to the models underlying the games or the simulations: this is a critical issue in education, because the elements underlying these systems have to be verified and need to be accessible. It is critical for educators to be confident that educational software and resources correspond to what is acceptable in their educational system. Perhaps even this is a point for which educational authorities should give a label in order to avoid what might be called hidden defects.

Another form of conformity to be taken into account is linked to the specific cultures of the different contexts: linguistic cultures, national or local cultures, cultures of a community, etc. Numerous studies have been led (see, e.g., concerning gender issues, Brugeilles and Cromer 2009) on the representations of minorities in textbooks and are relevant to interactive products.

On this point, even if it is the duty of authorities (scientific or hierarchical, sometimes religious in some countries) to certify acceptable educational resources, the process of legitimization carried out by peers is essential. The fact that others have been able to use a product and recommend it is a guarantee of utility and usability. This form of legitimation is very important in communities of teachers because it lowers the risk of trying new things in the classroom.

As far as noninteractive products are concerned, the example of the evaluation of Wikipedia articles is enlightening. The elements offered by Wikipedia, with the history of the successive versions, through the discussions and models of editing and automated processes of correction are very rich. But if all these data are searchable, their analysis takes time, and there is still no visual summary that provides effective information. The quality labels self-assigned by Wikipedia are most often the only ones available (see https://en.wikipedia.org/wiki/Wikipedia:WikiProject_assessment).

Discussion

As we have tried to explain, designing and evaluating IT tools for learning have evolved quite a lot in the last decades, and research is facing a brand-new situation: IT tools are everywhere in the life of students, and most of these tools may be used for learning purposes, but not necessarily in line with current educational standards.

The perspective on IT tools for learning has changed with the spread of learning contexts occurring outside of the school, either at a distance, in the home, or anywhere, and having often a nonformal character. The notion of learning resource has tended to supersede the concept of computer-assisted learning, and instructional design has given way to learning design (Baron 2011).

Furthermore, the design of IT tools and resources is often subordinated to existing general purpose platforms, like Moodle, EdX, or similar systems. These platforms actually play an important role in the design of courseware and also of diverse resources. Processes of design are often makeshift or artisanal, with limited range (at best a group of teachers united by some proximity).

Regarding evaluation, research consistently shows that it is pointless to evaluate IT tools without taking into account the educational context in which learning activities are taking place. Much depends upon who is prescribing or suggesting the interest of using a particular tool; much depends upon the kind of learning design that has been incorporated and is being implemented in educational activities. To summarize, what matters are the situations set up by teachers and even a bad product may be useful in a particular context. Educational assessment refers to the situations set up and only indirectly refers to the tools used.

This view has profound implications, highlighting the importance of allowing teachers to develop their agency in the field of educational resources. This implies to empower them and to accept them as trusted partners.

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International Large-Scale Computer-Based Studies on Information Technology Literacy in Education

77

Julian Fraillon

Contents

Abstract

The first international large-scale study in Information Technology (IT) literacy was conducted in 1987, and a broad range of studies that assess IT literacy and related areas of digital learning have followed. This chapter discusses recent developments in international large-scale studies of IT literacy-related achievement with a focus on their shared necessary attributes and the associated challenges with operationalizing these attributes in the test instruments. Two key attributes addressed are: (i) that the test contents reflect real-world use of Information and Communications Technology (ICT) and (ii) that the tests make use of the dynamic functionality and multimodal opportunities afforded by the computer-based environment. Challenges associated with these attributes include ensuring that the individual tasks within each assessment are independent of each other, maintaining a standardized test-taker experience, providing test-takers with plausible feedback from the computer-based environment, and maintaining construct validity. Examples are discussed of how the common challenges in creating

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the test instruments are addressed in the design of the instruments with some further discussion of possible future directions in large-scale international studies related to IT literacy.

Keywords
Information technology · Information technology literacy · Information and communication technology literacy · ICT literacy · Large-scale assessment · Computer and information literacy · Digital literacy

Introduction

In 1960 the IEA Pilot Twelve-Country Study collected assessment data from 13-year-old students in five areas: mathematics, reading comprehension, geography, science, and nonverbal ability. The authors suggested that the study "may well be described as an unusual addition to the literature of education" (Robinsohn 1962, p. 5) and differed from other studies in comparative education in that it sought to "introduce prominently an empirical approach into the methodology of comparative education, a field that has, in the main, relied on cultural analysis as its chief mode of enquiry" (Foshay 1962, p. 6).

This chapter examines recent developments in international large-scale studies that seek to research achievement outcomes relating to digital or ICT literacy (ILSA-ICT). The focus of this chapter is on large-scale studies that are computer-based, and consequently, it is important to make the distinction between those studies that use the computer as a vehicle for test-takers to demonstrate their proficiency in a given discipline (such as in science, reading, or mathematics) and those studies which measure digital or ICT literacy-related outcomes (see Fraillon et al. (2013) for further discussion of this distinction). While, at face value, the distinction might be clear, there will always be some lack of clarity around the edges of the domains where ICT-related skill such as navigation on web-pages, running an application, making evaluative judgments around the credibility of information, or using information ethically may be regarded as within the scope of both a subject-based discipline and a broader digital literacy. This chapter begins with a brief history of ILSA-ICT-related studies before focusing on the methodological issues associated with designing and conducting computer-based performance assessments ILSA-ICT.

The Beginnings of Large-Scale International Studies Relating to ICT

International large-scale assessment relating to IT began with the IEA Computers in Education study (COMPED). The study was conducted in two stages between 1987 and 1992 (Pelgrum and Plomp 1993; Pelgrum et al. 1993). Stage 1 was a descriptive survey of computer use in elementary, lower secondary, and upper secondary schools. Stage 2 was conducted in two parts. The first part was a follow-up of Stage 1. Part 2 "was intended to study the relationship between policy, practice and outcomes with respect to computers in education" (Pelgrum et al. 1993, p. 1). Stage 2 included a 30-item Functional Information Technology Test (FITT) that was completed by students using pencil and paper with a further optional short computer programming test (Anderson 2008, p. 70; Pelgrum et al. 1993) (A more detailed description of COMPED can be found in Pelgrum and Plomp (2008).).

In 2003 the results of a feasibility study, commissioned by the OECD, on the inclusion of ICT (information, communication and technology) literacy in PISA were released. For the study, ICT literacy was defined as: "*the interest, attitude, and ability of individuals to appropriately use digital technology and communication tools to access, manage, integrate, and evaluate information, construct new knowledge, and communicate with others in order to participate effectively in society*" (Lennon et al. 2003). The study included a pilot administration of computer-delivered assessment tasks of ICT using a "toolbox of ICT user interface components assembled for the study" (Lennon et al. 2003, p. 14) as well as computer delivered questionnaire materials for students. Data were collected from students in Australia, Japan, and the United States. The study concluded that conducting tests of ICT literacy as part of the PISA suite was "both feasible and worth doing" (Lennon et al. 2003, p. 10), although the authors acknowledged that it would be challenging and recommended a "phased approach" (Lennon et al. 2003, p. 12) to the implementation so that the inevitable (known and unknown) hurdles could be overcome along the way. Even though the assessment of ICT literacy has not yet become part of the PISA suite of assessments, the ideas explored and articulated in the feasibility study can be clearly seen in contemporary large-scale assessments of ICT literacy. In particular, the essence of the definition of ICT literacy as having a focus on digital information literacy skills, and the application of computer-based *real-world* (also referred to as "authentic") contexts for applying ICT literacy has continued to be fundamental to large-scale ICT literacy assessment.

The IEA Second Information Technology in Education Study (SITES) was conducted across two modules (SITES-M1 and SITES-M2) with a follow-up survey referred to as SITES 2006. Data collection was in 1998–1999 for SITES-M1 and in 2001 for SITES-M2. SITES did not include a direct assessment of student performance. In SITES-M1, data were collected from principals and technology coordinators in 26 countries (or education systems). SITES-M1 focused on school management and the support for the use of ICT in schools, ICT infrastructure, staff development, and support regarding the use of ICT and school objectives with respect to ICT (Pelgrum and Anderson 1999). SITES-M2 built on the work of SITES-M1 with a view to exploring innovative pedagogical practices relating to the use of technology. Innovative classrooms within schools were identified in participating countries according to a common set of selection criteria. Data were collected from the schools and classrooms across 28 countries. These were qualitative case-study data collected from multiple sources including interviews with administrators, technology coordinators and innovative teachers, focus groups with a range of school community members, administration of selected SITES-M1 questions, classroom observations, and review of school documents. SITES-M2 reported on analyses of 174 case-studies (Kozma 2003). SITES 2006 sought to investigate the extent to which innovative pedagogy using technology was present in classrooms and how the presence of innovative pedagogy related to contextual factors at the school and system levels (Law et al. 2008). Questionnaire data were collected from school principals, technology coordinators, and teachers of mathematics and science in representative samples of schools in 22 participating countries.

Recent Developments in International Large-Scale Studies Relating to ICT

In the 1990s and early 2000s, the uncertain availability of suitable computing technology, including Internet connectivity, was regarded as a risk and likely barrier to the implementation of the computer-based performance assessments in large-scale international studies. Around that time, the most widely accepted technical option to ensure collection of standardized computer-based performance data was for test-takers to be provided with computers configured for the testing. An example of this is the Programme for International Student Assessment (PISA) Computer-Based Assessment of Student Skills in Science. Data were collected in 2006 from 15-year-olds in three countries using laptop computers loaded with purpose-built software (OECD 2010). In many contexts, the cost and administrative complexity of facilitating such delivery were regarded as too great to make computer-based data collection viable. However, ongoing improvements in Internet connectivity, increases in the affordability, and prevalence of digital devices and increasing agreement about the importance of digital literacy-related competencies have led to the development and implementation of large-scale international studies that include computer-based collection of performance data.

Five preeminent large-scale international studies that include computer-based tests of performance relating to ICT literacy are: the IEA International Computer and Literacy Study (ICILS), the IEA computer-based component of the Progress in International Reading Literacy Study (ePIRLS), the OECD Programme for International Student Assessment (PISA) Digital Reading Assessment, the Assessment and Teaching of twenty-first Century Skills (AT21CS), and the OECD Programme for the International Assessment of Adult Competencies (PIAAC).

ICILS

ICILS investigated differences among and within 21 education systems countries in computer and information literacy (CIL) (see also ▶ Chap. 6, “Students and Their Computer Literacy: Evidence and Curriculum Implications” by Ainley in this Handbook). Computer and information literacy is defined as:

> *an individual’s ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society.* (Fraillon et al. 2013, p. 18)

The ICILS assessment framework describes CIL as comprising two strands, each specified by a number of aspects.

Strand 1, collecting and managing information comprises:

1. Knowing about and understanding computer use
2. Accessing and evaluating information
3. Managing information

Strand 2, producing and exchanging information comprises:

1. Transforming information
2. Creating information
3. Sharing information
4. Using information safely and securely (Fraillon et al. 2013).

ICILS focused on variations in CIL between and within countries and student and school factors that were related to those variations (Fraillon et al. 2014). The study took place in 2013 and involved almost 60,000 Grade 8 students in more than 3,300 schools. It was delivered using USB drives and could be run on school computers. In addition data were gathered from teachers from each school, principals, and ICT-coordinators. National research coordinators coordinated information procured from national experts about policies for the use of ICT in education. A second cycle of ICILS data collection, including some new CIL test content and an optional (at the country level) test of computational thinking, is being conducted in 2018.

OECD PISA Digital Reading Assessment 2009

In 2009, PISA included an assessment of digital reading. This was completed by subsamples (36,500 students from 3277 schools) of the national samples of 15-year-old students in 19 countries. Students answered additional computer-based questions to assess their capacity to read digital texts (OECD 2011). Digital texts included dynamic windows and frames, hyperlinks and networks, multimedia, and augmented reality and provided for engaging with on line discussion and social networks (OECD 2011, pp. 34–35). As a consequence, although the processes to obtain meaning from digital texts were similar to those for reading print-based texts, digital reading was argued to include additional skills because readers had to construct their own paths through digital texts and had greater opportunities to engage with text by adding comments to blogs or responding to email messages (Mendelovits et al. 2012). Navigation was also regarded as an important skill in digital reading.

IEA ePIRLS

IEA ePIRLS was conducted in 2016. It is a computer-based assessment of reading literacy for fourth grade students that could be completed as an optional (at the country level) extension to PIRLS (Mullis et al. 2017). The ePIRLS reading literacy assessment was completed by almost 74,000 students in 14 countries (with a further 12,000 students in two benchmarking participants) (LaRoche and Foy 2017). The tests were delivered mostly by USB drives (with some delivered on Local Area Networks (LAN)) that as for ICILS contained all required software resources to be run on computers. ePIRLS measured student reading comprehension of electronic informational texts. This includes the application of comprehension skills and strategies that largely “parallel those assessed in PIRLS” (Muillis and Martin

2015, p. 24) but with the inclusion of navigation skills (such as clicking on links or tabs to navigate to web-content) and dynamic text stimulus (such as animations). In ePIRLS, questionnaire-based data relating to the context in which students were learning to read and reading were also collected from students, teachers, and principals.

The Assessment and Teaching of Twenty-First Century Skills

The Assessment and Teaching of twenty-first Century Skills (ATC21S) is a project that sought to define the capacities that needed to be developed so that people progressing through school would be better prepared for life in modern society (Griffin and Care 2015). The emphasis was on formative assessments for teachers to use, and the focus was on students aged between 11 and 15 years (Griffin et al. 2012). Two areas that involved digital technology were included in the assessment. One of these was an assessment of collaborative problem solving that utilized computer technology (Hesse et al. 2015; Care et al. 2015). The other was an assessment of learning in digital networks (Wilson and Scalise 2015). The construct "learning in digital networks" was seen as comprising four strands:

- Functioning as a consumer in networks
- Functioning as a producer in networks
- Participating in the development of social capital through networks
- Participating in intellectual capital (i.e., collective intelligence) in networks (Wilson and Scalise 2015, p. 59).

OECD PIAAC Problem Solving in Technology Rich Environments

The OECD Programme for the International Assessment of Adult Competencies (PIAACC) provides internationally comparable measures of three sets of skills: literacy, numeracy, and problem solving in technology rich environments (PSTRE) (OECD 2013). It provides national estimates for people aged 16–65 as well as relationships with a range of characteristics. The most recent cycle was conducted in 2011–2012 and involved around 166,000 adults in 24 countries or subnational regions. Twenty of those countries or regions administered the PSTRE assessment (OECD 2014).

The focus of the assessment was intended to be on the cognitive skills required to access and make use of computer-based information to solve problems rather than on the application of computer skills. The PIAAC assessment was delivered on laptop computers to test-takers in their homes as part of an integrated computer-delivery platform. The PSTRE assessment involved a series of problems set in realistic computer environments. Test-takers had to solve each problem using the information and tools that were accessible in simulated computer environments. A range of applications was provided, such as an Internet browser and web pages, common applications, such as e-mail, word processing, and spreadsheet tools and special applications such as a room-reservation system. The problems involved different levels of complexity, numbers of steps, levels of inferential reasoning, and requirements for the evaluation of the relevance and credibility of information (OECD 2013, p. 86).

Attributes of Large-Scale International ICT-Related Performance Assessment Instruments and Their Associated Challenges

Mendelovits (2017) suggests that the demands of good large-scale assessments are that they:

1. Ensure construct validity (i.e., measure what they purport to measure)
2. Are fair to all test takers (i.e., there is no disadvantage or advantage to any given sub-group of test-takers)
3. Balance the claims of various stakeholders
4. Balance the demands of reporting changes over time with the capacity to innovate.

This section contains a discussion of the attributes of ILSA-ICT in the context of their unique characteristics and the challenges that these bring to bear. The challenges are discussed in terms of the necessary compromises that exist when balancing the demands of large-scale assessments suggested by Mendelovits (2017) and the desirable attributes of the performance assessments. Ultimately, in most cases, there are trade-offs between achieving the ideal characteristics and managing the conceptual and operational limitations in the instrument design and delivery. How these trade-offs influence instrument design is also discussed in this section, with a particular emphasis on how the trade-offs are managed in ICILS.

Reflecting Real-World Use

Characteristics

A common expectation of ILSA-ICT performance assessments is that they require test-takers to complete tasks that reflect plausible real-world use. In the case of computer-based assessments of digital reading, there is an expectation that the digital texts will be multimodal and contain standard navigation features (such as hyperlinks and website tabs) but in addition will address content and contexts that participants could typically expect of digital texts based on their real-world experience. ePIRLS, for example, used only informational text types, whereas the paper-based version uses both informational and literary texts (see Mullis and Martin 2015) and the PISA digital reading assessment included digital environments relating to real-world contexts such as a job search website (OECD 2011). The AT21CS assessment of learning in digital networks used real-world school-based contexts such as a peer-to-peer second language learning environment (Griffin and Care 2015).

In ICILS, the real-world applicability of the tasks is represented through the implementation of a test design using 30-min "modules" in which test-takers complete a sequence of tasks based around a common theme. Each module involved a number of discrete tasks that were to be completed as a lead-up to a final large task. The large tasks were typically communication tasks using some form of productivity software (such as a poster maker or presentation software). For example, in one module, students set up an online collaborative workspace to share information and then selected and adapted information to create an advertising poster for an after-school exercise program (An annotated video demonstration of this module can be viewed at: http://www.iea.nl/icils-past-cycles.) (Fraillon et al. 2014, p. 18).

The ICILS Assessment Framework describes three broad types of task included in the test modules. These are:

1. *Information-based response tasks* that are similar to those that could be delivered in a static format on paper but using the slightly richer format available for the computer-based environment.
2. *Skills tasks* that have test-takers complete single-action (such as clicking on a link) or multiple-action (such as changing the settings on a web-page).
3. *Authoring tasks* that require students to edit or create information products using purpose-developed computer applications (such as text editors or presentation display software). These tasks are typically open, in that test-takers are free to explore the functions of the software, undo, redo, and continue to edit features without restriction (Fraillon et al. 2013, pp. 36–42).

The ICILS assessment instrument includes both *point in time* assessments of knowledge, understanding, and skills and *real-world performance* skills. Typically, the information-based response tasks and skills tasks described above assess *point in time* knowledge understanding and skills and the authoring tasks assess *real-world performance* skills.

Challenges

Maintaining Local Independence of Tasks and a Standardized Test-Taker Experience within the Real-World Testing Context

There are a number of challenges in instrument development in ILSA-ICT associated with maintaining a real-world experience in the computer-based performance assessment while keeping the integrity of a large-scale standardized test-taking experience.

The first relates to maintaining local independence of scores obtained from individual tasks or items. Large-scale international proficiency assessments are typically scaled using Item Response Theory (IRT) (Berezner and Adams 2017), and local independence of items is an assumption common to all IRT models (Finch and Jeffers 2016). Empirical analyses of the data collected in large-scale assessments can be conducted to identify the existence and magnitude of local dependencies, and decisions can be made about how to treat them if and when they are identified (see for example Fraillon et al. 2015, pp. 161, 162). The focus of this chapter is, however, on instrument design, and consequently this section will describe the potential that using of real-world contexts in ILSA-ICT has to create local dependency in test materials and explain how test design can try to minimize the impact of local dependency on the quality of the data obtained from the tests.

From the perspective of instrument construction, local independence means that the experience of completing any given item (and consequently the response to any given item) on a test is not influenced by or related to a test-taker's experience of completing any other items on the test. In its simplest form, a violation of local independence (i.e., local item dependency) would take place when the answer to a given item is somehow provided in another item. In most cases considerations of local independence are more subtle than this. For example, local item dependency can exist in a set of items that refer to a common stimulus in which a test-taker's broad engagement with or comprehension of the text may exert a common influence on the test-taker's capacity to manage all the items relating to the stimulus. Local dependency can also occur in criterion-based scoring of individual pieces of work (such as in the assessment of a piece of writing or some other artifact) if the individual criteria are somehow mutually dependent, dependent on the same attributes of the work, or if judges' ratings on more than one criteria in a piece of work are influenced by their overall impression of the quality of the work.

The ILSA-ICT described earlier typically use clustered items (testlets) that include some real-world stimulus materials referenced by more than one item. In the PISA Digital Reading Assessment (DRA) and ePIRLS, the reading stimuli are electronic web-style texts with multiple pages. In PIAAC and ATC21S, there was a range of digital stimuli to which the tasks referred. In each of these cases, there was a trade-off between maintaining the real-world presentation of the stimuli and the potential for this real-world presentation to introduce some local dependency. Typically, the aim is for the individual items to address clearly different skills and aspects of the relevant constructs and also to reference a range of different parts of the stimulus texts. In this sense, as long as test-takers are dealing with the individual items on their merits, it is reasonable to assume that the items are not conceptually interdependent.

In ICILS, a similar approach is taken to the general design of the individual performance tasks. In many cases, the overarching context in which the tasks are being conducted is not directly relevant to the performance skill that is being assessed. Students may, for example, be asked to click on a hyperlink or reformat some text. In these cases, the real-world context of the module theme is unlikely to be the cause of local dependencies. However, each ICILS test module relies on an internal narrative structure that has test-takers working towards a final goal. Test-takers may, for example, first search for some information, then evaluate the usefulness and credibility of information from a variety of sources, then reframe selected information (such as create a diagram to represent a sequence of events in text) before they begin to create their information product using the resources they have assembled along the way. While this represents a typical real-world sequence of events, it introduces methodological challenges relating to standardization and local dependency in the test design.

In order for the test to be fair to test-takers, it is necessary that the initial state of each individual task be the same for each test-taker. The challenge to this in ICILS is that in the natural narrative of a real-world ICT task, one builds a repository of resources in sequence with the outcome of each task affecting the starting point of the next. This introduces a natural local dependency. For example, a sequence of tasks could ask test-takers to:

(i) Enter a search term in response to a given research question
(ii) Identify the most relevant website from the search results;
(iii) Find a relevant piece of information from a website (from within a set of competing and irrelevant information)
(iv) Copy and paste the information into a presentation (including an accurate citation)
(v) Reformat the information to match the presentation style

Table 1 shows the sequence of example tasks described above with a suggested standardized initial state for each task, a summary instruction to test-takers, and the outcome space of possible responses.

The sequence of tasks and outcomes shown in Table 1 illustrates the challenge that the real-world context applied in ICILS creates in managing standardization and avoiding dependencies between items. If the sequence were to be completed in an unstandardized real-world environment then the character string generated as a search term in (i) would affect the search results shown in (ii). The selection of the search result in (ii) would affect the nature, presence or absence of the information shown in (iii). Whether or not the participant could execute the copy and paste in (iv) would then influence whether or not it was even possible for any reformatting to be conducted in (v).

Table 1 Sequence of tasks in an assessment of ICT Literacy

Task	Standardized initial state	Summary task instruction	Outcome space (ignoring nonresponses)
(i) Enter search term	Search engine search field available	Generate a search term	Any character string
(ii) Select search result	Predefined set of search results displayed	Select the best search result	Selection of any one of the predefined set of displayed search results
(iii) Locate relevant information	Predefined web-page presented	Select relevant information on the web-page	Selection of anything on the web-page
(iv) Copy and paste specified information	Predefined information selected on page	Copy and paste information to presentation file	Execution of any available command
(v) Reformat text	Predefined text displaying in presentation	Reformat text	Execution of any available command

In order to maintain standardization and to minimize the potential for item dependency, ICILS adopted two essential design features. Firstly, all tasks began with a fixed, predefined state, and in many cases this state showed the "best" response to the preceding task (or tasks). So in the example shown in Table 1, the search results shown for task (ii) were in response to the "best" possible search term for task (i) regardless of what the test-taker had completed in task (i). Similarly, the text that was displayed in task (v) was the copied and pasted text from task (iv) which in turn was the "best" text selected in task (iii). The initial state of each task was independent of what had been completed by a test-taker on any previous task. Having each task begin in a fixed predefined state ensured standardization and also removed one source of item dependency – the potential for a test-taker's performance on a previous task influencing his or her performance on the next.

However, this solution in of itself created the possibility that as test-takers moved from task to task, they would see the "best" response to earlier tasks. Some test-takers may then want to go back to an earlier task and change their responses to better match what they saw later in the test (i.e., to correct their earlier responses). In order to account for this second potential source of item dependency, the decision was made to allow test-takers to progress only forward through the test and so that once they had completed an item, they were not able to return. The PISA DRA adopted a similar approach. However, it is of course possible that some test-takers may develop insights into how to complete subsequent tasks through the process of being provided the "best" responses to earlier tasks regardless of whether or not they can return to complete them. This would, somewhat ironically, be a situation in which the attempt to remove item dependency created some dependency. Ultimately the design decision must be based on which of the possible design alternatives will most likely *minimize* item dependency and yet retain the real-world context, and some compromises may need to be made as part of this decision.

A further compromise relates to the feedback that test-takers receive from the computer during the assessment. One feature of working in the computer-based environment is that typically one receives immediate feedback from the computer about whether or not one has executed a command correctly. For example, when a user tries to change a font to bold, the user immediately can see whether or not the command has been executed correctly. In the previous section, the three broad categories of ICILS task were described (information-based responses, skills tasks, and authoring tasks). In the design of ICILS, deliberate decisions were made about the feedback that test-takers would receive when they completed each type of task. The CIL construct includes the execution of generic and fundamental skills and the expression of knowledge about how computers work and of "using information safely and securely" (Fraillon et al. 2013, pp. 22–23). In ICILS, these types of knowledge, skills, and understanding are tested using the information-based response and skills tasks.

When students complete information-based responses, they receive no feedback. While this is typical of any assessment that is scored at a later time, it is unlike typical "real-world" computer use experience. When test-takers complete skills tasks in ICILS, they also do not receive any feedback from the system about whether or not they have correctly executed the task. Continuing the example from above (changing font to bold), in ICILS if a test-taker was instructed to change selected font to bold then, as soon as the test-taker had executed a command (any command), they would receive feedback from the system to indicate that an action had been recorded. The test-taker would not "see" the font change (although in subsequent tasks it would show as bold regardless of what the test-taker had done in this task) but would be offered the opportunity to try again (once) or move to the next task. In this case, the real-world authenticity of the skill assessment is compromised in favor of collecting information about the *point in time* skill execution of the test-taker. In contrast, the ICILS authoring tasks, in which test-takers work in an open software environment, support the full experience of trial-and-error skill application, review, and revision that is typical of computer use. ICILS was designed to include both task types as a way of collecting data on both test-takers' *point in time* knowledge and the *real-world performance* skills as they relate to CIL.

A further challenge brought by the real-world approach in ICILS is in the scoring of large tasks. ICILS is the first large-scale international study to use analytic criterion-based scoring of test-taker products. The decision to include information products in ICILS was made in order to incorporate the real-world contexts in which CIL is typically expressed. The two critical challenges in using the analytic criterion-based scoring system were to maximize standardization of scoring across countries (although this is a challenge in all international studies, the potential impact of differences was exacerbated in ICILS by the application of multiple criteria to each large task) and to minimize the impact of dependency across the analytic criteria within each task. The mitigation for each of the two challenges was largely the same. Firstly, a rigorous "train the trainer" scoring training model was implemented in a similar way to that conducted in most large-scale international surveys (see for example Turner 2017). Secondly, the analytic criteria were devised independently and specifically for each task. The criteria within each task were designed to be independent of each other by assessing different aspects of the work. In broad terms, there were criteria that typically related to the quality of the information content in each task (such as the adaptation of information from sources, or targeting to a specified audience) and those that related to the visual presentation of the work in the context of the typical design conventions for the software environment (e.g., poster, presentation, or website). The conceptual hierarchy in scoring layout referenced the degree to which the individual layout features were applied in ways that supported or enhanced the communicative effect of the work.

Optimizing Use of the Computer-Based Environment

Characteristics

An implicit demand of computer-based testing is the expectation that the computer-based testing system will make use of the dynamic and multimodal opportunities afforded by the computer-based environment that are not available in static paper-based testing. ILSA-ICT performance instruments are designed with this expectation in mind and typically attempt to maximize the potential offered by the computer-based environment.

One explicit expectation is that the computer-based assessment will make extensive use of the computer-based functionality that is typically available to users when using similar software in their day-to-day computer use. For example, when working in a browser-based web environment, typical available features include navigation between pages using a variety of means: using the back and forward arrows, clicking on hyperlinks, clicking on or opening new tabs, direct entry of addresses into the address bar (including by copying and pasting), bookmarking pages, and using the history function in the browser. The assessment design needs to include careful consideration of which functions should be included in order to ensure that the environment is fit for purpose. In PISA DRA and ePIRLS, for example, the available navigation features are typically limited to those that are most commonly used when reading digital texts (back and forth arrows, clicking on tabs, or links). In ICILS, the CIL construct is broader and includes execution of a range of navigation skills. In this case, decisions around which options are available are determined in part by what skills are being assessed. For example, if the skill being assessed is to navigate to a site when provided the URL as plain text, then entering the URL into the address bar of a browser is a necessary available function. In assessments where specialized ICT skills are not essential to the construct, there is greater opportunity to restrict the functionality of the system without compromising test-takers' capacity to demonstrate their achievement. In ICILS, decisions must be made about how the inclusion or exclusion of software features relates to measurement of the CIL construct.

A further expectation in the optimization of the computer-based assessment environment is that the test-takers' capacity to engage with the test content will be independent of operating systems and devices. For example, even though all the ILSA-ICT described in this chapter require test-takers to navigate a web-based environment, none assume that navigation is being tested in relation to one particular web-browser or operating system. In ICILS the position is most complex because the CIL construct includes (explicitly and implicitly) the application of a broad suite of commands. In addition to basic navigation and editing, test-takers are expected to work with a range of types of productivity software tools and web-based data resources, in particular in the execution of their skills for the purpose of communication. Across all studies, the common solution is to use purpose-developed (or adapted) applications that make use of generic commands that reflect interface design conventions common across operating systems, software applications, and devices.

Challenges

Achieving Standardization Across Platforms and Devices

ILSA-ICT are expected to make use of the unique features the computer-based testing environment and yet remain operating system and device independent. This provides significant test design and technical challenges. As described previously, one test design solution is to create an environment in which test-takers make use of generic commands that can reasonably be expected to be equally familiar to test-takers of equal ability regardless of their experience with particular software systems or devices. However, while this solution is generally suitable for dealing with different software systems (including operating systems), it becomes more problematic across device platforms. As the rapid rise of tablet technology is only relatively recent, the full extent of their impact on large-scale assessment is as yet unknown. Increasingly, however, there is an expectation that tablet devices be used to deliver assessments. The two biggest challenges to this are: the screen size that is available on smaller devices, such as some tablet devices or netbook computers, and differences between the suitability of tablet devices and computers with external keyboards for undertaking some specific tasks.

All ILSA-ICT instruments incorporate some form of test taking interface (that typically allows test-takers to navigate between tasks, monitors progress, and gives an indication of the time available/remaining). While the design of these interfaces varies across ILSA-ICT, they typically are a constant feature on the visible screen and take up some screen space. The remaining screen space is used by the test content (stimulus and items/tasks). Even though smaller screens may be able to display accurately the test interface and content, there is a point at which the absolute screen size becomes so small that it may interfere with a test-taker's capacity to manage the content and compromise standardization of the test experience. Test-takers using smaller screens may need to scroll more than those using larger screens and text and screen content may be difficult to read or manipulate on small screens. In most ILSA-ICT, there are specifications for the minimum permissible screen size. The problems associated with screen size are exacerbated on tablet devices used without an external keyboard. On-screen keyboards may obscure assessment content or at least reduce the available screen space to display the test contents. Typically in ILSA-ICT there is a requirement to make use of an external keyboard for all devices.

Maintaining Construct Validity Across Platforms and Devices

In ICILS, there is a further issue relating to construct validity if the assessment were to be delivered on tablet computers. The performance test includes the need for students to create and communicate using productivity tools, and currently there are questions about whether tablet devices are used in the same way as conventional computers (or even at all) for the completion of larger productivity or communication tasks. Haßler, Major, and Hennesy (2016) following an extensive literature review of reported use of tablet computers in schools suggest:

> *Unsurprisingly, certain technologies are more appropriate for particular tasks than others and this is also true when considering uses for tablets: for example, keyboards, larger screens and specialized software (perhaps only available for certain operating systems) may be needed to support specialized tasks such as extensive writing, mathematical constructions and computer programming.* (Haßler et al. 2016, p. 148)

The above conclusions have significant impact on the conceptualization and design of large-scale international studies which focus on digital literacy (such as

ICILS, PIAAC PSTRE, or AT21CS). In these cases, in addition to resolving technical issues associated with achieving standardized delivery across devices, there are questions of whether construct validity can be maintained on tablet devices if tablet devices are not typically used or suitable for given tasks that remain within scope of the assessment contracts.

Balancing Test Delivery Infrastructure Requirements with Test Content and Validity

At a technical level, there is a trade-off between the available delivery infrastructure (web-based, server-based, or locally run on USB or from the local hard drive) and the standardization, security, and richness of content that can be delivered. In this case, the trade-off includes multiple parameters. While the concept of Internet-based delivery is inherently appealing, it brings with it risks associated with reliance on local users' Internet connectivity and speed. Furthermore, without some intervention on local devices (to create a consistent set up across devices and to prevent or monitor use of other applications), the level of standardization of user experience and security of Internet delivery must be assumed to be relatively low. This relates to a further trade-off between the degree of standardization and level of security and the amount of work that needs to be done to set up devices to support testing. Typically, greater standardization of test-taker experience and test security in a given assessment are commensurate with higher necessary levels of local configuration of the test-takers' devices (see Walker 2017 for a discussion of issues relating to computer-based delivery of large-scale assessments).

Test content development is also influenced by the delivery infrastructure. Rich multimedia including streamed video, for example, makes high demands on bandwidth and may not function well if delivered using the Internet to a number of test takers concurrently in a given location. Consequently, the inclusion of rich media in an assessment may only be feasible if a local delivery option is being used. Audio could technically be included in a test instrument, but this places further demands on the delivery technology. In ILSA-ICT, these issues are further complicated by the significant variation in available infrastructure across countries. The typical approach in ILSA-ICT is to adopt a strategy that balances some innovation in test design with a design that caters to the lowest quality expected delivery infrastructure.

Future Directions in Large-Scale International Assessment

United Nations Sustainable Development Goal target 4.4 is by 2030 to "substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship" (UN 2016). Indicator 4.4.1 under this goal is the "proportion of youth and adults with information and communications technology (ICT) skills, by type of skill" (UN 2016). This is a formal recognition of the current and ongoing value of digital ICT-related skills. In this section, the future direction of ILSA-ICT is considered in terms of current trends in the area, necessities, and the challenges they may bring.

In order to remain relevant and useful, international large-scale assessment must remain up to date with developments in digital technologies and their use. This is a particular challenge when considering the speed with which change occurs, and the challenge is manifest in design choices around assessment content, choices relating to delivery and in the ongoing conceptualization of the constructs that are being assessed.

The inclusion of DRA in PISA and ePIRLS in the PIRLS assessment suite were responses to changes in technology and the increasing prevalence of computer-based reading. The restriction of ePIRLS to include only information text types was a deliberate decision in light of the types of electronic texts that Grade 4 students can be expected to read. As technologies develop, it is plausible, for example, that the text types in large-scale international assessments of computer-based reading may expand to reflect changes in reading behaviors. It is also plausible that they may not. Such decisions need to be made carefully and strategically in light of data about patterns of use and whether these represent enduring reflections of changes in reading as a construct.

Previously in this chapter the relationship between tablet device use and the measure of computer and information literacy in ICILS was discussed. This is one example of a challenge that changes in technology can bring to the measures of digital literacies. The imperative solution in this case is to determine what is “core” to the digital literacy discipline and what is peripheral to a domain in the context of how it can be assessed and how changes in technology may affect assessment. In ICILS, the core skills relating to information literacy in the digital context, which had their roots in the 2003 PISA feasibility study, are the ones that have endured. However, ICILS 2018 has included computational thinking as an optional international assessment in response to increasing interest and formal application of this domain within countries. This is a response to changes in the field, not as a result of changes in technology but rather as part of the natural evolution of priorities and thinking in the domain.

Stage 2 of the COMPED study conducted over 25 years ago included the FITT with domains that relate closely to those covered in computational thinking. The ICT processes that were first determined as having international applicability in the PISA feasibility study represented a shift in focus of the domain away from computing towards information literacy using the Internet and computers (now digital devices) as tools. While this thinking dominated the domain in the first decade of this century, recently there has been a shift of interest to include computational thinking as a domain worthy of curriculum definition (see, for example, Angeli et al. 2016), teaching, and assessment (see, for example Bocconi et al. 2016). With an eye to the future, one must determine whether the current resurgence of interest in computational thinking will be sustained, with computational thinking joining a lasting core of ICT-skills, or whether it is peripheral to a central core. Decisions about how to work with computational thinking now and into the future are simply contemporary examples of the general principle that it is important to monitor and evaluate what is core and what is peripheral to IT-related domains in the context of continuous and rapid technological change.

Changes in technology can, however, continue to influence the core constructs of interest. For example, in the past decade, collaboration and social media-supported publishing have become significantly easier and faster. With relatively little technical skill, it is possible for users to publish information in the public domain. With this technological development, there has been consequent broadening in the focus of the assessment of safe and ethical computer use to include the user as an information producer and publisher as well as a consumer. This has resulted in a broadening and shift in emphasis of constructs covering this aspect of the domain.

As technologies develop, policies evolve, and device use changes, the fundamental questions that need to influence the planning and development of large-scale international assessment of IT-related literacy relate to the relevance, scope, and anticipated longevity of the changes. Those changes that relate to core issues in the domains and that are likely to be sustained are the ones that need at the very least to be incorporated into the design of future large-scale assessments.

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78 Measuring the Impact of Emerging Technologies in Education: A Pragmatic Approach

Mutlu Cukurova and Rosemary Luckin

Contents

Abstract

The evaluation of emerging technologies is important for their impacts to be effectively integrated into learning and teaching settings to bring the best benefit to learners and teachers. Educators, learners, parents, and policymakers alike, therefore, need reliable methodologies for evaluating the effectiveness of such emerging technologies. However, the impact evaluations of technology in education are challenging. This challenge is more significant for emerging technologies, as change is the essence of emerging educational technologies. Therefore, the value of traditional impact evaluations in education requires being reconsidered within this context. Here, we present a pragmatic approach to measuring the impact of emerging technologies in education which focuses on the suitability of the proposed evaluation methods and the types of evidence rather than on the hierarchy of these methods and evidence types. The approach has two main steps. First one is the creation of a clear theory of change to identify outcome measure(s) and assumptions that are behind the expected impact of the emerging

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technology intervention. Second is the identification of the type of evidence and methods to generate it that are the most appropriate for the current innovation stage of the emerging technology.

Keywords
Evidence-informed practice · Emerging technologies · Impact evaluation · Pragmatism · Evidence

Introduction

The impact of technology on learning and teaching is often at the forefront of demands, particularly from those who dictate the funding available to pay for technology within education systems. This is not an unreasonable request and there is merit in impact evaluations of educational technologies including emerging technologies. Nevertheless, as has been shown in numerous meta-level investigations (see for instance Cox et al. 2003), evaluation of the impact of technology on educational outcomes is a challenging task. This challenge is even greater when evaluating emerging technologies. This is at least partially due to the connotation that, in traditional impact evaluations, evidence regarding the impact of an intervention is considered as *a shield against change*. The generation of scientifically robust evidence about the impact of an educational technology can be therefore taken as a message for the stakeholders of this technology to standardize it and scale it up. *However, change is the essence of emerging technologies.* Measuring the impact on educational outcomes is certainly a necessity if we are to increase our confidence in our educational technologies for their potential to meet their expected outcomes. However, particularly in the case of emerging technologies, the evidence generated from impact evaluations might rather be used to provide "informed change" instead of a justification for standardized practice and manuals for implementations.

This fundamental difference between emerging technologies and more traditional educational interventions is important and it must be taken into account in the discussions about and designs of studies to evaluate the impact of emerging technologies. In the context of emerging technologies, the value is in the careful consideration of different types of evidence as well as robust methods to generate them. In this chapter, we will focus on two key particularities of emerging technology interventions, and based on these, we will suggest a pragmatic approach to evaluate the impact of emerging technologies.

Defining Emerging Technology

When simply defined, particularly within the context of education, emerging technologies are those that have the potential to change the current state of affairs in education. Emerging technologies include but are not limited to virtual reality implementations (Merchant et al. 2014), augmented reality implementations

(Dunleavy and Dede 2014), mobile learning devices (Crompton et al. 2017), physical computing tools (Katterfeldt et al. 2018), Internet of things hardware with sensors (Cukurova et al. 2018), and technologies that allow collaborative learning at a great scale (Cress et al. 2016). Change is at the core of these technologies not only because they evolve by time, but also arguably their *raison d'être* is to transform the learners' current experience. Therefore, the change is not only in the educational technology that is aimed to be evaluated, but also in the learners' experience of the interventions through which the impact of the technology will be evaluated. When change is such fundamental to emerging technologies, how can we measure their impact in a robust and meaningful manner? Next, we will go through the notion of evidence-based education and how evidence is being generated to measure impact in more traditional educational settings with the purpose of presenting the (in)compatibility of these ideas to the nature of emerging technologies.

Evidence-Informed Emerging Technologies in Education

The notion of impact and the demand to be shown that something really "works" requires evidence of some kind of influence or effect of the educational technology on their users. In educational technologies, as well as in education broadly, often this evidence of effect is measured in terms of learner attainment (see for instance Cox and Abbott 2004). Measuring impact on student attainment might be considered as somewhat narrow, and increasingly there is a recognition of the value of illustrating effects on a much wider range of outcomes. The previous edition of this book presents some of these examples such as those relating to emotional well-being (Ainley et al. 2008) or motivation (Cox 2008). Regardless of the type of outcome measured to show the impact, high-quality evidence that relates to the potential of an educational technology to achieve its expected learning outcomes and the information regarding the process of how these learning outcomes can be achieved is key for impact measurements.

Although there are some concerns regarding the centralization of such evidence as the only source of input for decision making on which to base educational practice (see, for instance, Biesta 2007), it is hard to argue against the potential value of evidence to inform and improve practice (Petty 2009). Recently, interest in effectiveness evidence in educational practice and policy has increased globally (Buck and McGee 2015; Greany and Maxwell 2017). For instance, in the UK, the department for education invested a £125 million founding grant to Education Endowment Foundation in 2011 aiming to improve evidence-based practice in education. Department for International Development is preparing an approximate £20 million investment to create a global research hub to form a global "what works" evidence hub to catalyze effective innovation in the education sector. This initiative aims to provide decision-makers with evidence to harness the transformative potential of educational technology – to deliver better learning outcomes for all (DfID 2017). Similarly, in the USA, 2015 Every Student Succeeds Act encourages the use of an educational practice that meets evidence standards from experimental or quasi-experimental evaluation studies. Fundamentally, these initiatives point out that educational policies and practice should be chosen based on evidence on their effectiveness (Slavin 2017).

Governmental initiatives as mentioned above lead to discussions around impact and evidence in primary and secondary education practice with an emphasize on "what works," suggesting that practice should implement teaching methods that are presented to be effective at maximizing learning outcomes by research (Hattie 2008). However, despite the significant amount of academic interest and policy focus as well as the resources directed to educational technology's impact, it is still a significant challenge to generate and identify robust evidence on the effects of technology in education, particularly for emerging technologies.

After decades of research in the field of technology in education, there are still significant questions waiting to be answered that relate to the impact of technology on students' learning (Cox 2008). There are various reasons behind this lack of robust and reliable evidence regarding the effects of technology in education.

As categorized by Cox and Marshall (2007), these include issues that relate to different assumptions about how learners think; the broad range of technology types and their varied uses leading to different effects; curriculum design and implementation-related variance of technology adoption and use; problems of the pedagogical approaches of the teachers; and issues that relate to the identification and use of research instruments as well as the interpretation of results generated from their use. In addition, it can also be argued that there are other challenges that are more practical in their nature such as the lack of investment and interest from educational technology companies in measuring the impact of their products on educational outcomes, strategic challenges such as the lack of cross-sector learning and multidisciplinary collaboration in educational technology research and practice (between developers, designers, entrepreneurs, educators, and academics). To exemplify the first point, for any pharmaceutical product to be available in the market, it has to go through a very strict evaluation process and impact trials. Yet, educational technology products can go straight into the market as soon as they are developed without any evaluation of their impact on their expected educational outcomes, or identification of their potential detrimental effects. To make it clear, we do not have any purpose of comparing medicine as a discipline to education; however, the point we are making is that, at the moment, there is a great uncertainty around the impact of educational technologies on their expected outcomes, and this should be decreased to a certain extent through appropriate impact evaluations. This approach would be unacceptable, unethical, and illegal in various disciplines including medicine, agriculture, engineering, or architecture. However, yet it appears to be acceptable in educational technology contexts. The demand regarding the decreased uncertainty around the impact of educational technologies would also encourage educational technology producers to be more interested in and invest into impact evaluations. Regarding the second point, efforts to ensure that promising research has at least some chance of being "translated" into useful products are explicit in many other disciplines (see for instance https://www.elsevier.com/connect). On the other hand, attempts to create a shared understanding between the key stakeholders in educational technology, including technology developers, academia, and educators, are extremely rare (see for instance https://educate.london).

It is clear that generating evidence about the impact of educational technologies is a challenging enterprise. Furthermore, evaluating the impact of emerging technologies, which is the particular focus of this chapter, is even more challenging. In this chapter, we discuss two main reasons for this argument. Firstly, compared to more mature and established educational technologies, it is more challenging to explicitly diagnose and identify the actual educational "problem" specific to the contexts of emerging educational technologies, which also makes outcome measure(s) and their relationship to the expected impact hard to identify. However, transparency of interventions in terms of outcome measures, their definition, and contextual factors is fundamental for the emergence of evidence in educational research (Cukurova et al. 2017). In some cases, the solutions created through the emerging educational technology do not relate to any particular educational outcome which would be the key outcome measure of the impact evaluation of the emerging educational technology created. This leads to the result that neither the emerging educational technology interventions created nor the evidence of their impact on certain outcomes has much value for practitioners and policy-makers. Evidence presented in previous reviews (see, for instance, Cox and Abbott 2004) shows that likely effects of technology interventions on learning are often present *only when* outcome measures are closely linked to the actual expected learning outcomes of the technology.

Secondly, there has been a tendency in recent educational research to move towards experimental research designs that aim to generate evidence to inform teaching practice while undervaluing other types of research approaches (see for instance Slavin 2017). This movement towards positivist research methodologies in education has led to heated debate over the last few years about the way in which evidence in education is perceived, and the relationship between research and practice in educational research (De Bruin 2015), with much discussion focusing on how to generate a positive relationship between educational research and teaching knowledge and practice (Pampaka et al. 2016). Here, we argue that due to the ever-changing dynamic nature of emerging educational technologies, the traditional methods of more positivist impact evaluations, such as randomized control trials (RCTs), should *not* be considered as *the only* solution. Such research methods require mature practices, long-term implementations, and big sample sizes which are all problematic to satisfy for emerging educational technologies. In measurements of emerging technology impact, it might be a more appropriate approach to collect evidence in an iterative and adaptive process, disseminating findings as they evolve, and contribute to the maturation of both technology and its implementation in particular educational contexts. After such maturation of technology and its implementation has been reached, the value of more positivist approaches becomes more apparent in the impact evaluations. Traditional positivist impact evaluations cost a significant amount of resources, and they require long treatment periods to be meaningful. They do have a great value for more established interventions, which are refined with pilots and early research that use postpositivist approaches with both qualitative and quantitative data. However, for emerging technologies, their value is open to criticisms. Here, we will argue that small-scale rapid cycle evaluation type of investigations might be more appropriate for most of the emerging technologies until they reach a certain level of maturity.

Transparency of the Intervention and Identification of the Outcome Measure(s)

As we mentioned above, the diagnosis and identification of the actual educational "problems" specific to the contexts of emerging educational technologies is a challenging but a necessary step in impact evaluations. This challenge might lead to the omission of key contextual factors and clear outcome measures for the impact evaluations of emerging technologies. The omission of contextual factors is hard to understand when one considers that a wide range of research has illustrated that it is impossible to understand how people work or learn without also taking into account the people and artifacts that make up their context (Nardi 1996). Although the term context is probably the term that is used most frequently within educational research papers to index the circumstances in which learning takes place (Cole et al. 1996), it is still a complex concept with its various definitions and interpretations by educational researchers. It is very difficult to "pin-down" in a way that enables context to be used as the basis for informing the practice of teaching and learning. However, the context has been subjected to two principal conceptions: the first conceptualization is "that which surrounds," which is open to the criticism that context is portrayed as a container rather than part of the same situation. The second conceptualization requires that we interpret mind in a relational way: "as distributed in the artefacts which are woven together and which weave together individual human actions in concert with and as part of the permeable, changing, events of life" (Cole et al. 1996). In this chapter, our interpretation and use of the word context are similar to the latter conceptualization of context. In this sense, context is a reflection of the interactions that the learners have experienced with multiple people, artifacts, and environments. This interpretation of context includes a range of factors such as the learning tasks and the learning interactions of social constructivist learning processes, as well as its relatively simplistic interpretation as being that which surrounds learning and learners. It is sadly true that the treatment of context in educational studies, particularly when it is considered in this broader sense described above, is "under-examined, under-theorized and under-developed" (Gulson and Symes 2007). Context is often so poorly reported within the educational technologies research literature, that a sustainable and systematic manner in measuring emerging technology impact in primary and secondary schools evades the research community. The omission of contextual information from much educational technology research devalues the impact of this research both on the practice of educators and on the practice of policy-makers (Cukurova et al. 2017).

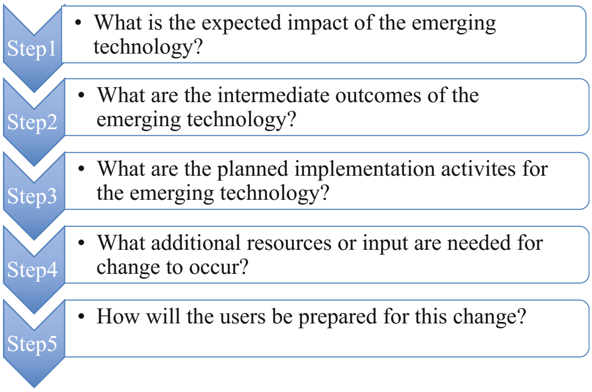
In the past, due to limitations of technology and its use in education, impact evaluations were often completed through straightforward questions such as "what are the effects of this physics teaching software on students' understanding of the concept of gravity?" or "Is there an impact of students' understanding of chemical bonding after engaging with this simulation?" etc. The evaluations were also undertaken with traditional methods such as pre- and posttest evaluations (Cox 2008). However, in the case of emerging technologies, the aim is often to transform students' experience of traditional education. Therefore, what exactly this experience involves, including the expected outcome measures and contextual factors, should be clearly defined as the initial step of the impact evaluation process. If we take the position that the context is the sum of one's experiences, then the context in which the impact measured should be as transparent as possible in order to be able to clearly identify the outcome measure(s) which will be investigated during the impact evaluations of emerging technologies. The complex design of emerging educational technologies requires much more understanding of human-computer interactions (Cox 2005) as well as the wider learning context in which they are being implemented.

Emerging technologies vary enormously, and multiple researchers have made it clear that the design and use of an educational technology plays a big role in its impact on educational outcomes (see for instance Reeves 2008; Pilkington 2008). Not all emerging technologies are equal in their potential to afford efficacy. Any kind of impact evaluation in educational technology research, therefore, also requires detailed knowledge of the nature of the evaluated technology, their different representations, and the ways in which they may contribute to learning (Pilkington 2008). There could be various methods to bring this transparency of the emerging technologies and their contexts, next we will present one of them.

A Theory of Change for Emerging Technologies

Change is the essence of emerging educational technologies. This change involves changes in the technology as well as the changes in the experience of learners. According to the theory of change, until a change occurs, a state of equilibrium exists in which any forces that might drive change are equal to the forces that are resisting change. For change to happen, the balance in the equilibrium needs to be upset (Fullan 1983). This imbalance can be achieved either by strengthening the driving forces behind the change or by removing the barriers that resist the change (Fullan 2001). In the context of emerging technologies, a theory of change can essentially be represented as a diagram that explains how an emerging technology might have an impact on its users. It should mainly outline all design features that an emerging technology has, the ultimate impact that it aims to have on its users and all the potential outcomes that lead or contribute to this ultimate aim. A theory of change diagram is very useful in impact evaluations as it enables one to identify the steps that are necessary to take in order to reach the expected educational outcomes as well as the assumptions taken for granted between those steps. It also ensures that these outcomes may actually lead to emerging technology's overall impact and that the impact is measurable. The transparency that a theory of change brings into the problems that an emerging technology aims to tackle in education is the first step to take for impact evaluations. There are five main steps of creating a theory of change (Fig. 1):

Fig. 1 Theory of change diagram steps for emerging educational technologies



Step 1: This step can be considered as the identification of the expected primary impact of the emerging technology. In other words, to what issue in education this emerging technology product might provide a solution to? One of the key challenges here is that impact should be measurable, and ideally, the impact should be the direct impact of the emerging technology that can be observed in realistic timescales. There is no point in creating multiple impact scenarios that are not specific to the emerging technology; therefore, the impact should ideally be one to three bullet points that are specific.

Step 2: These intermediate outcomes lead to the overall impact and can be defined as the expected change/benefit that your users of the emerging technology will experience. These also should be measurable; however, unlike impact, these outcomes should be comprehensive in order to be able to explain all expected changes the users will experience as part of their engagement with the emerging technology.

Step 3: There is great evidence that the activities, in which the technology in education is being used, affect the expected learning outcomes (Cox et al. 2004). Activities in which the emerging technologies are being used might range from using what are essentially traditional methods with only small interaction with the technology to more fundamental changes in the teaching and learning practices. For instance, a natural language processing artificial intelligence (AI) tool (such as Amazon Alexa) can be used by a teacher as part of her teaching practice, essentially as a handy dictionary to define unknown words that might emerge during her teaching activities. However, it could also be used as part of students' group activities in which students talk with the AI agents in order to improve their pronunciation, motivated to be understood by the natural language processors of the AI agents (Underwood 2017). Clearly, the impact evaluations of these two interventions with the same technology would be significantly different. Therefore, in impact evaluations, clear explanation of the implementation activities of the emerging technologies is very important. Activities may comprise everything that the emerging technology does for its users and everything that users do when they are using it as part of the intervention.

Activities should only include things that influence the users directly, not operational tasks that are done in advance of the teaching and learning activities or that might impact the user in an indirect manner. As part of a theory of change, activities and their outputs need to be linked to intermediate outcomes identified in step 2. It is useful to draw arrows indicating this potential causality on a theory of change.

Step 4: There are often other resources needed to use the emerging technologies – other than the technology itself. These could include access to the Internet or other software or hardware requirements. Likewise, other inputs, such as particular skills or training, might need to be present for successful implementation of the emerging technologies in education. It is important to bring transparency to these resources as part of a theory of change.

Step 5: In addition to making sure the users have the resources and skills necessary, there might be many other challenges with the process of change, especially in education. It is important to consider these when planning for impact evaluations, as they would affect the size of the impact. This step is particularly useful for the interpretation of impact measurements as well as the process of it. A few issues to consider are presented below;

(a) **Readiness for change**: Change in education is a slow process, compounded by the fact that many educational practices have not changed in decades. Ensuring that the users of the emerging technology are ready for the change, in terms of understanding and accepting the need for the change, is vital for its impact.

(b) **Urgency or need for change**: When processes and practices are so intertwined, it is often difficult for participants to understand why change is necessary. Clear explanations and data that demonstrate why the change is positive and necessary can help convince stakeholders of the need for change.

(c) **Learning anxiety**: Participants need to feel that the conditions are safe for a change. One way to combat this anxiety is to include practice phases as part of the implementation so that participants can test the change and iron out mistakes.

(d) **Implementation dip**: There is good evidence that confidence in using technologies is vital for impact on educational outcomes (Condie and Munro 2007). When people realize that they are required to learn new skills and that they are not as confident in the new practices as they were in the old, an implementation dip occurs. This is a decrease in both performance and confidence during the change process. The implementation dip is to be expected, especially in education, and requires coaching and other support to help people through this transition.

A Pragmatic Approach to Impact Evaluations

Impact evaluations of any emerging technology require the generation of evidence regarding any effects arising from an educational intervention that involves that emerging technology. However, views about what constitutes "evidence" may vary considerably among and between stakeholders. For instance, although most educational technology developers would present quotes from their users as evidence of the impact of their product or service, such anecdotal instances would not impress most academics. This variance brings more confusion into the already complex endeavor of educational technology practice and decreases the likelihood of employing evidence-informed practices in educational environments. When the discussion is on measuring impact, evidence is often categorized in four groups as elaborated below (Hoeken 2001). It is important to note here that the type of evidence does not necessarily reflect the quality of the evidence and different types of evidence have different advantages and disadvantages (Marshall and Cox 2008). Different types of evidences' quality are judged with different criteria, and different types of evidences are more appropriate for different research purposes and contexts. Exploration of the quality criteria for different types of evidence is outside the scope of this chapter (for further information please see O'Leary 2004). Nevertheless, the point that requires to be made here is that each type of evidence should be judged with appropriate evidence quality criteria and a type of evidence's appropriateness should be considered for specific questions and within particular research contexts.

Types of Evidence

There are four main categories of evidence: anecdotal, descriptive, correlational, and causal evidence.

1. **Anecdotal evidence** is evidence from personal statements or claims based on one or more people's personal experiences. When compared to other types of evidence, anecdotal evidence is generally regarded as limited in value due to a number of potential weaknesses regarding the evidence quality measurement values such as subjectivity. Therefore, it is hard to argue about the impact of emerging technologies using only this type of evidence. However, anecdotal evidence can be considered within the scope of the scientific method as long as it satisfies some of the quality of evidence criteria (auditable and transparent), empirical and verifiable. Often the real value of anecdotal evidence is in its potential to indicate the potential context in which an emerging educational technology can be effective. For instance, in a recent case study, Perry (2015) investigated the potential impact of a new augmented reality-based mobile learning tool which was created for first-year University French students in order to bridge the gap between gaming and education through quest-based learning. As part of the study, volunteers were sought from first-year University level French-language classes and a total of 11 students participated in the study. Based mainly on student excerpts, the study concludes that game-based mechanics can be positive motivators for learners. While this study provides an interesting piece of evidence that could be used as a supplement to a larger body of evidence, it is too limited in scope and sample to stand on its own. However, it addresses several benefits and limitations of the emerging educational technology

investigated via a case study, and it offers theoretical and practical implications that will shape the future more targeted studies. For instance, the evidence generated from the case study is used to shape further analysis of student interactions with each other and their interactions with the tool in order to provide a comprehensive analysis of the emerging technology's use and its impact on student motivation.

2. **Descriptive evidence** stems from the summary of characterizing individuals and groups who use a specific emerging technology and depicting events, processes, trends, or relationships that emerge from users' interaction with an educational technology resource. This type of evidence can provide more insight into effectiveness; however, the main criticism of this type of evidence is that it does not control the other variables that could potentially have an impact on the results generated (Marshall and Cox 2008). Educational technology research and commercial documents are replete with such evidence (see, for instance, Beraza et al. 2010).
3. **Correlational evidence** is the identification of the relationship between a condition or initiative and a specific outcome. When the results show correlations, these might be due to the intervention or another causal factor. The correlation results, therefore, cannot answer why questions, yet they are still very useful for evidence-informed predictions.

   For instance, Bakker et al.'s (2015) longitudinal study, which is conducted over 2 years, includes a much larger sample size than the aforementioned case study (719 pupils from 35 primary schools) in order to examine the effectiveness of computer "mini-games" in primary education. Such game applications can barely be considered as an emerging technology; however, due to lack of longitudinal research on emerging technologies, potentially due to aforementioned dynamic nature of these technologies, we will use this example here. This work is labelled as a controlled longitudinal study. The three groups researched included pupils who used the computer games at home, with no in-school discussion, pupils who used the games at home but discussed them in school, and pupils for whom the games were played in school as a part of the mathematics curriculum. The study found that the games were most effective in improving the multiplicative skills of students who used them at home with follow-up at school.

   In designing this study, researchers considered several meta-analyses of the use of technology in mathematics education and included a control group so that the variation between the control group and experimental groups could be attributed to the influence of the technology intervention (in this case, the mathematics mini-games) (Bakker et al. 2015). Due to its relatively large sample and somewhat controlled nature of the study, it provides a nice example of correlational evidence and its value in terms of providing a relatively high level of confidence in the results generated. Even so, the researchers point out the fact that this study cannot be generalized beyond the sample and experimental conditions used here. One of the reasons for this is that their sample was not representative of Dutch schools as a whole, due to the dropout in participation they experienced from their original sample size. Also, the students were not distributed randomly into groups which brings doubts about the equivalence of students in control and intervention groups in terms of potential confounding factors such as their motivation and confidence.

4. **Causal evidence**: Strong causal analysis can only be achieved by ensuring that the only difference between the group that receives an educational technology intervention and the comparison group is the intervention itself. Many guidelines for evidence-based practice indicate that the best-quality evidence comes from randomized controlled trials (RCTs). RCTs assign large numbers of subjects into either a control or a treatment group by chance. The treatment group then receives the educational technology intervention being tested and the control group does not. An RCT is one of the strongest forms of design for an impact evaluation in general, because it establishes whether a specific intervention caused an outcome or not.
   Evidence of the causality of an intervention is relatively rare in educational technology research, particularly that involving emerging technologies. In order to exemplify this type of evidence, we will have a look at the research conducted by Miller and Robertson (2011). The main objective of their research was to create a large-scale study that examined the impact of the use of computer games in schools on pupils' mental computation skills and mathematics self-concept. In this study, they collected data from 634 primary pupils across 32 schools in Scotland. Pupils were randomly assigned at a school level to experimental or control conditions. In the experimental schools, pupils spent 20 min per day for 9 weeks on a mathematics brain training game. Control schools simply progressed with normal activities in mathematics classes.

   The Miller and Robertson study found significant gains in both groups from the pre- to posttest periods of the research, but the gains of the experimental group were 50% greater than the control group in terms of accuracy and twice that of the control group in speed. In contrast to the previously cited longitudinal study, the authors of this research asserted that their findings can be generalized. However, even in this case of strong evidence, it is worth to mention that the findings would only apply to a restricted part of the curriculum that is investigated in this research. Furthermore, Stern (2015) argues one can draw conclusions from a causal inference based on an RCT that a specific intervention led to an increase in expected learning outcomes. However, when it becomes evident that the same intervention does not always lead to the same learning outcomes in all places, people start to ask "why?" Another important issue in emerging technologies research is that it is hard to recruit large numbers of participants that are needed to achieve the statistical power required to iron-out various differences between individuals. Regardless, RCTs are an essential part of impact evaluations due to their power to generate reliable causal evidence.

5. **Meta-level evidence**: The confidence in evidence studies increases through their meta-level analysis. For instance, Li and Ma (2010) reviewed studies on the impact of technology in general and on the mathematics learning in primary and secondary classrooms. From existing literature, the authors identified 46 studies encompassing 36,793 learners. Nearly all studies were well controlled, using a random assignment of students to either experimental or control conditions. In

their analyses of preexisting research, the authors found statistically significant positive effects of the use of technology on students' achievement in mathematics, as well as several other findings that numerous reviewed studies have in common. However, Bakker et al. (2015) note one of the challenges with this meta-analysis is that it only looks at "computer technology" in general, rather than a specific intervention, and thus is difficult to apply the results of such a metalevel evidence into specific emerging technologies. In addition, as also argued by the authors, "It is impossible for any meta-analysis to evaluate the design quality of the programs used in primary studies" (Li and Ma 2010, p. 235). Due to the challenges of identifying individual emerging technologies from review studies and the lack of details about the design quality of the technologies in primary studies, values of such metalevel investigations in practice are limited. These issues emphasize the value of a clear theory of change in impact evaluations (see section "A Theory of Change for Emerging Technologies").

It is also worth to make it clear that meta-level evidence does not have to come from quantitative studies (see for detailed discussion Noblit and Hare 1988). For instance, Tondeur et al. (2012) reviewed 19 qualitative studies that focused on strategies to prepare preservice teachers to integrate technology into their lessons. In their synthesis, they explain key themes explicitly related to the preparation of preservice teachers (e.g., using teacher educators as role models, learning technology by design, scaffolding authentic technology experiences), and conditions necessary at the institutional level (e.g., technology planning and leadership, co-operation within and between institutions, training staff). The meta-level evidence generated then used to create an overarching model that explains the relationship between these factors. More extensive meta-studies are also discussed in ▶ Chap. 75, "Meta-analyses of Large Scale Datasets: A Tool for Assessing the Impact of Information and Communication Technology in Education" in this volume.

It is increasingly clear then that different types of evidence in impact evaluations of emerging technologies have different advantages and disadvantages. Therefore, relying on one study or one type of evidence is unlikely to provide enough reliable evidence to judge the impact of an educational technology. Unfortunately, for most traditional experimental methods, once the generalization has been made, the assumption, particularly among practitioners, is that the result will occur regardless of the means of getting there, both in terms of the context and the process. This results in issues that even though well-established evidence regarding the impact of emerging technologies on various learning outcomes exists, it is hard to argue that the evidence would be strong under every contextual factor or even so, its strength would be the same (Cukurova et al. 2017). In addition, as argued by Kelly et al. (2008) emerging technology interventions should respond to new knowledge emerging from recent research studies. This is not common in more traditional educational research and might even be considered as unproductive. However, given the pace of change in emerging technologies, it is not always easy for researchers in the field to get satisfying support from the findings of the effectiveness of previous interventions investigated. As one potential solution to this, Ann Brown (1992) discusses strategies to transform schools into communities of learning and interpretation where students are provided opportunities to take charge of their own learning and calls for new and complex methodologies to capture the systemic nature of learning, teaching, and assessment in their own contexts. Such approaches to empowering other stakeholders of educational technologies rather than relying only on researchers in impact evaluations might potentially be valuable for measuring emerging technologies' impact in primary and secondary education (see for instance https://educate.london). Similarly, more recently, Design-Based Implementation Research (DBIR) aims to organize research and development that addresses the challenge of creating effective, scalable, and sustainable policies and programs in education. The approach argues that continuous close connection between researchers, teachers, and their local education districts is fundamental for effective implementation of educational interventions (Coburn et al. 2012).

Multiple sources of evidence are needed in order to strengthen the argument that a particular technology intervention will be successful under a variety of conditions. Both quantitative and qualitative sources of evidence are valuable for the statistical power of their large sample sizes (correlational and causal evidence) and the explanatory power of more in-depth questioning (anecdotal and descriptive evidence). It would be premature if decisions were taken about whether or not to implement an intervention based on one type of evidence only. A more holistic approach is needed in order to reach a complete picture regarding the impact of emerging technologies in education. All evidence types may shed light on why an intervention of an emerging technology succeeded or not and in what circumstances. Rather than arguing about the overall superiority of one particular type of evidence or research approach over others, perhaps a more important questions to ask are what type of evidence is the most appropriate for a particular emerging technology innovation? and how can we design and implement interventions that might help us generate this type of evidence? Such questions are particularly important in domains with little prior research (Cobb et al. 2003) which is, by definition, is the case for emerging educational technologies.

Innovation Stages of Emerging Technologies

The spiral above was developed by Nesta (2016) to capture the different stages of the innovation process, and it can be used to identify different innovation stages of emerging technologies. As argued by Nesta (2016), different stages of innovation would require different types of evidence. For instance, initial stages of exploring opportunities and challenges, as well as generating ideas, it would be beneficial to focus on literature reviews and design principles, identifying what has worked or failed in the past in different contexts and using this evidence in the design decisions made for the emerging technologies. These design principles and lessons can help both developers and users of emerging educational technologies follow strategies that are more likely to have an impact. During the developing and testing stage, rapid cycle evaluations that would generate anecdotal and descriptive evidence would be beneficial, whereas at making the case stage it would be beneficial to

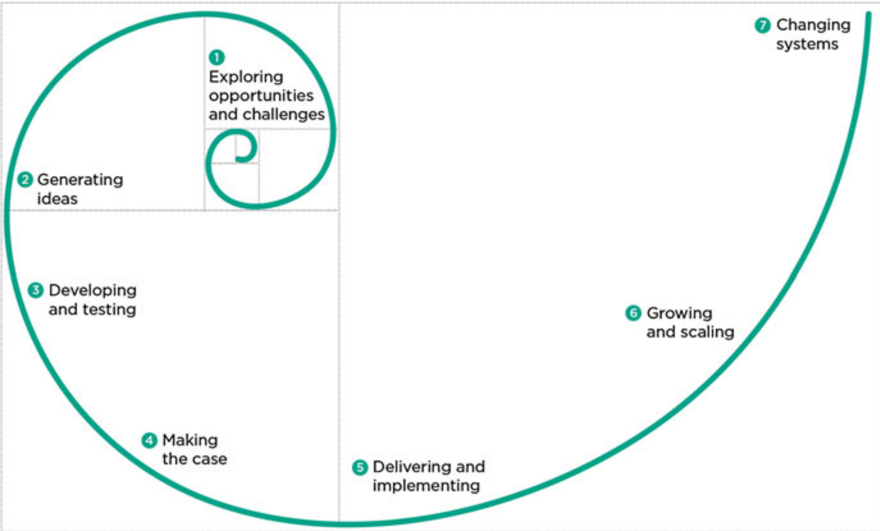


Fig. 2 Innovation cycle as presented in Using Research Evidence: A Practical Guide (2016)

undertake impact evaluations that would generate some correlational evidence. Once an emerging technology reaches certain level of maturation through these stages, during the delivery and implementation stage, it would require causal evidence that would show causal impact. On the other hand, growing, scaling, and spreading stage would require bigger scale experimental evaluations. System-level change can only be provided through multiple big scale evaluations from various contexts and clear implementation manuals that would ensure impact in multiple places. It is interesting to note here that by the time an emerging technology reaches to system changing level, or even the growing and scaling level, it would have reached a certain level of maturation so much so that its emerging nature would be questioned (Fig. 2).

The approach put forward by Nesta considers evidence in a holistic manner and recognizes the value of different types of evidence at different stages of emerging technology innovation. It contrasts with the more traditional approach of considering evidence types in a hierarchical manner, in which causal research evidence is considered as "gold standard" and other types of evidence are undervalued. We argue for the synergy of evidence types and research methodologies to generate different types of evidence during impact measures of emerging technologies. This position is based on the view that kite-marking a certain technology as "effective" based on "gold standard" causal evidence and encouraging its scaling might be a futile approach for emerging technologies. As mentioned in the introduction to this chapter, emerging technologies are constantly evolving and being implemented in different contexts with different populations. Therefore, the value of previous experimental evaluations for an emerging technology is limited. In addition to this, meaningful big scale positivist evaluations of emerging technologies are expensive and they take a long time to be completed. There are various research methodologies that can produce *valuable indicators of the potential impact*, and they should be encouraged before encouraging researchers, emerging technology companies and users for such big scale evaluations.

Conclusions

Emerging technologies have a vitally important role to play in any change management in education. Emerging technologies can also disrupt and bring about unexpected change, the consequences of which must then be managed. Either way, the evaluation of these emerging technologies is a key part of the way in which their impacts are effectively integrated into learning and teaching settings to bring the best benefit to learners and teachers. Artificial Intelligence technologies for use in education are a good example of an emerging technology that will inevitably bring change. Educators, learners, parents, and policymakers alike, therefore, need reliable methodologies for evaluating the effectiveness of such emerging technologies.

Discussions about the impact of emerging educational technology should focus on the suitability of the proposed evaluation methods, and it should focus on the types of evidence rather than on the hierarchy of these methods and evidence types. Different impact evaluations have different purposes. It is therefore important to recognize that any research design and methods can only meet the requirements of a subset of the possible evaluation purposes. We, therefore, argue for an approach that focusses on the identification of the specific research questions that are appropriate for the educational issues that are relevant to the context of the intervention to be evaluated. Finding the right research method to generate the right type of evidence is of crucial importance. Impact evaluations of emerging technologies should be considered as a process, rather than as a one-off case if we are to progress to a more productive way forward in evidence-informed educational technology discussions.

In this chapter, we have introduced an approach that can be adopted as one potential process of measuring the impact of emerging technologies in education. Our approach has two main steps. First one is the creation of a clear theory of change to identify outcome measures and assumptions that are behind the expected impact of the emerging technology intervention. Second is the identification of the type of evidence and methods to generate it that are the most appropriate for the current innovation stage of the emerging technology. We argue that the more traditional approach of generating causal evidence through empirical research studies and argue for the "effectiveness" of an intervention in order to scale it might not be a productive approach for emerging technologies. Rather we suggest that during impact evaluations of emerging technologies all types of evidence both generated from intervention trials, case studies, and existing literature should be leveraged at different innovation stages of emerging technologies.

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Looking Back, Moving Forward: Impact and Measurability of the Use of Educational Technology

79

Norbert Pachler and Keith Turvey

Contents

Abstract

In this chapter, we carry out a critical review of the various historical analyses of the impact of technological interventions in education. The purpose is to analytically explore and learn from some of the methodological limitations and strengths of the approaches adopted to measure and capture the impact of educational technology. This retrospective examination is then used to explicate methodological design principles that can increase the use and value of research evidence regarding the impact of educational technology. Capturing and

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understanding the impact of digital technologies in and on learning is inherently problematic. It is exacerbated by the continually developing nature of digital technologies and their formal and informal boundary crossing. We posit methodological design principles that are sympathetic to the fact that evidence of the pedagogical application of digital technologies is both borne out of, and brought to bear in, complex and dynamic contexts that are mediated by, and impact upon, the various ways in which technologies are appropriated for educational purpose. The chapter concludes with a call for methodological perspectives that are not confined by paradigm, but are able to bridge and integrate research paradigms in order to respond to the complex sociocultural ecologies within which digital technologies are implicated.

Keywords
Educational technology · Impact · Methodological innovation · Design principles

Introduction

This chapter presents the case for a nuanced and qualitative understanding of the impact of digital technologies on learning; that is, an understanding that complements but also recognizes the limitations of the quantitative turn seen globally with the proliferation of large datasets or quantitative meta-analyses of education interventions.

The concepts of measurability and impact are inherently problematic in education. This is exacerbated when focusing on technology-supported learning, due to the continually developing nature of digital technologies and their crossing of boundaries between formal and informal contexts (Voogt and Knezek 2008; Cox 2013; ► Chap. 74, "Researching Information Technology in Education: Meeting the Challenges of an Ever-Changing Environment"). It is necessary to frame any discussion of impact and its measurability, in a way that enables us to learn from critical debate surrounding methods and what they do or do not afford. Otherwise, we simply run the risk of being confined by methodological paradigms and learn little of any consequence. Conceptualizing impact merely as a post hoc concept or measure of "what works" is problematic. Impact in the field of education, we contest, is not an abstract or singular entity that can be isolated from context and adequately measured post hoc; rather impact is borne out of constituent action(s) carried out by sentient agents with and without technologies in a sociocultural ecology of factors, giving rise to pedagogical and methodological tensions and opportunities (Turvey and Pachler 2016). Even in the realm of physical matter and materials, designers and engineers work with tolerances because of the range of variable factors at play in any context. There is merit in looking back historically at methods for measuring impact in technology supported learning with a concern for how we design contingencies for future desirable impact, in new and emerging contexts.

With these concerns in mind, we structure the first half of this chapter around a retrospective critical examination of some of the various historical analyses of the impact of technological interventions in education. Our concern is to look back in order to move forward in terms of what we can learn from the methodological approaches adopted, their limitations, and their innovations. We acknowledge that we are unable to offer a fully comprehensive review of the literature but a pragmatic and valid starting point. In the second half of the chapter, we identify four methodological design principles based on key lessons from the evidence of impact and methodological approaches taken. Our concern here is to examine emergent research paradigms in the field of technology-supported learning and what methodological design principles can be identified to improve the reliability and validity of the data and evidence for sustainable innovation in the field of educational technology. Again, we acknowledge that this will fall short of a comprehensive review, but we believe a genealogical approach focusing on some of the methodological innovations, enables this chapter to make a valid contribution to the debate, and knowledge surrounding the issues of measurability and impact where digital technologies are used to mediate learning.

Looking Back

Defining Terms and Parameters

At the outset of this diachronic review, it seems necessary to touch briefly on definitional matters. In the literature, many terms are used, often interchangeably, to discuss technology use in educational contexts such as, among others, IT, ICT, new technologies, digital technologies, and educational technology. To underscore our interest in learning, we use the term "educational technology" here and its definition by the Association for Educational Communications and Technology (AECT):

> "Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources." (Januszewski and Molena 2008, p. 1)

Another important precursor to evaluating the impact of educational technology and the quality and findings of related research is to clarify the purposes of underlying work in the field. Pachler (2009, p. 2) argues that a discussion about the appropriateness of research methods needs to take into account the specific aims, objectives, and questions posed by individual researchers and research projects. He references Kjeldskov and Graham (2003) who delineate the following research purposes for the field of human-computer interaction: understanding, engineering, reengineering, evaluating and describing. Judgments, therefore, about specific pieces of educational technology research arguably need to be made in terms of the appropriacy of the chosen methods relative to the underlying epistemological and ontological framing, the intended aims, and objectives as well as research questions. This is in line with advice given in a recent paper by Twining et al. (2017) who set out to address the problem of the imbalance in the number of quantitative and qualitative papers published by highly ranked journals. They deduce a set of guidelines for the design, implementation, and reporting of qualitative research. Their paper includes the recommendation to be clear about the theoretical stance underpinning the research, and to ensure it aligns across methodology, design, methods, instruments, data, and analysis.

In contextual terms, it is important to bear in mind when examining the available research that a key policy driver behind the integration of technology over recent decades has been the perceived need to compete at a system level internationally in the wake of the increasing importance of global comparisons such as PISA. As a result, research in the field is often judged in terms of its ability to inform policy decisions.

The focus on efficacy, i.e., impact, in turn, is very much a result of the growing importance of accountability and financial exigency in education. It also reflects the significance of spending normally associated with and required for technology-supported educational interventions at an organizational (class, school) or system (local authority/district, state/national) level. And, in the wider policy arena, recent decades have seen an increasing emphasis on evidence-informed decision making which, in turn, can arguably be seen to have led to persistent educational reform programs. These have often included technology-supported interventions and innovations.

Identifying the Gaps

The use and efficacy of educational technology research has been a topic of considerable interest to researchers for some decades and, consequently, a large number of studies have been published in the field. As Cox and Marshall (2007, p. 59) note, despite the efforts of generations of researchers from a range of perspectives, several questions about the long- and short-term impact of technology on students' learning remain and unambiguous answers are elusive. An important omission from existing studies can be seen to be "major policy analyses that encompass a wide range of settings and look for commonalities and differences as a result of systemic conditions" (ibid, p. 60).

Particularly important findings from education technology research arguably are that very specific uses of ICT have the most impact on attainment (Cox and Abbott 2004) and that teachers' knowledge about their subject and of pupils' understanding of the subject influence the effect of educational technology on attainment (Cox et al. 2004); this has clear implications for generalizability of research findings:

"The effect on attainment is greatest when pupils are challenged to think and to question their own understanding, either through pupils using topic-focused software on their own or in pairs, or through a whole-class presentation." (p. 3).

Thus, it is of particular concern that many research papers in the field appear to lack a clear description of how teachers and/or students are using technology as well as valid and reliable measures of their use of technology for teaching and learning. As Bebell et al. (2007) point out, measuring the use of technology by teachers has become increasingly difficult in view of the growing complexity and dispersal of technology (p. 4) and much research limits itself to focusing on technology access as a proxy (p. 3).

Bebell et al. (2007) report a widely held view among researchers and others that much of educational technology research is methodologically weak. Weaknesses, according to them (p. 2), include limitations in the way technology use is measured with poor alignment between prior achievement and control groups, and paper-based assessment with insufficient sensitivity to detect changes in learning. These weaknesses are also compounded by a failure to account for hierarchical structures of schools that “mediate the relationship between technology use and achievement” (p. 13).

Reeves and Oh (2016) provide a more recent overview of goals and methods of educational technology research. They categorize the goals of educational technology research as follows: theory development/synthesis, exploratory/hypothesis testing, descriptive/interpretivist, critical/postmodern, design/development, and action/evaluation (p. 2).

In their review of available research, Cox and Marshall (2007) draw attention to considerable difficulties with assessment and evaluation tools owing to their rootedness in particular educational paradigms, ones that “usually fail to examine the cognitive processes which students employ to reach their goals” (p. 61) with instruments and evaluation processes which often have only a poor match with the inherent goals of the technology-supported interventions they are used to measure. They go on to identify the following five problems with educational technology research (pp. 62–68) which, they argue, need to be addressed in order to provide robust and reliable research results:

- A failure to understand how learners think
- A problem with identifying actual types of educational technology use contributing to learning gains
- A lack of knowledge about the kinds of curriculum implementation and classroom settings that are most influential
- The variability in teachers’ knowledge and pedagogical use of educational technology
- A lack of match of learning objectives and the learning outcomes being measured

Jenkins (2009, p. 274) posits that educational technology research often fails to provide significant insights into how students interact with the learning tools and how new knowledge has developed through the use of technology. She highlights the gap between knowledge and understanding as being significant, for knowledge is “more readily captured with traditional methods of evaluation” whereas, “understanding, given its emergent nature, is more elusive” (p. 276).

Among other areas, Kirkwood and Price (2014) identify difficulties in attributing causality and the types of evidence gathered. They note, and rightly in our view, that whilst quantitative measures of student interaction might be comparatively easy to collect, they do not necessarily contribute a lot to our understanding of how participation in collaborative processes can promote qualitative developments in learning (p. 24). Kirkwood and Price also make the point that technology-based interventions often necessitate, or are accompanied by substantial curricular changes and that it is often not clear what led to improvements and/or gains made.

Latchem (2014, p. 9) draws his readers' attention to the fact that educational technology research tends to be carried out by individuals or small groups working in isolation and that work in the field would benefit from multisite, multiperspective, cyclical collaboration into a larger number of similar interventions at different stages of development across different sectors. He recommends the development of indicators that are designed to capture the immediate, short- to medium-term, and longer-term positive improvements in the learning and lives of those involved (p. 9).

In their review of educational technology research, Ross et al. (2010, p. 18) conclude that because of the significant diversity of approaches to educational technology research, it is very difficult to offer "even a characterization of the field today" and they note the importance of a wide range of research approaches including:

- Highly controlled basic research studies of cognitive processes relating to the interaction with computers
- Descriptive and evaluative studies of how learners use educational technologies as tools
- Context-specific design-based studies focusing on how particular technologies operate in particular environments
- Applied research focusing on solving specific problems

Aggregation, Opportunities, and Limitations

In order to critically evaluate a large body of research evidence, meta-analyses and systematic reviews have become popular in educational, social science, and medical research. This also applies to the field of educational technology. While different methodological approaches to such reviews exist, they tend to share the purpose of combining the results of comparable studies and improve the power of small or inconclusive studies. According to Pérez-Sanagustín et al. (2017), meta-analyses can bring together insights from a wide range of settings and help "identify gaps in current research and formulate a research agenda that poses new ideas and directions for future investigation in the field" (p. A2). They cannot, however, improve the limitations of original studies such as a lack of quality of original reporting.

Examples of recent meta-analyses and literature reviews in the field of educational technology research include:

- Higgins et al. (2012), who conclude that "taken together, the correlational and experimental evidence does not offer a convincing case for the general impact of digital technology on learning outcomes" (p. 3);

- ICF Consulting (2015), who come to the view that there is conclusive evidence that educational technology can support attainment in general and in math and science in particular; that there is indicative evidence that it can support attainment in literacy and that it can close the attainment gap between groups; and that there is promising evidence that educational technology can provide assistance to overcome challenges faced by some learners, employability skills, and knowledge of career pathways, improved communications with parents and time efficiencies for teachers (pp. 3–4);
- Kirkwood and Price (2014), who identify several desired enhancements to learning and teaching in higher education through technology: operational improvement (increase in flexibility and accessibility), quantitative change in learning (increased engagement and attainment), and qualitative change in learning (promotion of reflection, deeper engagement, and richer understanding) (p. 14);
- Livingstone (2012), who offers up three forms of critique of the claims made in support of educational technology: an "analytic critique," which requires a skeptical analysis of claims made as a result of which she concludes that the "jury is still out" on whether educational technology supports learning; an "explanatory critique" which asks about competing theories and alternative explanations; and an "ideology critique" exploring technology in relation to the societal configurations in which they exist (pp. 20–21).

A recent report published by the OECD in 2015 provides an international comparative analysis of digital skills acquired by students. It concludes that there is a lag between the promise and reality of technology in schools and that "their impact on student performance is mixed at best" (p. 3). This by-and-large reflects the findings of an earlier review by Luckin et al. (2012) who found that often the impact identified is relatively modest in scale and that the focus tends to be on how educational technology supports existing practices rather than on transforming them (p. 9). While Luckin et al. conclude that "much existing teaching practice may well not benefit greatly from new technologies" (p. 64), they also claim to have found proof that educational technology can work, i.e., that different technologies can improve learning by augmenting and connecting proven learning activities, by putting learning first (p. 63).

The key gaps in the literature identified by Pérez-Sanagustín et al. (2017, p. A12) are:

- A preponderance of quantitative research
- A lack of research from different parts of the world
- A gap with regards research from the humanities, natural, and "formal" sciences
- A lack of preschool studies
- Studies which lack a focus on teachers' pedagogical actions with limited value
- Only few studies involving participants in their design
- A need to increase sample sizes in research with objectivist approaches
- A lack of private sector funded studies

The field has also seen the publication of a second-order meta-analysis by Tamim et al. (2011), which provides an overview of 37 of 60 or so meta-analyses published since 1980 capturing some 1050 primary studies out of a total of 1250 or so primary studies covered by meta-analyses with nearly 110,000 participants. It helpfully sets out the codebook developed for the study covering inter alia information about the identification of studies, contextual, methodological, and analysis features. This data is important to ensure transparency and comparability.

Theoretical Positioning

In addition to exploring the efficacy of research methodology, an important antecedent of determining the impact of educational technology is how learning is defined and what the purpose of education is. Depending on one's conceptualization of learning, different uses and affordances of technology will come to the fore which are susceptible to different types of measurements and instruments. A focus on basic skills and the recall of content, for example, can normally be measured fairly efficiently through standardized tests to determine attainment gains linked to educational technology. If, however, learning is viewed more in line with Kalantzis and Cope (2004, p. 46), as conditions of belonging and transformation, i.e., engaging the learner's identity and taking them on a "journey into the unfamiliar," or with Kirschner (2006, p. 11) as interaction-based and dialogic, standardized tests become problematical as measures of attainment gain linked to technology use.

In her critical reflections on the literature, Livingstone (2012), for example, references the work of Turkle (1995, p. 35) who characterizes the modernist to postmodernist transformations brought about by the emergence of the internet, which she characterizes as a shift "from a culture of calculation" to a "culture of simulation based on tinkering and experimentation," much less concerned with hierarchical structures or rules (p. Livingstone 2012, p. 17). In such a paradigm, different ways of measuring learning gain are required.

One strand of educational technology research has focused on barriers to and enablers of the integration of technology into formal education. In their overview of related research, Hew and Brush (2007, p. 241) identify the relationship and interaction between what Ertmer et al. (1999) have called first-order (lack of resources, institution, subject culture, assessment) and second-order (attitudes and beliefs, knowledge, and skills) barriers.

Shortcomings in teacher preparation and development, and teachers' pedagogic beliefs and knowledge, are issues identified by several studies as an important barrier in effective technology uptake, as are integration strategies.

Scardamalia (2006) outlines three areas where technology can be seen to have the potential to contribute to depth of understanding: computer-assisted instruction; simulations, games, and laboratory instruments; and discourse.

With the emergence of mobile technologies, learning environments characterized by one-to-one computing and bring-your-own-device (BOYD) have increasingly become the focus of research. Alas, often the same limitations apply to these emerging research fields that we diagnosed for traditional educational technology research: they tend to be undertheorized, i.e., do not tend to build on explicit or sufficiently robust conceptualizations of key concepts such as clear definitions of learning and learning gain; are small-scale, short-term, one-off and “piecemeal” rather than large-scale, longitudinal, and cumulative; are qualitative rather than mixed mode or quantitative; are descriptive or exploratory rather than correlational, quasi-experimental, or randomized mixed-mode; are over-reliant on self-reported perceptual data; and are often characterized by weak documentation of research methodology (see e.g., Hew and Brush 2007, p. 246).

Ross et al. (2010, p. 24) stress the importance of educational technology research achieving a balance between rigor, what they call “internal validity,” and relevance, what they call “external validity” in order to be able to help tackle “real-world” educational problems. Internal validity, they argue, enables the drawing of valid conclusions about the causal effects of one variable on another and external validity enables the generalization of results to conditions of interest. They further suggest that randomized controlled trials can maximize internal validity but can be liable to low external validity (p. 25).

A number of studies appear to point toward the dependency of efficacy of educational technology on its integration in teaching programs. In order to understand the most effective way of designing new teaching programs utilizing educational technology, Bai et al. (2016), for example, carried out a clustered randomized controlled trial. According to Sibbald and Roland (1998), randomized controlled trials are the most rigorous way of establishing cause and effect between an intervention and its outcome as well as its cost effectiveness. One key advantage can be the reduction in selection bias by random allocation to treatment or control group of participants once subjects have been checked against eligibility criteria for participation.

Crook et al. (2010, pp. 7–8) identify two broad forms of impact research: relatively short-term studies focusing on particular educational technology supported practices in a rather unsystematic way which they call “contained interventions”; and “system-wide’” interventions, which focus on large-scale adoption of educational technology. Both, they argue, are characterized by methodological and interpretative challenges and can lead to unjustified skepticism about the value of investment in educational technology. Given the complexity of sites of teaching and learning, Crook et al. argue for a broadening of the definition of impact and related research that yields a better understanding of learning practice and outcomes. To achieve this, they call for “research that documents the reported experience of integrating technology into ongoing practices of teaching and learning, as they are pursued at the classroom level” but also within the broader ecology of educational practice as even “piecemeal approaches disturb the larger ecology of teaching, not just the ecology of individual lessons” (p. 8).

The impact of educational technology is predicated on increasingly sophisticated technology being integrated into complex education systems and ecologies as well as the perpetual obsolescence of technologies making replication studies difficult. The growth in personal ownership of devices adds further complexity and leads to a diffusion of the technological infrastructure involved in many research projects. In turn, this impacts on the locus of control with an increase in user agency and use in informal contexts governed by different social and cultural practices than that of formal education settings and a decrease in influence on the research context by the researcher (see e.g., Pachler 2009, p. 3; Pachler et al. 2010). Therefore, research and evaluation models are required that reflect this complexity. This can involve the recasting of the role of learners into coresearchers. Technology can be seen to "disappear" more and more by virtue of its integration and by being embedded further and less visibly into our physical and social world (Bruce and Hogan 1998). Consequently, what is needed, we argue, are approaches to educational technology research that capture the complexity of technology-based interventions at a micro (classroom, program), meso (institutional), and macro (system) level from multiple perspectives rather than a dogmatic application of particular research designs. Jenkinson (2009), for example, argues the case for design-based research to capture the "messy" elements of technology interacting with the educational endeavor, because of the collaboration between researchers and practitioners it affords.

Recognizing the increasing complexity of technology use in educational contexts, in part as a result of technological transformations and the increasing affordances of educational technologies, VasabØ and Gudmundsdottir (2014, p. 2) problematize how best to research networked learning within multifaceted technology environments. They ask what research designs to use, how to interact with the key stakeholders, how to capture and understand interaction between contexts and across different dimensions, and how meaning is made in and across physical places and virtual spaces. Their questions, coupled with Crook et al.'s (2010) analysis and the shortcomings we have identified above, point toward the need for a paradigm shift in educational technology research to which we turn now.

Moving Forward

To identify the character of such a paradigm shift, we consider four research design principles that could help shape this shift and increase the efficacy of research attempting to measure the impact of educational technology. The principles we outline here are by no means extensive but we believe what is most important is that they are rooted firmly in the methodological lessons emerging from past educational technology research and motivated by the need for a progressive framing of sustainability in educational technology research. As Bachmair and Pachler (2015, p. 1) argue, there is a need for both pedagogical and methodological practices associated with educational technology to establish the "ability to maintain innovation over time and to become embedded into mainstream practice." This can only come from methods that offer the potential for increased understanding of the appropriation of digital technologies in the lives of both students and teachers across formal and informal boundaries. We also enter the caveat that although these design principles are numbered and discussed linearly in what follows, they are interrelated as our discussion of such will reveal. The following methodological design principles could, we believe, act as a catalyst for sustainable methodological innovation that progresses the field of educational technology research. We express these principles thus:

1. Methodological and pedagogical interoperability should be prioritized, which means a call for far-sighted innovation that resists becoming confined by methodological or pedagogical paradigms.
2. The quantitative should be qualified, as far as possible.
3. Post hoc analysis should be accompanied by concurrent description and analysis.
4. Impact needs to be both defined broadly and also theorized rigorously, to understand and document the complex social cultural ecology into which educational technology is integrated.

We briefly outline these principles in more detail below.

Interoperability

We define interoperability as the ability of one methodological or pedagogical design or system to make use of another through, for example, the exchange of data or methods and can be seen to be inherent in meta-analyses which aggregate and synthesize data across various studies. But how might this be achieved across qualitative studies or between quantitative and qualitative research? Without such interoperability, it is impossible to envisage how educational technology innovation could be built upon and sustained. This is not to reject either positivist or interpretivist paradigms but to concur with others who call for methodological innovation in educational technology research (Jenkinson 2009; Crook and Garratt 2011; Cox 2013; Latchem 2014; Kirschner and Kester 2016). Indeed, Crook and Garratt (2011, p. 215) argue that critical reflection about methods, the ethical engagement with participants, and the significance of context can all be seen to emerge from the legacy of positivism, as can the conception of context as a "social ecology rather than a structure of causal relations that is more rigidly mechanical." Such concerns and problems of methodological design are not confined by paradigm so why should the data or analysis that is generated be confined and how do we render such data and analysis open to reuse? There are, of course, no simple answers to such questions, but it is important to imagine and begin to design methodologies that are genuinely more complementary in the way they bridge established research paradigms to promote efficacy. As Kirschner and Kester argue (2016, p. 538), methodology should be free of "dogmas that split the world into quantitative, empirical positivists versus qualitative anecdotal ethnographers."

In imagining more complementary and sustaining research methodologies whose methods, outputs, and outcomes lend themselves to greater levels of interoperability, our second design principle is invoked. There is a need for increased qualitative detail in datasets. Our retrospective review above found that methodological innovation is a necessary factor in being able to measure with increasing validity, reliability and granularity, the impact that technology can have on learner outcomes. It also highlights that increased granularity in measuring impact often comes from a richer understanding of the qualitative conditions of the context. Such a view, we contest, necessitates the development of methodologies with greater granularity across the increasingly leaky formal and informal boundaries that educational technologies encompass.

Qualifying the Quantitative

There is an urgent need to qualify the quantitative if we are to design research methodologies that genuinely deepen our understanding of the complexities of learning with and through digital technologies. By "qualify" we mean to offer rich or sufficient qualitative contextual detail. Meta-analyses (see also ▶ Chap. 75, "Meta-analyses of Large Scale Datasets: A Tool for Assessing the Impact of Information and Communication Technology in Education" by Liao and Lai) of the impact of various educational interventions, including those incorporating educational technologies, have gained favor with policy makers in recent years. They conveniently lend themselves to the relatively simple reporting of impact in the popular media and are also compatible with the global econometrics used to measure and make crude comparisons of the performance of international education systems. But what do they measure? (UNESCO 2014; OECD 2015). The key issues with meta-analyses and the experimental studies they synthesize, we argue, is a tendency to view their results and findings at face value and a failure, tendentiously, in the experimental research studies they synthesize to adequately qualify the quantitative effect sizes they produce. Higgins et al.'s meta-analysis of educational technology interventions (Higgins et al. 2012) found that the introduction of digital technologies on average can offer "moderate learning gains" of approximately 4 months progress. Hattie (2009), using comparable methods estimates a similar potential effect size on average. But, the actual effect sizes of the different studies that Higgins et al. (2012) synthesized in their meta-analysis, vary significantly. Useful though these are, the only firm conclusion to be drawn is that digital technology can have positive, negative, or indeed little to no impact on attainment and learning. Similarly, Haßler et al.'s (2015) meta-analysis focusing on the use of tablet devices in schools highlights the significant problem of redundant findings or data when there is a failure to qualify the quantitative. Out of 23 studies, Haßler et al. (2015) found 16 reported positive learning outcomes, five no difference, and two negative learning outcomes. The authors make the important point that much of the research included in their review did not go beyond face value, stating that "a large proportion of identified research offers limited or no details of the activities that learners engaged in," making it difficult to identify important contextual detail necessary in recognizing more or less effective use of the technology (Haßler et al. 2015, p. 151).

While there is increased availability and access to large quantitative data sets, singular or paradigmatically-confined approaches leave significant questions unanswered such as: how have people learned or not learned with the technology? And: are there significant characteristics of pedagogical design shared by those interventions where educational technology has had a negative, positive, or no effect on learning? Similarly, how has the formal and wider informal context influenced this? One strand of the ImpaCT2 study (Somekh et al. 2002) complemented the quantitative analysis of the impact of educational technology through a rich picture of contextual detail using visual methods to capture important qualitative information pertaining to pupils' use of ICT in the home and broader community. This illustrates how questions of context and pedagogical design can only be addressed by invoking our third design principle that post hoc analysis should be accompanied by methods that also facilitate concurrent description and analysis.

Post Hoc and Concurrent Analysis

By concurrent analysis, we mean the analysis of data are as close as possible to the source of any educational technology-based intervention. Concurrent data affords greater insight and lends itself to reuse and further methodological innovation or analysis. Jenkinson (2009, p. 277) argues strongly that to answer questions about the numerous contextual and agent-centred variables influencing the impact of educational technology, there is a need for "quantitative and qualitative data sets that tightly integrate concurrent and retrospective" data-capture and analysis. The recent systematic review we referred to in the first half of this chapter (Pérez-Sanagustín et al. 2017, p. 12) claims studies that ignore what teachers do "are unlikely to be of much value." We fully concur with this view but would extend this to include as full a range of contextual and agent-centred variables as possible such as, inter alia: dispositions toward educational technologies and learning, prior experience with the technology both formal and informal, how learners experience or perceive educational technology, and the subject in which it is being used. The more contextual and concurrent data (quantitative or qualitative) available, the more we can learn about the use of educational technology. This is particularly evident when comparing studies with greater and less scope.

For example, an area where limited methodological approaches are sometimes seen, is in some of the research into the use of mobile phones in schools. Beland and Murphy's (2015) research on mobile phone use in schools simply analyzed, post hoc, the correlation between schools who banned or allowed the use of mobile phones (gathered via a headteacher survey) and data from the National Pupil Database (UK) on examination performance. The only thing of potential significance from this is that impact appeared to vary according to the students' different and current levels of attainment. That is, the use of mobile phones in school appeared to have no positive or negative impact on higher attaining children but was negatively correlated with lower attaining children. The concurrent variable in this limited study allowed some small yet potentially significant insight to emerge with regards different student characteristics as a moderating variable. But the research tells us very little beyond this about the use of mobile devices as educational technology.

Contrast this with another recent meta-analysis (Chauhan 2017), which attempted to offer greater insight into the various correlations between the impact on learning outcomes and educational technology by differentiating a greater range of concurrent moderating variables. Chauhan synthesized a number of international experimental studies (N = 122) via moderating variables such as subject domain, type of digital application, duration of the intervention, and learning environments. Identifying such concurrent moderating variables can support increased contextual granularity. For example, differentiating by subject domain, highlighted greater effect sizes reported for digital technology supported interventions in Science, suggesting subject cultures can also influence the impact of educational technology, although it should also be noted that there is a dearth of experimental research in the use of educational technology in subjects such as music and art. This still does not offer insights into the actual pedagogical designs and contexts in which Science teachers incorporated digital technologies across these studies. While the use of concurrent moderating variables offers the potential for greater granularity, it also raises questions regarding potentially significant concurrent variables not captured, such as teacher knowledge and pedagogical design, learner dispositions, and socioeconomic characteristics or wider contextual influences. It would seem prudent for future studies to develop an agreed standard in terms of what concurrent moderating variables (quantitative and qualitative) should be included as a minimum expectation in educational technology research. Such agreement could lead to the increased power of both statistical and qualitative meta-analyses as a more "robust and reliable taxonomy of the relationship between different ICT resources, teachers' pedagogies, and students' learning' (Cox and Marshall 2007, p. 68). But there is also a risk here that we make assumptions, which is why we invoke our fourth design principle that impact needs to be both defined broadly and also theorized rigorously, to understand and document the complex social cultural ecology into which educational technology is integrated.

Broadly Defined but Rigorously Theorized

The principle of embracing a broadly defined yet rigorously theorized conception of impact may seem paradoxical but, we argue, it is prudent to assume that as well as not knowing what we should know after decades of research (Cox and Marshall 2007), the constantly changing nature of educational technology means we also cannot assume we know what we do not know. Those at the forefront of appropriating educational technology formally into practice have valuable insights to contribute in this respect and participatory methodologies such as narrative approaches (Pachler and Daly 2009; Turvey 2012) and learning design (Laurillard 2012; Persico and Pozzi 2015; see also ▶ Chap. 38, "Teaching as a Design Science: Teachers Building, Testing, and Sharing Pedagogic Ideas" by Laurillard) are significant. As various studies have shown, the teacher is the most significant variable in the appropriation of educational technology (Harrison et al. 2002; Cox et al. 2004; Somekh 2007). From this perspective, design-based research methods such as those encompassed by the field of learning design are an important area of methodological innovation that can facilitate a bottom-up approach to measuring impact that, if rigorously theorized, can enable a greater understanding of the sociocultural ecology of educational technology. As Laurillard asserts (Laurillard 2012, p. 226), the pace of change and the potential impact of digital technologies more broadly not only enable the treatment of teaching "as a design science, they also require it."

Persico and Pozzi (2015, p. 244) claim that learning design "addresses the decision-making process of individual teachers." Furthermore, innovations in learning design have attempted to synthesize the gap between quantitative and qualitative data by drawing on the ease of availability of online data (e.g., learning analytics) when learners engage in online platforms. The ease and speed with which such data can be available, combined with the computational processing power that can be used to provide teachers with data representations to inform their pedagogical designs, to some extent addresses our concern expressed in the third design principle regarding the bridging of post hoc and concurrent data analysis. Similarly, Mor et al. (2015, p. 221) encapsulate these design principles further in their defining of the focus of learning design which they claim is concerned primarily with "understanding how the intuitive processes undertaken by teachers and trainers can be made visible, shared, exposed to scrutiny" and improved further. That is, there is a concern with the micro and meso-level detail (qualitative and quantitative) influencing teachers' actions and motivations involving educational technology, as well as improving the visibility, and therefore the reusability and interoperability of pedagogical processes.

However, promising as such approaches are, Persico and Pozzi's (2015) note there is still the potential for misunderstanding with regards the use of educational technologies and pedagogical approaches. As they state, learning design research must guard against "producing a plethora of different representations, approaches and tools that are not interoperable" (Persico and Pozzi 2015, p. 245). While there is a need to broadly define impact, there is also a need for progressive focusing from the subjective toward a more objective shared understanding of the different kinds of impact that may emerge and how those more desirable impacts may be reseeded through appropriate and reusable pedagogical designs. This, we argue, can only come through understanding and articulating the various subjectivities involved as practitioners appropriate educational technology, a process that is facilitated significantly through dialogue and narrative. Narrative analysis, in particular, can support an inductive and iterative process that enables participants "to achieve a certain degree of consensual interpretation" (Pachler et al. 2009, p. 81).

The fields of learning design and narrative methodologies lend themselves to the rigorous scrutiny and theorizing of the impact of pedagogical practice with educational technology in ways that other methodological approaches often omit. In their paper on sustainability and innovation in mobile learning, Bachmair and Pachler (2015, p. 5) state that there is a need for "relevant knowledge about the practices of mobile learning" and that "we cannot succeed without objectified tools and operational implementation procedures." Such knowledge and procedures cannot emerge from research designs that ignore or omit the need for carefully scrutinized and theorized pedagogical intervention and as Bachmair and Pachler (2015) go on to establish, hermeneutical research approaches that foreground intentional pedagogical intervention and professional dialogue have a significant role to play in addressing this issue.

It is beyond the scope of this chapter to give an in-depth review of learning design and narrative research methodologies other than to highlight the potential for innovation they offer. But this brief discussion also illustrates that the four design principles we have outlined are common concerns across various research paradigms. The challenge moving forward is how to shift out of the relative comfort zones that have been established in educational technology research in order to establish a more innovative and sustainable approach to impact and measurability in educational technology research.

Conclusion

The Programme for International Student Assessment (PISA) remains a globally influential dataset that lends itself predominantly to quantitative post hoc research analysis. Pérez-Sanagustín et al. (2017, p. 12) call for a need to "redress the balance between quantitative and qualitative research" as their systematic review of educational technology found only 55 out of 352 studies drew on qualitative methods over a period of 4 years. This rebalancing is an important step but we also ask: would such a rebalancing necessarily draw us out of our respective paradigmatic comfort zones, to achieve further sustainable methodological and pedagogical innovation? We argue that, together with redressing this balance, there is a need for further integration of paradigms and of quantitative and qualitative research designs. The latest cross-country analysis (OECD 2015) of the purported impact of digital technologies on students' learning outcomes highlights further this need to qualify the quantitative through greater integration and innovation. It illustrates how face-value approaches to measuring impact that employ only post hoc instruments to find correlations or associations between technology take-up and school performance indicators simply raise more questions than they answer, without more detailed levels of granularity that complementary and concurrent qualitative data could afford. We concur with Alexander (2015) who questions this tendency to equate such measurable yet narrow proxies as attainment in education as the ultimate and only indicators of quality. Quantitative studies themselves illustrate that student characteristics and dispositions toward digital technologies, as well as teachers' pedagogical decisions and motivations about digital technologies could well be the basis for the significant variability in their findings. But, such qualitative factors are not adequately captured or accounted for in many of the research approaches. Intervention, context, and impact **is**, we argue, too often conceived as a simplistic mechanical causal structure rather than a sociocultural ecology. Contemporary design-based approaches to research in this field are attempting to address the problem of measurability and impact of educational technology. Drawing out principles of design, based on a genuine attempt to learn the lessons of past educational technology research is, we believe, a useful and sustainable way forward for further innovation in research methodology.

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Section XIII

International Policies on Information and Communication Technology in Primary and Secondary Schools: Cross-National Policies

Section Introduction: International Policies on Information and Communication Technology in Primary and Secondary Schools

80

Birgit Eickelmann

Abstract

As an introduction to the section on "International Policies on ICT in Primary and Secondary Schools" an overview over the aims and content of the section is provided.

Keywords

ICT policies · Primary and secondary schools · International perspective · Section overview ICT policy section

The digitalization of practically all spheres of life has entailed significant developments on a global scale. In view of their responsibility to prepare students for what is commonly referred to as the digital age, educational systems have taken on a key role in imparting digital competencies and in using ICT for learning on future generations (Edwards 2012). In this respect, research revolves around the potential of technological developments to change or improve learning processes and support students' competencies to ensure the students' participation in a digitalized society. While the former aspect refers to the technological potential as well as to the meaningful integration of digital media into scenarios of teaching and learning, the latter addresses overarching concepts such as equity and successful participation. All

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these issues are relevant for research as well as for policies towards ICT integration into schools, curricula, and school systems (Vanderlinde et al. 2012). While there is a broad range of knowledge on schools and on which factors contribute to adapting schools to the affordances of changes in the digital society, comparably little is known about the developments of educational systems and how it is affected by policies (Ball et al. 2012). Closing this research gap, the following section on "*International Policies on IT in Primary and Secondary Schools*" elaborates on this. The section pursues the section *"International and Regional Programs and Policies"* by Jef Moonen (2008) which is to be found in the first edition of the international handbook. Again, now in the scope of the second edition of the handbook, the following section brings together recent developments regarding ICT policies and how they affect teaching and learning with technology in schools from all parts of the world. The section consists of seven chapters. It describes and analyses the current state of research as well as developments concerning ICT policies in primary and secondary schools. By doing so, all chapters of the section refer to a set of core questions aiming to get an up-to-date impression of recent developments and results. Consequently, each chapter answers the following set of questions from the perspective of one of the seven regions in the world: How does policy deal with integrating ICT in teaching and learning in primary and secondary education and which trends as well as developments can be identified most recently? Which overall policy plans, strategies, and papers exist and what is characteristic of and common in policy documents of international organizations about IT and education? How useful and effective are these and in which range can one identify indications that certain policy measures are more successful than others? Which aspects can facilitate success and sustainability? All chapters close with an outlook on future developments and challenges.

The regions that are covered in the book are: Australia and New Zealand, Asia, Europe, Latin America and the Caribbean, North America, North Africa and the Middle East, and Sub-Saharan Africa.

In view of the multiplicity of educational systems around the world, it is not surprising that educational policies, in this case with regards to ICT, globally show a great degree of variation. This section therefore aims to provide an overview of features and characteristics the experts in the respective regions have figures out. The efforts made in the section were only possible through the work and contributions of the authors of the individual chapters which put together recent developments of ICT policies in their regions and present them in a systematic and most informative way.

One overall result of the section on ICT policies around the world is that cross-national as well as world-wide strategies and plans for different regions of the world influence national or regional strategies on integrating ICT into schools in different ways. In addition to the manifold national policies and initiatives, cross-national and world-wide strategies for the implementation and promotion of ICT and ICT-related skills equally have an effect on the perspectives on how and ways in which digital media are integrated into educational curricula.

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Cross-National Policies on Information and Communication Technology in Primary and Secondary Schools: An International Perspective

Birgit Eickelmann

Contents

Abstract

The use of ICT in primary and secondary education has gone through a number of different phases over the last decades. Alongside rapid technological developments and changes in pedagogical paradigms, ICT policies have proven to be one of the main driving forces behind the implementation of ICT in education settings. The following chapter examines the relevance of such policies, plans, and frameworks from an international perspective, focusing thereby on the primary and secondary school sectors. In doing so, it provides valuable insights into international ICT policies. Aiming to provide a holistic view, it presents analyses of cross-national international policies as well as cross-national policies

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in different parts of the world. Given the multiplicity of education systems around the world, education policies regarding ICT vary considerably. Nonetheless, the analysis of cross-national studies uncovers a number of common core topics, directions, challenges, and potential future directions for ICT policies in primary and secondary schools. This compilation and examination of findings from international studies and their implications for ICT policies in turn reveal and reinforce the need for research-based and research-informed policies and strategies. The chapter concludes by collating the different lines of reasoning and developments and deducing potential directions for the development of powerful and responsible policies toward the use of ICT and its implementation in schools and school systems.

Keywords
ICT policy · Current developments on ICT in education · Future challenges · National and international plans

Introduction

In view of their responsibility to prepare students for what is commonly referred to as the digital age, education systems have assumed a key role in imparting digital competencies to future generations. The core questions in this respect revolve around the potential of technological developments to change and improve students' learning processes and outcomes, thereby ensuring their participation in a digitalized society. While the former concerns both the technological potential and the meaningful integration of ICT into teaching and learning scenarios, the latter addresses overarching aims of education and education policies such as equity and successful participation in all areas of society. Education policies on the use and implementation of ICT in schools and school systems play a crucial role in this context. In contrast to the other chapters in this section, this chapter does not look at such ICT policies in specific regions of the world. Instead, it aims to provide a more holistic view on the scope and topic of ICT policies for schools and school systems by adopting an international perspective. In so doing, the first part of the chapter endeavors to characterize ICT policies by defining categories to describe and analyze them. The second part elaborates and discusses the role of ICT policies formulated by international organizations. Commonalities in ICT policies in different parts of the world are outlined in the third part of the chapter, which also elaborates on the key challenges addressed or to be addressed in ICT policies. Findings from international initiatives and studies on ICT in schools and the implications drawn for ICT policies bring research and policies together in the fourth part. The chapter concludes by emphasizing the key role that ICT policies play as drivers for educational change and pointing to the responsibility that education stakeholders and researchers have to improve primary and secondary education in the digital age.

Characterizing Educational Policies Toward ICT in Primary and Secondary Schools

Education policies focus on overarching decision and planning strategies as well as on setting goals for education systems. Ideally, they forge a bridge between education plans and practice, shed light on the necessity for change, and provide both the solutions and the means for meeting and overcoming current or future needs in education. Analyses of education policy look both at how it has evolved and how it has been implemented and evaluated (OECD 2017). Comparisons of education policies in individual countries have to review corresponding trends and actions on the student level, e.g., in terms of student outcomes (especially equity and quality), preparation for the future, evaluation and assessment, or the quality of improvements to schools. They also have to look at such trends on the system level, e.g., how education systems are organized in terms of governance and funding to deliver education policy (ibid.). When it comes to policies on the use of ICT in primary and secondary education, Moonen (2008) points to the potential impact of ICT-related evolution on education policy. Seen from this perspective, ICT policies aim to improve and optimize the impact of the use of technologies in schools at regional, national, and international level. Moreover, it is assumed that they take the socioeconomic, educational, and cultural context of their respective education system(s) into account (Kozma 2011; Roumell and Salajan 2016), an aspect that affects their substantive and strategic impact: "The diversity of the technological, pedagogical, and cultural situation in a region has, most probably, a profound impact on what kinds of policies can be possible" (Moonen 2008, p. 1077).

A look at ICT policies for primary and secondary education from a global and meta perspective reveals that education policies in general – and in particular those that address the use and implementation of ICT – are characterized by a number of different aspects:

1. *Target group*: Policies can be characterized by their target group, i.e., the group or actors in education and education systems that they deal with or to whom they refer. Education policies for ICT in schools most commonly relate to students' learning culture and the organizational culture of schools (Ball et al. 2012). In order to have an effect on such cultures, policies may target education decision-makers, teachers, or school principals. They may also provide recommendations for curriculum development and thus function themselves as addressees (Vanderlinde et al. 2012).
2. *Authorship*: Policies can likewise be characterized by their authors and their corresponding background and philosophy. The different roles and formal positions of these authors (e.g., political stakeholders, political bodies, or nonprofit organizations) in the education system determine how a policy is aligned to the content of policy plans and how ideas, concepts, and aims are rationalized.
3. *Obligation*: The degree of liability and obligation characterizes the placement of the policy.

4. *Understanding of teaching and learning*: In the case of ICT policies, the way in which teaching and learning with ICT are understood differs and therefore constitutes a central characteristic of policies.
5. *Geographical scope*: Similarly, the geographical scope and radius of the policies or corresponding strategies can have an impact on their implementation.
6. *Timeframe*: The designated timeframe is likewise important for the success and sustainability of ICT policies. Defining this timeframe can be more challenging than it might seem: policymakers work in legislatures, and longer-term ICT policies require ideas that disregard technological developments. Although developing such ideas is a challenge, the resulting policies do appear to have greater potential to be sustainable. Technology-based policies tend to be more concrete and incorporate current or upcoming technological developments, which can be advantageous, especially when they meet the need of pedagogical ideas.
7. *Means*: Last but not least, the means needed to support the realization of education policy concepts and plans, e.g., support for schools, teacher professional development, and funding, can form part of ICT policies (and indeed should if they aim to be successful). Indeed, policies based on education programs in which resources are aligned with policy intentions seem to be more successful (Cohen and Hill 2001).

All in all, characterizing ICT policies by identifying their particular mind-set can help to understand and analyze them. However, the different characterizing aspects are not always documented (or at least evident) in all policy concepts and frameworks to integrate ICT into primary and secondary education. This has two main implications for their potential effectiveness. First, gaining a sound understanding of the concepts and the reasoning behind them remains a challenge, which in turn makes them difficult to realize as intended. Second, the lack of clarity regarding the different characteristics can diminish acceptance and purview by pedagogical actors, both of which are crucial aspects if education policies are to have an impact and induce change. Policies are deemed to have failed to have an impact in the classroom when they have no explicit links to teaching practice and teachers are unable to recognize their implications for teaching (Cohen and Hill 2001).

In light of the above, it can be concluded that all of the aforementioned aspects have to form part of (and be addressed by) an ICT policy if it is to be successful, forward looking, and productive. This assigns a high level of responsibility for education systems and societies as a whole to those who are in charge of developing ICT policies for school systems around the world. With such policies, policymakers fulfill the need to ensure alignment between the development of ICT in society, its integration into schools, and its use in teaching (UNESCO 2011a).

ICT Policies Provided by International Organizations

Responsibility and the sharing of expertise in formulating ICT policies for education and school systems are often assumed by international or regional organizations. Cross-national policies are important for providing social opportunities, e.g., by facilitating social participation, prosperity, and social cohesion. This is especially relevant in the case of ICT policies, whose function is to provide general orientation in a world that is becoming more and more complex. Cross-national policies support countries and regions in the development of national or regional policies and thus enable the development of specific cross-national ICT policies (Moonen 2008). The actual purview of such policies depends not only on the core ideas contained therein but also on their legal range. Since most countries are members of international or at least regional organizations (e.g., UNESCO or the OECD), multinational plans are developed to cover interests that extend beyond a single country or region. In this regard, global institutions and organizations such as the World Bank (cf., e.g., Trucano 2016) or UNESCO have long shown their commitment to exploring the potential of digital technologies for student and teacher education alike, e.g., in terms of the opportunities they afford for e-learning or professional development. UNESCO, for example, already began developing ICT policies at a very early stage. Indeed, one of its core current papers describes a competency framework for teachers (UNESCO 2011b). The paper updates the 2008 UNESCO document on teacher standards and is aimed at "helping countries to develop comprehensive national teacher ICT competency policies and standards, and should be seen as an important component of an overall ICT in Education Master Plan" (ibid, p. 1). It contains a description of the rationales and overarching aims of the policy, statements regarding its understanding of ICT in education (e.g., the link between education and economic growth), and a clear and differentiated modular competence framework with indications for its practical application by different groups (e.g., school principals). The paper shows some of the typical characteristics of cross-national papers: it demonstrates expertise, elaborates on research findings and pedagogical experience, sets out concrete ways for implementation, but is non-binding, i.e., does not establish any obligation. Although the latter is not the aim of such a paper, this lack of obligation clearly restricts its implementation into education practice. As far as the categorization system for ICT policy papers (see above) is concerned, the paper refers (at least briefly) to all aspects apart from timeframe (aspect 6).

The analysis of education policies of the seven regions included in this section of the handbook (Australia and New Zealand, Asia, Europe, Latin America and the Caribbean, North America, North Africa and the Middle East, and Sub-Saharan Africa) mirrors the role that this and other cross-national policies play and how they have been transferred into practice – or at least how their ideas have been included in regional or national policy papers.

Commonalities and Challenges of Cross-National Regional ICT Policies in Primary and Secondary Education

Given the multiplicity of education systems around the world, it is not surprising that education policies, in this case with regard to ICT, also vary greatly. Although there appears to be a common understanding of the potential of ICT for learning, its use can still differ to some extent in pedagogical practice in line with the conditions and needs of an individual region or country. Against this background, the following part of this chapter offers an overview of the main developments in this context in the abovementioned seven regions. In so doing, it considers recent developments in ICT and ICT policies, the relevance of cross-national strategies for individual regions, as well as the corresponding challenges and prospects. Elaborating on the insights and findings in the regional chapters in this section, the analysis contrasts developments and identifies core cross-national and cross-regional developments.

The contributions from the different regions indicate various recent developments and initiatives in ICT policies and implementation. One such development is the recognition and acceptance of the need for and benefits of a national ICT integration plan. While such plans and policies do, of course, differ in terms of their content, goals, and obligatory nature, the common thread that runs through them is an aim to reach all students within their education systems and enable all young people to participate in the digital age.

In Europe, for instance, many countries have already developed their own guidelines and projects. These include the "National Plan for the Digital School" in Italy, the "Digital Literacy Green Paper" in Malta, the "Lehrplan 21" ["Curriculum 21"] curriculum in the German-speaking cantons of Switzerland, the "Fit 21" program in Austria, or the nationwide "Bildung in der digitalen Welt" ["Education in the Digital World"] strategy in Germany (cf. ▶ Chap. 87, "Information and Communication Technology Policy in Primary and Secondary Education in Europe" by Ottestad and Gudmundsdottir). Such strategy papers either pursue the aims of rectifying lower than anticipated performance, e.g., in ICILS 2013 (Germany), improving resource availability (Denmark), and focusing on newly emerging competencies such as computational thinking (Czech Republic, Finland) or simply emphasize the importance of ICT for personalized learning (Estonia).

ICT has also been incorporated into national curricula in other regions of the world, where the strong economies in particular have set objectives for specific periods of time (ranging from a few years to over a decade). In Asia, for instance, Malaysia introduced the "Education Blueprint 2013–2025" to promote Internet access and support special needs, Singapore published its third "ICT Master Plan" (covering the period 2009–2014) to develop both collaborative and self-directed learning, and Thailand's second "ICT Master Plan" (2009–2013) aims to improve thinking and problem-solving skills through ICT, as does the fourth phase of South Korea's "ICT in Education Master Plan" (cf. ▶ Chap. 82, "Information and Communication Technology in Educational Policies in the Asian Region" by Yuen et al.). Taiwan's 10-year infrastructure program, which was introduced in the 1990s, now includes digital literacy as an official curriculum component, demonstrating a trend to incorporate ICT into teaching and learning processes. This trend is likewise evident both in China's three 5-year plans to enhance its ICT infrastructure and integrate ICT into school curricula as well as in Japan's "Knowledge Construction with Technology 2010" initiative to transform didactic teaching styles with ICT. India's "CLASS" studies and "ICT@Schools 2004" project view the decade from 2010 to 2020 as a period of innovation. Hong Kong has already moved beyond the ideal of integrating ICT into teaching and learning that was promoted in its third "IT in Education Strategy" (2008–2013); its fourth strategy now focuses on the promotion of computational thinking (in analogy to the developments observed in other countries around the world).

In the Middle East and North Africa region, Kuwaiti and Jordanian approaches to ICT policy incorporate related skills at all levels of education (e.g., "National ICT in Education Strategy," Kuwait, 2008), with both countries also taking their policies beyond the mere provision of indispensable infrastructure (▶ Chap. 86, "Information and Communication Technology and Educational Policies in Primary and Secondary Education in the Middle East and North African (MENA) Region" by Alayyar et al.). Jordan, as a role model for the Arab world for the implementation of digital media in the school curriculum, has developed a policy framework that is continuously updated to meet the requirements and challenges of the ever-evolving technological domain. Saudi Arabia, on the other hand, has adopted an approach that involves numerous annual ICT releases instead of a stand-alone ICT policy. Like their counterparts in Egypt, Saudi students only learn ICT skills in secondary school; such skills have not been made a priority in primary schools in these education systems. While the funds for purchasing the necessary infrastructure are available in Saudi Arabia, other countries have cut funding for technology in education. This is the case, for instance, in the USA, where the "Enhancing Education Through Technology (EETT)" initiative was dropped in favor of a modernized "E-rate" program that lays the foundations for digital learning in conjunction with the "National Educational Technology Plan."

While some countries enact these policies at national level, others make a clearer distinction between states, provinces, or territories. In Canada, education remains a matter for the individual provinces, despite current national initiatives for online instruction. The province of Alberta, for example, has adopted the "Alberta Learning and Technology Policy Framework," which specifies the following (and other) priorities: student-centered learning, research and innovation, professional learning, access, infrastructure, and digital learning environments (▶ Chap. 84, "Information and Communication Technology and Educational Policies in the United States of America and Canada" by Davis et al.).

Many countries in Latin America and the Caribbean have likewise initiated digital agendas, most notably Uruguay's "Plan Ceibal," which goes beyond equipping primary and secondary schools to also install computers in private homes (▶ Chap. 88, "Information and Communications Technology and Educational Policies in Latin America and the Caribbean" by Castillo-Valenzuela and Garrido Miranda). Other education systems in this region have paid particular attention in their ICT policies to the professional development of teachers, e.g., those in Argentina ("National Teacher Training Plan") or Brazil.

While South Africa has made the integration of ICT a priority at all levels of schooling, other countries only have formal recommendations in place, the success of which varies greatly. The highest variance in the establishment of ICT policies developed and realized by national plans can be found in Sub-Saharan Africa (▶ Chap. 85, "Information and Communication Technology and Educational Policies in the Sub-Saharan African Region" by Tilya). Although all countries in

Sub-Saharan Africa have policies to guide the provision of education, not all of them have a policy on ICT in education. Those that do place particular emphasis on improving the quality of subject teaching and learning. One conclusion to be drawn here is that the most basic requirements (like ICT equipment and electricity) cannot be taken for granted in some of the countries in this region, resulting in poor conditions for digital learning. Their approaches to ICT are likewise manifold: ICT is taught as a school subject in Tanzania and Madagascar (from secondary school level), Kenya has developed an "ICT Trust Fund" to provide schools with the necessary equipment, while the Seychelles and Botswana both have an "ICT Master Plan" and a "Revised National Policy on Education" that includes digital media. In contrast, Burkina Faso and other countries in the region do not even have any formal recommendations in place regarding ICT in education.

Beyond the cross-regional trend to develop national ICT policy plans – be it with reference to overarching plans or not – some core ICT policy topics are common to many or even all regions:

1. Developing ICT infrastructures that reflect pedagogical aims, especially the fostering of one-to-one and BYOD ("bring your own device") concepts, often in combination with personalized learning
2. Focusing on access, equity, and participation
3. Reaching all students and improving teacher training
4. Bridging and linking formal and informal learning
5. Integrating the aims of (subject-specific) learning with ICT with more general education goals such as creating a skilled workforce for the twenty-first century
6. Introducing new topics (e.g., computational thinking) and modernizing curricula
7. Pointing to new potentials such as those afforded by new forms of online learning and online assessment as well as to risks and more critical issues like data privacy

These overarching topics can be rationalized by the challenges that education regions face with regard to the integration of ICT in primary and secondary schools. Like the other aspects of ICT policies and strategies discussed above, the implementation challenges are manifold and differ across education systems. While countries in Sub-Saharan Africa lack the essential prerequisites of basic infrastructure, hardware, connectivity, and electricity, other regions face less substantial but nonetheless still complex challenges. In North Africa and the Arab countries, for instance, a major focus needs to be placed on the pedagogical integration of ICT into teaching and learning processes. This meaningful use of ICT, along with teachers' digital competences and professional development, will likewise need to be a focus for further progress in Europe, Asia, and Latin America. The closing of the digital divide, both on a national and an international level, appears to be a global challenge in ICT policy and integration. The assessment of Latin American concepts points to a particular lack of coordination between global, regional, and national ICT policies, which can at times be contradictory or misaligned. Further emphasis should also be placed on personalized learning (e.g., in Australia, New Zealand, the USA, Canada, and Latin America) as well as on the responsible use of ICT, including issues of cybersecurity (Asia) or privacy (the USA, Canada). The Asian contribution (▶ Chap. 82, "Information and Communication Technology in Educational Policies in the Asian Region" by Yuen et al.) also notes that a continuous measurement and evaluation of ICT literacy skills are imperative for improving student competencies and securing their participation in society. In contrast to the majority of the abovementioned education systems, Canada exhibits only minor issues in digital equity, while developments in the digital domain in Australia are largely "on track." The less-developed education systems do, however, still need to pay more attention in this respect, yet not be oblivious to the fact that digital technology – and consequently the potential that is linked with its integration into the education system – is an ever-evolving, dynamic domain that requires constant attention, development, and evaluation through ICT-related policies.

Research-Informed ICT Policies: The Role and Impact of International Research Initiatives and Studies

If we look back over the last decades, we can identify different driving forces behind the implementation of ICT in formal education. Alongside the more ambivalent discussion of economic interests, technological innovations (cf. Pereira and Pereira 2015), the potential for pedagogical change afforded by ICT, and the transition to an information and knowledge society (with its associated need for new forms of learning and new competencies) all call for a modernization of schools and school systems. Beyond political, social, and economic interests and aims, research findings provide evidence-based knowledge that supports the need for changes in education. The EduSummIT (International Summit on ICT in Education) initiative's 2013 working meeting focused, for example, on "research-informed strategies to address educational challenges in a digitally networked world" from an international perspective. It highlighted the relevance of basing ICT policy decisions on research findings and engaging in dialog with stakeholders and practitioners to interpret and turn these findings into pedagogical practice (Voogt et al. 2015). Two of the main findings were the need to identify what works (and what does not work) in the integration of ICT into education and to make research accessible to a broad range of stakeholders, thereby also improving the link between research and practice (EduSummIT 2013). Parallel to this, international studies have investigated ICT use in schools, hindering and supporting conditions in different levels of school and education systems and student achievement. The IEA's SITES 2006 (Second Information Technology in Education Study, module 2006) and ICILS (International Computer and Information Literacy Study) studies and some sub-areas of the PISA (Programme for International Student Assessment), PIRLS (Progress in International Reading Literacy Study), and TIMSS (Trends in International Mathematics and Science Study) studies have together established a huge international information base for ICT policies (e.g., Plomp et al. 2009). On an international level, ICILS and PISA both formulate recommendations for a future-orientated development of schools and school systems which can be understood as guidelines for policies on

ICT in schools (Fraillon et al. 2014; OECD 2015). More specifically, some of the recommendations of ICILS 2013 (▶ Chap. 6, "Students and Their Computer Literacy: Evidence and Curriculum Implications" by Ainley; see summary on pp. 24–25) point to the fact that the knowledge, skills, and understandings described in the Computer and Information Literacy (CIL) scale can and should be taught. Moreover, and regardless of whether young people are considered to be digital natives or not, the findings show that it would be naive to expect relevant ICT competencies to materialize without coherent learning programs. The study also concludes that policy planning should focus on increasing teacher expertise in ICT use. At school level, endeavors to implement supportive collaborative environments that incorporate institutional planning focused on using ICT and teaching CIL in schools should be supported. Some regions have also taken up the findings of the ICILS 2013 study on a cross-national level. They form the basis, for example, of the European Commission's ICT policy recommendations for EU member states (European Commission 2014). These recommendations, which include placing more emphasis on active teaching practices with ICT to equip teachers for effective pedagogical use of ICT, are directly addressed to policymakers. The commission also draws conclusions for its own future activities, e.g., follow-up work on a digital reference framework for learners and the development of a framework for educators (ibid).

While ICILS and PISA look at secondary schools, PIRLS and TIMSS address primary schools. Beyond their findings on reading achievement and primary school students' competences in mathematics and science, the most recent cycles of TIMSS (2015) and PIRLS (2016) provide an international comparison and assessment of ICT use. Classroom reading activities with ICT (e.g., reading online) vary from country to country within and across regions and are related to reading competence in different ways. This could be an interesting conclusion for policymakers and one that might move education systems into the digital age. On average, students read digital texts (19%), apply strategies for reading digital texts (13%), critique texts on the Internet (17%), look up information (25%), research a problem (19%), and write something (17%) in classrooms on a weekly basis (Mullis et al. 2017). Nonetheless, and despite the fact that such findings supply highly interesting insights into and a comparison of education systems, their pedagogical approaches, and efforts, few conclusions have so far been drawn with regard to their implications for future developments.

While these and many other findings of the abovementioned (and other) studies are of considerable interest for policy decisions to improve school systems around the globe, the link between research and policymaking, with a few notable exceptions (Bundsgaard 2016; Eickelmann 2016), remains largely untapped.

Conclusion: The Potential of ICT Policies to Move Education Systems into the Digital Age

The speed at which digitalization is currently affecting all spheres of life and work is still not reflected in how ICT is used in primary and secondary education. Although there are huge differences in how education systems around the world embrace the potential of ICT to improve student learning processes and achievement and how they can help to establish modern school systems that provide everyone with access to knowledge and education, ICT policies can nonetheless function as a catalyst for educational change (Kozma 2011). The challenges facing education systems vary in different continents, countries, or even regions within countries. Developing appropriate ICT policies is therefore extremely challenging. Nevertheless, such policies play a key role in making sustainable changes, thereby empowering young people to participate successfully and autonomously in the digital age. The contrast between the rapid pace of digitalization and the slow pace of development of sound and well-considered ICT policies for school systems will remain a dilemma that can only be resolved when policies include not only different types of technologies but also overarching education aims such as participation, equity, and twenty-first-century competences. In this context, the PISA study provides both an in-depth analysis of ICT-related topics and research-based knowledge for policymakers (e.g., OECD 2015). Indeed, the OECD (2015) referred to PISA 2012 findings when formulating its "implications for digital technology for education policy and practice." These call on policy and practice to invest in skills to promote equal opportunities in the digital world, to raise awareness of the possible harmful aspects of internet use, to develop coherent plans (including teacher training) for the use of ICT in the classroom, and to learn from past experience to improve the effectiveness of future investments in technology.

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Information and Communication Technology in Educational Policies in the Asian Region

82

Allan H. K. Yuen and Timothy K. F. Hew

Contents

Abstract

The chapter analyses the various policies towards ICT in primary and secondary education from the perspective of Asian region, where it is the world's most diverse region, and the most heterogeneous, especially for integrating and sustaining ICT across several domains, including education. Using the Knowledge Ladder framework, this chapter explores firstly the rationale for the development of ICT policies in Asia in terms of four types of education models. Over the past decade, we can observe that the development of ICT policies in Asia are mixed. In certain nations, e.g., Lao PDR and Vietnam, the policy priority areas of basic education focused on poverty alleviation, improving ICT use by teachers and improving training in ICT for students. In other nations such as Malaysia, Singapore, Thailand, Hong Kong, Taiwan, China, Japan, Korea and India the policy priority areas supported knowledge deepening, knowledge acquisition or knowledge creation. This chapter shows that recent ICT policies in the Asian

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region have placed more emphasis on the development of students than of teachers. Other stakeholders such as parents are also included in the ICT policies in some Asian countries. From recent empirical research, we noted three main challenges: closing the digital divide, promoting the safe and responsible use of ICT, and measuring and evaluating ICT literacy skills. Finally, we also provide emerging perspectives for the development of ICT in education in Asia, namely alignment of local and international goals, student engagement in learning alongside social and leisure activities, and the context of Asian culture.

Keywords
Asian region · Development of ICT policies · ICT in primary and secondary education · Knowledge Ladder framework

Introduction

National policies on information technology (IT) or information and communication technology (ICT) in education can serve several important functions. Strategic policies can provide a rationale, a set of goals, and a vision for how education systems can operate with the introduction of ICT and how students, teachers, parents, and the general population can benefit from its use in schools. These strategic policies can motivate, change, and coordinate disparate efforts to advance a nation's overall educational goals (Kozma 2008). For a sensible policy to improve the impact of ICT on education, Moonen (2008) suggested three main policy lines from a global perspective. First, basic knowledge and skills about ICT should become available in education. Depending on the level of development of a country, teaching ICT knowledge and skills, or supporting its daily use in schools, should be encouraged. Second, policy should support the creation and facilitation of informal teacher networks. Teachers should become equals with their pupils in terms of attitudes and skills toward ICT. Third, policy should facilitate the use of ICT for the new generation of pupils by maximizing Internet access, not only in schools but also in libraries, sport facilities, and homes.

What are the developments of ICT in education policies in the Asian region? Are they related to the policy lines as suggested by Moonen (2008)? This chapter seeks to review the developments of ICT in education policies in the Asian region by focusing on primary and secondary education. In general, there are three subregions: (1) Northeast Asia (China, Hong Kong, Mongolia, Japan, North Korea, the Republic of Korea, and Taiwan), (2) Southeast Asia (Indonesia, Myanmar (Burma), Thailand, Malaysia, Brunei, Singapore, Vietnam, Laos, East Timor, the Philippines, and Cambodia), and (3) South Asia (India, Pakistan, Nepal, Bhutan, Bangladesh, Sri Lanka, and the Maldives). Of course, this chapter cannot cover all of these countries, and instead explores selected countries from different subregions.

The International Telecommunication Union (ITU) ICT Development Index (IDI) is a unique benchmark of the level of ICT development in countries across the world. The IDI combines 11 indicators on ICT access, use, and skills, capturing key aspects

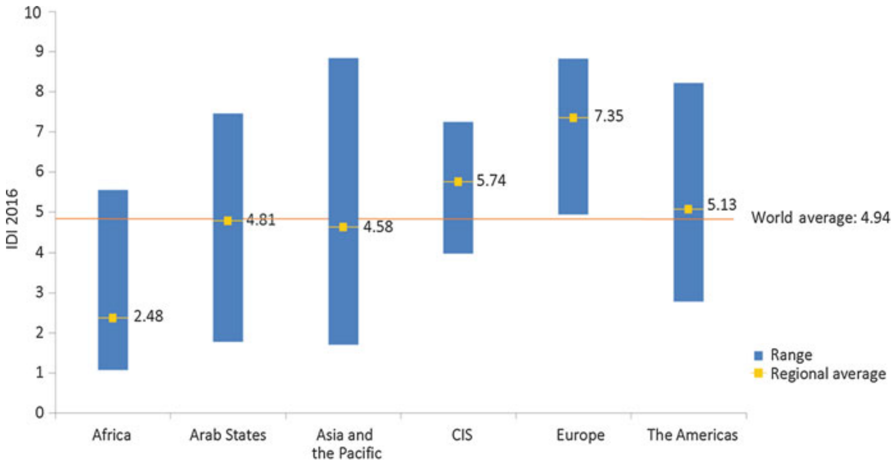

Fig. 1 IDI 2016 by region compared with global average (Source: ITU 2016, p. 44)

of ICT development in one measure that allows for comparisons across countries and over time (ITU 2016). IDI 2016, covering 175 economies worldwide and making comparisons to IDI 2015, highlights both progress and the persistent divides in the global information society. The 175 economies are grouped into 6 regions: Africa, Arab States, Asia and the Pacific, the Commonwealth of Independent States (CIS), Europe, and the Americas. The regional averages and ranges of IDI 2016 are presented in Fig. 1.

There has been greater improvement in the use of ICT than in its access. Nearly all countries improved their IDI values over the last year, but significant disparities persist between more- and less-connected countries. There is a strong association between economic development and ICT development, with the least developed countries at a particular disadvantage. The average IDI value rose by 0.20 points to 4.94 points (out of 10), with smaller increases at the top and at the bottom of the list. The gap between the highest- and lowest-performing countries – one measure of the digital divide – remained almost unchanged, at 7.76 points in IDI 2016. The Republic of Korea tops the IDI rankings in 2016 for the second consecutive year. The top 10 countries also include two other economies in the Asia-Pacific region and seven European countries (ITU 2016).

Table 1 presents the IDI rankings and values of 34 economies in the Asia-Pacific region. As this chapter does not refer to Australia and New Zealand, they are excluded in our discussion. The top 10 positions in the regional rankings for 2016 are almost identical to those for 2015, with China displacing Thailand in tenth place. The top seven economies in the region (among them the Republic of Korea, as the global top performer, Hong Kong, Japan, Singapore, and Macao) have IDI values above 7.5 and occupy the highest quartile of the IDI rankings. They are all high-income economies that have maintained high IDI performance ever since the first publication of the Index. These findings for the Asia-Pacific region reveal a greater

Table 1 IDI rankings and values, Asia and Pacific region, 2016 and 2015

Economy	Regional rank 2016	Global rank 2016	IDI 2016	Global rank 2015	IDI 2015	Global rank change 2016–2015
Republic of Korea	1	1	8.84	1	8.78	0
Hong Kong, China	2	6	8.46	7	8.4	1
Japan	3	10	8.37	11	8.28	1
New Zealand	4	13	8.29	16	8.05	3
Australia	5	14	8.19	12	8.18	−2
Singapore	6	20	7.95	19	7.88	−1
Macao, China	7	28	7.58	26	7.47	−2
Malaysia	8	61	6.22	66	5.64	5
Brunei Darussalam	9	77	5.33	74	5.25	−3
China	10	81	5.19	84	4.8	3
Thailand	11	82	5.18	79	5.05	−3
Maldives	12	86	5.04	88	4.68	2
Iran (IR)	13	89	4.99	90	4.66	1
Mongolia	14	90	4.95	93	4.54	3
Fiji	15	102	4.41	102	4.16	0
Vietnam	16	105	4.29	104	4.02	−1
Philippines	17	107	4.28	106	3.97	−1
Tonga	18	114	3.93	114	3.63	0
Indonesia	19	115	3.86	115	3.63	0
Sri Lanka	20	116	3.77	116	3.56	0
Bhutan	21	117	3.74	122	3.12	5
Cambodia	22	125	3.12	127	2.78	2
Vanuatu	23	127	3.08	131	2.73	4
Timor-Leste	24	128	3.05	125	2.92	−3
Samoa	25	130	2.95	128	2.78	−2
India	26	138	2.69	135	2.5	−3
Myanmar	27	140	2.54	153	1.95	13
Nepal	28	142	2.5	142	2.32	0
Lao PDR	29	144	2.45	144	2.21	0
Bangladesh	30	145	2.35	143	2.27	−2
Pakistan	31	146	2.35	145	2.15	−1
Kiribati	32	152	2.06	147	2.07	−5
Solomon Islands	33	153	2.04	150	1.99	−3
Afghanistan	34	164	1.73	162	1.62	−2
Average			4.58		4.35	

Source: ITU (2016, p. 56)

improvement in IDI values among middle-ranking countries than among countries in the top and bottom quartiles, suggesting that the Asia-Pacific region may be witnessing a reduction in the digital divide between developed countries and the majority of developing countries, alongside a worsening divide between the majority of developing countries and the least connected countries (ITU 2016).

In terms of ICT development, the Asian region is the world's most diverse region (IDI ranging from 1.73 to 8.84) and by contrast the most heterogeneous (ITU 2016). Especially for integrating and sustaining ICT across several domains, including education, the Asian region also exhibits significant economic disparity (UNESCO-UIS 2014). Thus, due to such differences and variations, it is a challenge to provide appropriate coverage, fair framing, and complete discussion of ICT in education policies in the Asian region.

Recent Developments on ICT in Asia

This section attempts to highlight the recent developments of ICT in education for some Asian countries as depicted in two comparative studies conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). In the late 1990s, the IEA decided to conduct the Second Information Technology in Education Study (SITES), which is an international comparative research program exploring the use of ICT in education. SITES 2006 was the third module in this program, and its aim was to provide a comprehensive understanding of how teachers teach, both generally and in situations when ICT is used, as well as how school- and system-level factors affect teachers' pedagogical adoption of ICT. A total of 22 countries were involved in SITES 2006, which included 5 Asian economies, namely, Japan, Taiwan, Singapore, Hong Kong, and Thailand (Law et al. 2008).

Most of the participating countries reported that the 5 years preceding SITES 2006 had seen an increase in the following pedagogies in their education systems: inquiry-based learning, individualized learning, collaborative projects, interschool collaboration, and international collaboration projects. The following discussion focuses on findings about school practices and conditions for pedagogy and ICT (Pelgrum 2008).

The trend analyses regarding the presence of lifelong learning practices as perceived by school principals suggest that the most noteworthy change between the SITES assessments of 1998 and 2006 was the increase in pedagogical practices involving information handling (searching for information, processing data, and presenting information). The results showed that the lifelong learning indicator was quite high in many systems, although there was variation across countries. Noteworthy are the relatively high scores of Chile (3.66) and Thailand (3.56) versus the relatively low scores of South Africa (3.31), Hong Kong (3.29), and Japan (3.28). In contrast, Singapore scored 3.52 and Taiwan scored 3.45 (Pelgrum 2008).

The results showed that although principals were promoting all three visions (traditional, lifelong learning, and connectedness), they tended to give less support to connectedness than to the other two factors. School leaders generally underscored the importance of using ICT with pedagogical approaches for lifelong learning. In some systems, school leaders seemed, for example, relatively inactive in terms of trying to influence the pedagogical practices of their teachers, while in other systems they tended to be much more active. ICT was recognized as a catalyst for change by a substantial number of school principals in some systems (e.g., Chile, Taiwan, Israel, Lithuania, Slovenia, and Thailand), but this was not the case in other systems (Catalonia, Finland, and Japan). In Asian economies, the percentages of school principals who recognized ICT as a catalyst for change were as follows: Thailand 77%, Taiwan 47%, Singapore 44%, Hong Kong 23%, and Japan 16%.

For staff development, in most participating education systems, hardly any, or only a minority, of the schools required teachers to be trained in areas involving new pedagogy and ICT. The availability of courses also differed substantially across education systems. Courses on pedagogical issues related to integrating ICT into teaching and learning were available in more than three-quarters of the schools in Taiwan, Denmark, Estonia, Hong Kong, Lithuania, Moscow, Singapore, and Slovenia. However, there were also quite a few education systems (Alberta, Chile, Finland, Israel, Italy, Japan, France, Norway, South Africa, and Thailand) where sizeable numbers of schools did not seem to have access to such courses.

In SITES 2006, school principals were asked to indicate the possible actions they had undertaken to address the issues relating to change management. Principals in most countries said they had set up security measures, allowed students to use school computers outside of school hours, limited game playing, and specified skills that students were expected to acquire. Measures restricting the number of hours that students could use computers appeared to be most prevalent in the Russian Federation and Thailand, but such measures were of little consequence in Denmark and Hong Kong. Many schools in Taiwan, Hong Kong, and Singapore took measures to provide laptops for teachers. For most Hong Kong schools, this was also the case with regard to students. Taiwan, Moscow, Norway, and Thailand implemented incentive schemes to encourage teachers to use ICT in their lessons, but Finland, Japan, and Slovenia rarely did so. Many schools in Hong Kong included parents in ICT-related activities, but France and Japan appeared disinclined to do so.

The International Computer and Information Literacy Study (ICILS) studied the extent to which young people have developed computer and information literacy (CIL) to support their capacity to participate in the digital age. CIL is defined as "an individual's ability to use computers to investigate, create, and communicate to participate effectively at home, at school, in the workplace, and in society" (Fraillon et al. 2013, p. 17). ICILS also addresses the necessity for policymakers and education systems to gain a better understanding of the contexts and outcomes of CIL-related education programs in their countries. As an IEA international comparative study, the main ICILS 2013 took place in the 21 participating countries between February and December 2013. Only three Asian economies participated in ICILS 2013, namely, Hong Kong, the Republic of Korea, and Thailand.

Table 2 A summary of CIL results of Asian economies participating in ICILS 2013

Country	Average CIL score (standard errors)	IDI 2012 (country rank)	Student-computer ratios (standard errors)
Republic of Korea	536 (2.7)	8.57 (1)	20 (2.3)
Thailand	373 (4.7)	3.54 (95)	14 (0.9)
Hong Kong	509 (7.4)	7.92 (10)	8 (0.8)

Source: Fraillon et al. (2014, p. 96)

The following discussion focuses on some major findings of ICILS 2013 (Fraillon et al. 2014).

The CIL construct combines information literacy, critical thinking, technical skills, and communication skills as applied across a range of contexts and purposes. The variations in CIL proficiency (with the average CIL score ranging from 361 to 553) show that while some of the young people participating in ICILS were independent and critical users of ICT, there were many who were not. As the volume of computer-based information available to young people continues to increase, so too will the responsibility of societies to critically evaluate the credibility and value of that information. Table 2 presents the CIL averages, IDI rankings, and student-computer ratios of three Asian economies participating in ICILS 2013. It is worth noting that the achievement of the Republic of Korea is significantly higher than the ICILS 2013 average (500), whereas the achievement of Thailand is significantly lower than the average. As Hong Kong did not meet the sample requirements, no comparison was made.

Evolving technologies (such as social media and mobile technologies) are increasing the ability of young people to communicate with one another and to publish information to a worldwide audience in real time. This facility obliges individuals to consider what is ethically appropriate and to determine how to maximize the communicative efficacy of information products. Students were asked to report their performance of various activities at least once a week. Across the ICILS countries, one activity stood out from the others in terms of weekly use, namely, "communicating with others using messaging or social networks." The cross-national average for this activity was 75%. Student percentages in several countries exceeded the ICILS 2013 average by more than 10 such points. These were Norway (89%), Poland (88%), the Slovak Republic (87%), and the Czech Republic (86%). Those countries where the respective percentage was more than 10 percentage points below the ICILS 2013 average were Korea (42%), Thailand (49%), and Turkey (56%). Hong Kong was 60%. Also, all three Asian economies were lower than the average.

When responding to the ICILS student questionnaire, students indicated how well they thought they could perform each of 13 computer-based tasks. The difficulty of the tasks ranged from "search for and find information you need on the internet" to "create a computer program or macro." For the Asian economies, the national percentages of student confidence in performing the more difficult tasks were

Table 3 Internet access at home and CIL scores

Country	Students with internet access at home		Students without internet access at home	
	Percentages (standard errors)	Average CIL score (standard errors)	Percentages (standard errors)	Average CIL score (standard errors)
Republic of Korea	98 (0.3)	538 (2.6)	2 (0.3)	444 (14.5)
Thailand	57 (1.5)	400 (5.4)	43 (1.5)	339 (5.5)
Hong Kong	99 (0.2)	511 (7.4)	1 (0.2)	#

Source: Fraillon et al. (2014, p. 117)
Subgroup sample size too small for reporting reliable estimate

below the ICILS 2013 average in general. To some extent, this observation raises a concern about Asian students as digital natives with a self-developed capacity to use digital technology.

Even though we can discern within the ICILS findings high levels of access to ICT and high levels of use of these technologies by students in and outside school (especially at home), we need to remain aware of the variations in CIL proficiency within and across the ICILS countries. Table 3 presents the percentages of students with/without Internet access at home and CIL scores of Asian economies. Obviously, there is a lower percentage of Thai students with Internet access at home.

Teachers' ICT use was greatest when the teachers were confident in their expertise and were working in schools that collaborated on ICT use (and that had few resource limitations). These were also the conditions that supported teachers' ability to teach CIL. For professional development activities, the most common form of participation involved observing other teachers using ICT. On average across the ICILS countries, 46% of teachers reported this type of participation. The countries whose teachers most frequently reported observing their colleagues' use of ICT were Lithuania (60%), Australia (57%), and the Republic of Korea (57%). In contrast, there were lower scores for Thailand (53%) and Hong Kong (41%).

Recent Developments on Policies on ICT in Asia

Over the decade from 2006 to 2016, there have been major developments regarding ICT policies in Asian countries. What drove these ICT policies? To understand the rationale for the development of ICT policies in Asia across this time frame, we draw upon Kozma's *Knowledge Ladder* conceptual framework consisting of four types of education models: basic education, knowledge acquisition, knowledge deepening, and knowledge creation (UNESCO 2011).

In the *basic education* model, the curriculum focuses primarily on basic numeracy and literacy skills with minimum use of ICT. If available, access to the Internet is used for administrative support, access to online content, and professional development resources for teachers. In the *knowledge acquisition* model, the curriculum emphasizes a large number of facts and concepts within the school subject areas. ICT is used mainly to deliver instruction. In the *knowledge deepening* model, the curriculum stresses the understanding of key concepts within and across different subjects and their application to solve real-world problems. ICT is used to support collaborative projects and connect students and teachers outside normal school hours. Simulations and multimedia materials are used to support understanding of interrelated concepts, explore systems, and solve problems. In the *knowledge creation* model, the curriculum is responsive to student goals and contexts. It focuses on learning, inquiry, and the skills involving in creative and critical thinking. ICT is used to support knowledge sharing by students and teachers.

Over the past decade, we can observe that the development of ICT policies in Asia has been mixed. In certain nations (e.g., Lao PDR, Vietnam), the policy priority areas of basic education centered on poverty alleviation, improving ICT use by teachers and improving training in ICT for students. In other nations such as Malaysia, Singapore, Thailand, Hong Kong, Taiwan, China, Japan, the Republic of Korea, and India, the policy priority areas supported knowledge deepening, knowledge acquisition, or knowledge creation. We briefly describe the policies of these nine countries as follows.

Malaysia has an Education Blueprint 2013–2025 ICT policy, formulated by the Ministry of Education and the Multimedia Development Corporation (Malaysia Ministry of Education 2013). This Education Blueprint focuses on three priority areas: providing Internet access and virtual learning environment, augmenting online content, and maximizing the use of ICT for distance and self-paced learning. ICT is used to deliver instruction (knowledge acquisition) such as with EduWeb TV that provided 497 videos covering seven subjects for primary schools and 13 subjects for secondary schools. ICT was also used to support student understanding of interconnected concepts in STEM (Science, Technology, Engineering, and Mathematics) through robot-assisted secondary school programs. In Wave 2 (2016–2020) of the Education Blueprint, the Ministry of Education will focus on helping groups with specific needs such as under-enrolled schools, rural schools, and gifted students (Malaysia Ministry of Education 2013). The Ministry also aims to lower the student-to-computer ratios to a maximum of 10:1.

In Singapore, the country's third ICT Master Plan (MP3), implemented between 2009 and 2014, aimed to use ICT to develop students' proficiencies for collaborative and self-directed learning. MP3 was also designed to upgrade ICT infrastructure to support learning anytime and anywhere (Teo and Ting 2010). With MP3, bandwidth in schools was increased to 1GBPS, and 1-notebook-to-1-pupil schemes were implemented in more schools. Most recently, Singapore launched its fourth Masterplan for ICT in education (MP4) which aims to broaden the focus beyond self-directed and collaborative learning to develop knowledge (Educational Technology Division 2010–2015).

In Thailand, one of the key aims of the second ICT Masterplan from 2009 to 2013 was using ICT as a tool to improve student skills in thinking and problem-solving in conjunction with curriculum reform (UNESCO 2013). The Masterplan also aimed to promote online communities for the sharing of student knowledge (knowledge creation) and develop ICT hardware, software, and assistive technologies to help students with disabilities.

In Hong Kong, the Third IT in education strategy “Right Technology at the Right Time for the Right Task” was implemented from 2008 to 2013 (Education Bureau 2012). This strategy aimed to integrate ICT into teaching and learning to improve student learning outcomes. A depository of curriculum-based learning and teaching resources was developed to provide teachers with relevant digital resources and pedagogical advice for use in primary and secondary schools. These digital resources mainly supported knowledge acquisition and knowledge deepening. The e-learning Pilot Scheme was also launched in 2010 which involved 61 schools. The e-learning Pilot Scheme aimed to promote student self-directed and interactive learning and accommodate the diversity of learners. Most recently, the Education Bureau launched the Fourth Strategy on IT in Education (ITE4) to promote students’ self-directed learning, problem-solving, collaboration, and competency in computational thinking (Education Bureau 2016). This clearly resonates with the education model of knowledge creation.

The Taiwanese government has been making significant investment in the research and development on e-learning since the 1980s. With the announcement of a 10-year program on building school ICT infrastructure in 1997, Taiwan officially started the promotion of e-learning in school education in recent decades with three stages. Building on the achievements made in the first and second stage, the Taiwanese government continued the third stage (2009–2014), focusing on the following aspects: addressing the development of twenty-first-century skills, making digital literacy an official curriculum component, and introducing a mobile learning program (Kong et al. 2014).

In China, new technologies are being widely advocated as effective instruments for erasing differences between learners and learning communities, particularly with regard to transplanting “modern” education into rural communities (Schulte 2015). In 2000, China’s Ministry of Education held a historic meeting on e-learning for school education that produced two important decisions: implementing the campus network construction project for enhancing ICT infrastructure in schools and offering ICT-related curriculum for K–12 students while speeding up the integration of ICT into school curricula. The results of this meeting guided the Beijing Municipal Commission of Education to outline e-learning strategies and policies across the three five-year plans on educational reform and development in the 2000s (Kong et al. 2014).

Japan launched its Knowledge Construction with Technology led by the Consortium for Renovating Education of the Future (CoREF) project in 2010 with the primary aim of transforming traditional didactic teaching styles to more collaborative and knowledge constructive approaches. The targeted learning outcomes for primary and secondary school students include promoting collaborative problem-solving skills through the Knowledge Constructive Jigsaw pedagogy (Miyake 2013).

The Republic of Korea tops the IDI rankings in 2016 among 175 economies worldwide (ITU 2016). With the fourth phase of ICT in Education Master Plan having reached its completion, the MOE announced the fifth phase of its five-year master plan (2014–2018). The overall aim of the fifth Masterplan for ICT in education is to develop students' twenty-first-century skills, improve problem-solving skills, and reinforce self-regulated learning (Han 2013). The MOE selected a total of 30 strategic assignments in areas including kindergartens, elementary schools, secondary schools, research and development, lifelong education, welfare, special education, public information infrastructure, and the creation of a healthy cyber culture.

In India, the National Policy on Education 1986, as modified in 1992, stressed the need to employ educational technology to improve the quality of education. The policy statement led to two major centrally sponsored schemes, namely, educational technology and computer literacy and studies in schools (CLASS) paving the way for a more comprehensive and centrally sponsored scheme: Information and Communication Technology @ Schools in 2004 (Government of India 2012). Recently, India's government announced 2010–2020 as the decade of innovation. This identifies reasoning and critical thinking skills as necessary for innovation and schools as the foundation of these skills. Ideally, affordable ICT tools and techniques can be integrated into classroom instruction starting at the primary stage so as to enable students to develop their requisite skills. Most of the tools, techniques, and tutorials are open domain and accessible on web (www.icbse.com/ict-education).

In addition to supporting knowledge acquisition, knowledge deepening, or knowledge creation, it is important to note that some ICT policies acknowledge the need to safeguard student interests and help students become responsible digital learners. For example, the Singapore Ministry of Education uses a Cyber Wellness framework to develop elementary and secondary school students' well-being when using the Internet. In 2009, the Singapore Ministry of Education, IDA, and Microsoft launched a Cyber Wellness Student Ambassador Program to promote positive peer influence through student-led activities (UNESCO 2013). Malaysia is another country that has two national programs to address cyber safety issues (UNESCO 2016): Cyber Security Awareness for Everyone (CyberSAFE) and Klik Dengan Bijak (Click Wisely). ICT is also used in teacher education programs in Asia. Many of these courses to some degree aim to equip preservice teachers with the relevant knowledge and skills to appropriately and effectively use ICT to develop learning resources that can enhance students' learning experiences. For example, the Korea National University of Education provided preservice teachers a *Theory and Practice for Instructional Media Development* course to help them develop visual, audio, and video animation materials (Kim 2013). Singapore offers preservice teachers a mandatory *ICT for Meaningful Learning* course which emphasizes how ICT can be used to support the following five dimensions: real-world knowledge, engaging students' prior knowledge, learning by doing, collaborative learning, and self-directed learning (Wong and Divaharan 2013).

Relevance of Cross-national and Worldwide Strategies and Plans for Asia

Policymakers can benefit from a large collection of resources that can aid them in policy formulation and implementation (Kozma 2008). Among these are works that list the current ICT policies of other countries, such as the *Cross-National Information and Communication Technology Policies and Practices in Education* (Plomp et al. 2008) and the *Meta-Survey on the Use of Technologies in Education in Asia and the Pacific* (UNESCO 2003). As suggested by Kozma (2008), UNESCO also has a policymaker's toolkit for ICT in education and a set of ICT standards for teachers. Also, the infoDev program at the World Bank has a variety of helpful knowledge maps, guides, and handbooks. Educational policymakers are in a unique position to initiate change as illustrated in the SITES Module 2 study of 174 ICT-supported innovative classrooms in 28 countries (Kozma 2003). With the collection of resources, policymakers can begin to craft and refine policies that can help ICT deliver on its promises and can build a community of like-minded policymakers (Schulte 2015).

The document – *Transforming Education: The Power of ICT Policies* (UNESCO 2011) – presents a conceptual framework known as the *Knowledge Ladder* (as described in the previous section) and makes recommendations that policymakers can use to craft policies and programs that unfreeze the current system and align it with the social and economic policies that move a nation toward an information economy and knowledge society. Within this context, ICT policies can be transformational.

Initial teacher training and professional development are important components of ICT in education policy. However, ICT in education policy can address much larger issues related to professional development, and they do so in a broader context of educational change, as does the *Knowledge Ladder* and the UNESCO ICT Standards for Teachers (UNESCO 2008). A significant challenge to Asian developing countries bringing more students into the education system is to increase the number of teachers. In many developing countries, ICT is being used to extend access to education for teachers, particularly those in rural areas. The UNESCO ICT in Education Toolkit Toolbox 3 provides helpful suggestions in this regard (UNESCO 2011). The *Knowledge Ladder* can also be used to examine policy goals and visions along with the other policy components such as related strategic programs and operational plans. These components include professional development, pedagogical and curricular change, assessment reform, school restructuring, and technological infrastructure comprising hardware, software, networks, and technical support.

As ICT adoption and use in the wider socioeconomic context of countries become more prevalent, it becomes clear that ICT adoption and policies in education are areas requiring further study. Demonstrating meaningful effects on learning and student outcomes in general is also needed to help policymakers effectively set national priorities and develop policies. The report – *ICT in Education in Asia* (UNESCO-UIS 2014) – examines the curriculum as fundamental to building a culture of ICT use in education. This is followed by a comparative analysis of ICT integration across Asia by looking at four specific types of data: the use of ICT in policy and key curricular areas, ICT infrastructure and its importance to integrating ICT-assisted instruction, participation in programs offering ICT, and teaching and learning as they relate to ICT in education. These data provide a snapshot of ICT access and of basic usage of ICT in education across the vast region. The analysis, using the framework of e-readiness (UNESCO-UIS 2009), can effectively contribute to facilitating evidence-based policymaking for ICT in education.

Recently, the document – *A Policy Review: Building Digital Citizenship in Asia-Pacific through Safe, Effective and Responsible Use of ICT* (UNESCO 2016) – presented the results of a policy review that examined the national policies, initiatives, and efforts of member states in the Asia-Pacific region relating to the promotion of safe, effective, and responsible ICT environments and ICT use by children. In particular, the review focused on national education policies relating to fostering digital citizenship in schools and among students, teachers, parents, and caregivers. It is hoped that member states can – through knowledge sharing, communication, and collaboration – adopt best practices, model initiatives, and learn lessons, to develop policies that will ensure that their children are better equipped to benefit from the digital world.

Challenges and Relevance of Research for Policies on ICT in Education in Asia

Probably the most important strand of empirical findings that needs to be considered, when it comes to developing policies for ICT in education, is concerned with questions related to the impact of ICT. Does access to ICT help students learn their school subjects? How can we best use ICT to help students learn their school subjects? And how can we use ICT to foster students' ICT literacy? The answers help policymakers justify the large financial investments needed to integrate ICT into education systems.

Unfortunately, thus far the empirical findings on the contribution of IT to learning appear to be mixed. For example, on one hand, two studies conducted in the United States suggested a positive relationship between computer availability in schools and test scores (National Centre for Educational Statistics 2001a, b). On the other hand, a recent report by the Organization for Economic Co-operation and Development (OECD 2015) that analyzed PISA 2012 test data indicated no appreciable improvements in student achievement in reading, mathematics, or science in countries that had invested heavily in ICT for education, even after accounting for differences in national income and in the socioeconomic status of students and schools. Yet, students who used computers moderately at school, such as once or twice a week, displayed somewhat better learning outcomes than students who rarely used computers (OECD 2015). In addition, OECD (2015) found that students who spend more than 6 h online per weekday outside school hours reported feeling lonely at school and arrived late for school. Other studies have suggested that computer use does increase student performance but this is due mainly to the use of computer at home rather than at school (Delen and Bulut 2011; Papanastasiou and Ferdig 2006; Spiezia 2010).

It is important for policymakers to note that the conclusions of these correlation analyses are limited because they cannot establish causality. Causality can only be determined by examining a substantial number of controlled experiments such as meta-analysis studies (UNESCO 2011). A comprehensive analysis of meta-analysis studies is beyond the scope of this chapter. We examined several recent and seminal meta-analysis studies including Cheung and Slavin (2013), Hattie (2009), Kulik (2003), and Means et al. (2013). The findings can be summarized as follows:

- In an analysis of 74 experimental studies, the results overall suggest that using ICT produces a positive effect size of 0.16 on mathematics achievement (Cheung and Slavin 2013). In particular, using ICT as a supplementary tool had the largest effect on mathematics achievement. Supplementary ICT tools (e.g., PLATO, Larson Pre-Algebra, SRA Drill and Practice) provide extra instruction to aid traditional classroom learning.
- In an analysis of 36 controlled studies, Kulik (2003) found that students who used computer tutorials in mathematics, natural science, and social science scored significantly higher on tests in these subjects. Students who used simulation software in science also scored higher.
- Hattie's (2009, p. 221) synthesis across 76 meta-analyses of computer-assisted learning found that computers are used effectively when (a) there is a diversity of teaching strategies; (b) there are multiple opportunities for learning such as deliberate practice and increasing time on task; (c) the students, rather than the teacher, is in control of learning (e.g., sequencing and pacing of instructional materials, choice of practice items, reviewing); (d) peer learning is optimized; and (e) feedback is optimized.
- In a meta-analysis of 23 study effects, Means et al. (2013) reported that students in blended learning conditions performed significantly better than students learning the same material through face-to-face instruction alone. In addition, available research evidence from nine comparison studies revealed that using prompts to help students perform self-reflection, self-explanation, and self-monitoring leads to more positive learning outcomes.

Taken together, these findings suggest the following implications. First, it is not sufficient to merely provide access to ICT in schools. Furthermore, the mere training of teachers does not seem to be sufficient. Therefore, to enhance the possible effect of ICT on students' academic performance, it is important for policymakers to address both the appropriate pedagogical use of ICT and the incentives for teachers to use ICT. The second implication is to consider proposing guidelines on Internet use. As mentioned, students who spend more than 6 h online per weekday outside of school hours reported feeling lonely at school and arriving late for school (OECD 2015). Consequently, what specific Internet use guidelines should policymakers in Asia consider? Currently, there is no single standardized policy on worldwide Internet use. Different countries have their own guidelines. The third possible implication is to consider developing a policy for ICT use at home. Several studies have indicated that student learning can be improved upon when computers are used at home (Delen and Bulut 2011; Papanastasiou and Ferdig 2006; Spiezia 2010). This suggests that policymakers should think about providing students and their families with the financial support for computer purchase and Internet subscription (Spiezia 2010). Spiezia (2010) further recommended that teachers should ensure integration between the use of ICT at home (based on self-directed learning and exploration) and the use of ICT at school.

Also, there appear to be three main challenges toward ICT in Asia. Closing the digital divide is one of the main challenges of ICT in Asia. Given the disparity in terms of GDPs among the many various countries in Asia, it is not surprising that wealthier economies such as Hong Kong, Japan, the Republic of Korea, and Singapore have computers present in almost every household. However, more than half of students in Indonesia (74%) and Vietnam (61%) did not have a computer at home. It is important to note that the issues of digital inequity are also found in developed economies such as Hong Kong (Yuen et al. 2016a, b).

Promoting the safe and responsible use of ICT is a second challenge faced by countries in Asia. A recent UNESCO (2016) study surveyed selected Asian-Pacific countries and reported the following findings. Countries such as the Republic of Korea, Bhutan, Nepal, and Lao PDR did not have any education policies targeting students in the lower primary school level (e.g., 7–8 years old). There were no policies regarding cyber security skills or the ethical use of creative content, and there were no programs promoting appropriate responses to cyberbullying. Although the Fourth Strategy for IT in Education in Hong Kong included students' ethical use of IT as one of its objectives, it provided no overarching framework. Furthermore, while some countries (e.g., Korea, Japan, China, Bhutan, Bangladesh) have policies that focus on cyber security skills, the ethical use of content, and proper responses to cyberbullying for students between 13 and 18 years old, these policies were not monitored or evaluated (UNESCO 2016). Without a proper monitoring and evaluation mechanism in place, it is impossible to determine how effective these policies are. In addition, only 55% of participating countries in the study have policies regarding secure Wi-Fi, networks, and encryption at the secondary level, only 51% have such policies at the primary level, and only 48% at the early primary level (UNESCO 2016). This suggests that many schools are vulnerable to unauthorized access and malicious attacks (UNESCO 2016).

The third challenge is measuring and evaluating ICT literacy skills. Many nations in Asia recognize the importance of promoting ICT literacy skills among students. However, evaluation remains a challenge. How do we actually define ICT literacy skills? How should we measure and assess these skills? Currently, different countries have their own basic ICT standards. For example, in Singapore primary-level students are expected to search for information over the Internet, create a short document using a word processor, and create a short presentation with multimedia elements, while secondary-level students are expected to use functions for calculations in a spreadsheet, represent data using graphs and charts in word processors and spreadsheets, and communicate over the Internet, among other skills (Singapore

Ministry of Education 2009). Hong Kong's secondary-level students are expected to explain the basic components of a computer and how they work to perform computational tasks, describe concepts related to an operating system, explain the social implications of ICT, develop concepts related to structured programming, and create the simple constructs of a computer program, among other things (Curriculum Development Council and Hong Kong Examinations and Assessment Authority 2015). However, in the ICILS 2013, the three participated Asian countries had not consistently exceeded the average score for most items being tested. For example, in the items that tested students' ability to produce and exchange information, Republic of Korea, Thailand, and Hong Kong scored 57%, 30%, and 69%, respectively, while the average score was 66% (Fraillon et al. 2014, p. 77).

Emerging Perspectives for Developments in Asia

This chapter has shown that the ICT policies in the Asian region are related to Moonen's (2008) three main policy lines. However, recent policies have placed more emphasis on the development of students than of teachers. Other stakeholders such as parents are also included in the ICT policies in some Asian countries. We discussed implications of recent empirical research and noted three main challenges in the previous section. Furthermore, we provide emerging perspectives for the development of ICT in education in Asia.

The Internet has become a tool for bringing together the small contributions of millions of people (Grossman 2006). Nonetheless, the Internet remains largely untapped in education. To transform the Internet into a truly universal tool for development, policymakers must tackle not only the supply-side challenges of the Internet, including infrastructural deficiencies and high prices, but also the demand-side barriers that exist outside the ICT ecosystem (ITU 2016). This means that addressing broader socioeconomic inequalities is essential (Yuen et al. 2016a). Above all, students need to acquire not only the necessary digital skills but also other twenty-first-century skills, such as basic literacy and numeracy, communication skills, and critical thinking skills to exploit the potential of the Internet. In terms of ICT in education, policymakers must act as part of a larger Internet ecosystem to empower students and make Internet content easily accessible to disadvantaged groups. ICT policies must also be linked to investments in education to develop the necessary human skills and raise levels of education, thus bringing more people online (ITU 2016).

ICT has served as a lever for change in most Asian countries. Today, ICT leaders may use the *Knowledge Ladder* to make decisions about the number and location of computers, the type of network, the development of teachers, and the purchase of software. More importantly, the *Knowledge Ladder* may be used to position ICT as a lever for changing other components of education and, ultimately, overall change in the system in a way that supports broader development. As technology is introduced or expanded, policymakers may work with others in the education system and use the opportunity to coordinate changes in pedagogy, such as, with teacher professional development that includes training for how new technologies can promote innovative teaching methods that advance development goals. For example, ICT policies in Singapore take ICT as a way of supporting pedagogical innovation and student-centered learning (UNESCO 2011). However, we need to consider the link between the alignment of local and international goals, such as the Millennium Development Goals, the World Summit on the Information Society, and Education for All (UNESCO-UIS 2009).

Fraillon et al. (2014) indicated that students were more confident in their digital competencies when they had high access to use ICT at home and at school. Confident students also tended to be positive about the effect of ICT on their work and leisure. The ICILS 2013 reported evidence showing that the pedagogical use of ICT is not simply associated with more abundant ICT resourcing. They observed that despite enhanced resourcing in the several years before the study, school use of ICT had not increased since 2006. This context enabled the study to draw attention to the lack of ICT policies in schools. From a sociocultural perspective, it is important to note that students' ICT use at home, either for learning or leisure, is a complex process of interaction between their intentions, objectives, attitudes, and the affordability of new technologies (Yuen et al. 2016a). The concepts of learning and leisure also need to be understood in the context of new digital practices (Drotner 2008). The blurring of ICT use in school and at home raises the issue of whether ICT in education policies need to consider enabling students to engage in learning activities alongside social and leisure activities.

ICT in education in Asia can be viewed from two different perspectives. The first reflects a development discourse that stresses the role of ICT in eliminating the digital divide by reaching the unreached and by providing support to those who cannot access essential infrastructure, trained teachers, and other educational resources. The second perspective adheres to an e-learning paradigm and is a response to the emerging knowledge society in which ways of teaching and learning are evolving at a rapid pace, thus fostering learner-centered educational environments that encourage collaboration, knowledge creation, and knowledge sharing. While countries are admittedly at different stages of integrating ICT in education, ultimately both perspectives will be increasingly relevant for countries in the Asian region (UNESCO-UIS 2014). However, it is important not to overlook Asian culture in addressing this dichotomy. Nisbett (2015) argues that all cultures in East Asia have roots in the Confucian tradition. The influence of the Confucian tradition is evident in Asian societies with different political structures, such as China, Hong Kong, Taiwan, and Singapore, and that such tradition may produce different positions and offer a cultural context for the development and implementation of ICT in education (Yuen et al. 2017).

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83 Information and Communication Technology in Educational Policies in Australia and New Zealand

Louise Starkey and Glenn Finger

Contents

Abstract

The chapter presents a summary of developments in relation to Information and Communication Technologies (ICT) in educational policies in Australia and New Zealand. It provides important insights into how policy decisions are influenced by the national and local contexts in those countries, and how policies are

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influencing the integration of ICT in teaching and learning in primary and secondary education. Trends and developments are identified through the analysis of policy documents and published research to highlight differences and similarities between the two countries. The chapter indicates that both countries have introduced digital technologies in schooling in ways which reflect learning with digital technologies, and are shown to be influenced by international trends. Both Australia and New Zealand have been developing curriculum to guide the teaching of students to learn about digital technologies, through computational thinking and coding. A key challenge continues to be providing equitable access to opportunities for teachers and students to integrate digital technologies effectively into teaching and learning. However, New Zealand has a nationally funded policy of providing universal access to Broadband Internet to all schools which research has found to correlate with improved achievement in the primary years and similar infrastructure priorities were evident in Australia. A further challenge is building teacher capability with and dispositions about digital technologies for effective implementation of policies in both countries.

Keywords
New Zealand · Australia · ICT policy · Digital technologies

Introduction to ICT in Primary and Secondary Education in Australia and New Zealand

This chapter presents a summary of developments in relation to information and communication technologies (ICTs) in educational policies in Australia and New Zealand. Throughout this chapter, we use ICT and digital technologies synonymously and interchangeably and recognize that ICT and digital technologies are not values-neutral "tools" which can be merely integrated into existing curriculum, pedagogy, and assessment, but are viewed as new and emerging technologies which impact upon curriculum, pedagogy, and assessment.

Subsequent to outlining the contexts of schooling in Australia and New Zealand, recent developments in ICT in schooling in Australia and New Zealand are discussed. Those developments are framed within international trends, challenges, and developments in technology through reference to the *NMC/CoSN Horizon Report: 2016 K-12 Edition* (Adams Becker et al. 2016). Given the dynamic changes in technologies and the implications for policy, recent policy developments are then highlighted. These include policies which respond to challenges relating to infrastructure, governance, curriculum, and expectations for current and future teachers. Relevance of cross-national and worldwide strategies and plans for Australia and New Zealand are then presented, together with a discussion about the challenges and relevance of research for policies on ICT in education in Australia and New Zealand. The chapter concludes with some key perspectives and emerging themes about developments in Australia and New Zealand.

Contexts: Australia and New Zealand

As Sawer et al. (2015) have noted, the contexts of both Australia and New Zealand today have been influenced by British colonization and settlements. They indicate, for example, as well as having the Union Jack and the Southern Cross on their national flags, both countries have inherited Westminster political institutions and that, when the process of federation began in Australia toward the end of the nineteenth century, there was some thought that New Zealand might become the seventh state, geographically separated by the Tasman Sea. Though this did not occur, Sawer et al. (2015) explain that there has been significant policy transfer between the two countries which are democratic nations, but the two countries also differ in terms of their political architecture.

In summary, Australia and New Zealand each has a unique identity and context developed over time through a range of historical, social, cultural, political, environmental, and geographical influences. To illustrate, while acknowledging the influence of British settlement on the democratic systems on education policy and the aims and purpose of education is evident in both countries, this chapter will establish that the educational policy responses are uniquely different. Therefore, directly relevant in this chapter is the understanding that these contexts are being shaped by and responding to technological developments. For example, ICT presents educational challenges and opportunities for addressing issues associated with the geographical isolation which is a feature of both countries, as both Australia and New Zealand have diverse population demographics and are distant from other Organisation for Economic Co-operation and Development (OECD) countries. How each country has responded to those challenges and opportunities is discussed in subsequent sections of this chapter.

Schooling in Australia and New Zealand

To logically follow the previous section which provided a summary of the Australian and New Zealand contexts, schooling in Australia and in New Zealand is briefly discussed in this section. This provides the essential context for the subsequent discussion on recent developments in ICT in schooling in both countries.

Schooling in Australia

Essentially, there are three school systems – government, independent, and catholic schools, located in state (New South Wales, Queensland, Victoria, South Australia, Western Australia, and Tasmania) and territory (Northern Territory and Australian Capital Territory) jurisdictions. According to the Australian Bureau of Statistics (ABS 2016a), in 2015, the number of students enrolled in schools in Australia was 3,750,973. Government schools were the major provider (2,445,130 students – 65% of all students), while the remainder (1,305,843 students – 35% of all students) attended either independent or catholic schools. Of those students, 200,563 students (5.3% of all students) were Aboriginal and Torres Strait Islander students. In 2015, there were 9404 schools (ABS 2016b, c), consisting of 6639 government schools, 1737 catholic schools, and 1028 independent schools. There was a total of 301,572 full-time equivalent (FTE) teaching staff in 2015, consisting of 218,849 female teaching staff and 82,723 male teaching staff (ABS 2016c).

These data enable a sense of the scale and diversity of schooling, in terms of sectors and school systems, in Australia. States and territories largely have responsibility for schooling in Australia. This can be traced back to British settlement which resulted in separate colonies which became states when the Commonwealth of Australia occurred with federation in 1901. This has created some tensions between the Australian government and state governments in relation to national approaches to education, while recognizing and respecting state authorities and responsibilities. Examples of different schooling resulting from state education policy decision-making and within the different schooling systems (government, independent, and catholic) include different starting ages of students, variations in curriculum, variations in ICT policy, infrastructure and resourcing, and different expectations and pay scales for teachers. Furthermore, individual schools vary in terms of their autonomy and agency in ICT strategic planning, decisions, and practices.

Schooling in New Zealand

In October 2016, there were 796,993 school students enrolled across New Zealand's 2501 schools. The schools vary in size with 186 having fewer than 30 students and 118 with more than 1000 students (Education Counts 2016a). The majority of students (96%) are enrolled in state or state-integrated schools (government funded with a special character). Each school has its own curriculum developed from one or both national curricula documents, and the purpose of both the English medium and Māori medium versions is to "develop the competencies [young people] need for study, work, and lifelong learning and go on to realise their potential" (Ministry of Education 2007, p. 6).

New Zealand has a devolved schooling system. For state and state-integrated schools, the central government sets educational policy such as national curriculum, pays teacher salaries, and allocates funding to schools for operational expenses and buildings. The state funds centralized quality assurance through the Education Review Office and sets accountability standards that focus on literacy and numeracy for primary schools and qualification attainment in secondary schools. Within this framework each school is self-managing with autonomy to set strategic priorities, develop a school curriculum appropriate for their context drawing on the broad national curriculum and manage resources provided through the operational grant. Thus the state has broad guidelines for curriculum and pedagogical approaches, and each school applies these as appropriate to their context. This creates opportunities and challenges for each school to develop their own approach to the integration and teaching of ICT or digital technologies.

Challenges and Opportunities in Integrating the Regions into One Chapter

Given the differences and variations, for example, between jurisdictions, sectors, and school systems in Australia, this presents a significant challenge within this chapter in representing Australia as a single educational entity with a single set of policies.

This task is exacerbated when attempting to construct a discussion about both Australia and New Zealand. However, while, acknowledging this challenge and the limitations associated with this, there is a wonderful opportunity and great value in attempting to provide a comparative exploration of the developments in ICT in schooling in both countries, through considering their policies in ICT in education, the role of research, and emerging perspectives.

Recent Developments in ICT in Schooling in Australia and New Zealand

Fullan, in his William Walker Oration titled *Leadership in a Digital Age* at the 2015 Australian Council of Educational Leaders Conference, highlighted the three big forces now evident – technology, pedagogy, and change knowledge. He argued that "technology outstrips the others in dynamic movement. . .In any case traditional schooling is an outdated failure...The internal challenge is boredom; the external challenge is uncoordinated threat and opportunity" (Fullan 2015, p. 6). Thus, the discussion in this section initially examines trends, challenges, and technologies from an international or "satellite" perspective, highlighting recent trends, challenges, and developments in ICT schooling in Australia and New Zealand.

Trends, Challenges, and Technologies: Horizon Report

In examining international trends, challenges, and technologies, the *NMC/CoSN Horizon Report: 2016 K-12 Edition* (Adams Becker et al. 2016) identified key short-term, midterm, and long-term trends accelerating technology adoption in K-12 education, challenges impeding technology adoption, and important developments in educational technology over three time-to-adoption horizons. As displayed in Fig. 1, the horizons relate to the period from 2016 through until 2020.

In that report, references are made throughout to developments in Australia and New Zealand, such as the following examples:

- **Long-Term Trend: Redesigning Learning Spaces**
  "The New Zealand Ministry of Education. . . . . .has published a set of guidelines and an assessment tool to help schools apply flexible learning spaces into redesigns and new constructions. All schools are required to comply with these standards..." (Adams Becker et al. 2016, p. 8)
- **Midterm Trend: Collaborative Learning**
  ". . .students and teachers in New Zealand. . .are using platforms such as WhatsApp to establish an online partnership to bring forth a greater understanding and perspective of the importance of each culture to one another." (Adams Becker et al. 2016, p. 12)
- **Midterm Trend: Deeper Learning Approaches**
  "New Tech Network is working with over 100 schools, districts, and communities across the US and Australia to implement PBL in public schools and offer professional development in facilitating meaningful projects. . .." (Adams Becker et al. 2016, p. 15)

Challenges
Solvable: Those that we understand and know how to solve ➢ Authentic Learning Experiences ➢ Rethinking the Roles of Teachers
Difficult: Those that we understand but for which solutions are elusive ➢ Advancing Digital Equity ➢ Scaling Teaching Innovations
Wicked: Those that are complex to even define, much less address ➢ Achievement Gap ➢ Personalizing Learning

Trends		
Short-Term (one year or less)	**Mid-Term** (two to three years)	**Far-Term** (four to five years)
➢ Coding as a Literacy ➢ Students as Creators	➢ Collaborative Learning ➢ Deeper Learning Approaches	➢ Redesigning Learning Spaces ➢ Rethinking How Schools Work

2016 2017 2018 2019 2020

Developments in Technology		
Near-Term (one year or less)	**Mid-Term** (two to three years)	**Far-Term** (four to five years)
➢ Makerspaces ➢ Online Learning	➢ Robotics ➢ Virtual Reality	➢ Artificial Intelligence ➢ Wearable Technology

Fig. 1 Trends, challenges, and technology developments in K-12 education (Adapted from Adams Becker et al. 2016, p. 2)

- **Short-Term Trend: Coding as a Literacy**
  "Australian parliament members are working to ensure coding is taught at all primary schools. . .by 2020. (Adams Becker et al. 2016, p. 17)

Trends, Challenges, and Technologies: Australia

Key trends, challenges, and technologies in schooling in Australia include ICT resources in schools and the take-up of digital technologies, implications for curriculum, and the changing knowledge base of future and current teachers to develop and demonstrate technological pedagogical and content knowledge (TPACK) (Mishra and Kohler 2006).

In relation to ICT resources in Australian schools, Thomson (2015) reported that ". . .on average, every three students have access to one computer, compared to the international mean of 18 per computer" (Thomson 2015, p. 12) and that there were little variations between jurisdictions, though this ranged from 1:1 ratio in the Northern Territory up to 4:1 in New South Wales. Almost a decade earlier, White

(2008) had also highlighted the substantial provision and take-up of and access to technologies by students in schools and in their homes. Importantly, White (2008) observed that major networking initiatives had been undertaken to improve technology infrastructure in Australian schools so that learning can be designed in the future that enables students to learn anywhere at anytime.

The implications of ICT for curriculum can be conceptualized according to two distinctive considerations in Australia. Firstly, it can be conceptualized as learning and teaching *with* digital technologies. That is, ICT enables teaching and learning experiences to be designed to enable students to access, share, revise, and create learning content using digital technologies. Secondly, it can be conceptualized as learning *about* digital technologies. This is evident through *The Australian Curriculum: Technologies Learning Area* (ACARA 2016a) consisting of two subjects, namely, *Design and Technologies* (ACARA 2016b) and *Digital Technologies* (ACARA 2016c), to be taught to all students from Prep to Year 10. Furthermore, *The Australian Curriculum* (ACARA 2016d) requires students to develop the ICT capability (ACARA 2016e) as one of seven general capabilities expected to be developed across all learning areas.

Both learning *with* and learning *about* digital technologies present new expectations for future teachers. This has been highlighted at the *Queensland Digital Technologies Summit 2016: Initial Teacher Education* (Finger et al. 2016). For example, the Digital Technologies Summit identified initial teacher education strategies (Finger et al. 2016) required for teacher graduates to develop the competencies *with* and dispositions *about* digital technologies required to demonstrate the Australian Institute for Teaching and School Leadership (AITSL) (AITSL 2011a, b) professional standards at the graduate level.

In relation to current teachers, Thomson (2015) drew upon the finding from the *International Computer and Information Literacy Study* (ICILS) (Fraillon et al. 2013) that the most problematic obstacle related to ICT skills of teachers. For example, in the ICILS, the Australian ICT coordinators who were surveyed reported that "75 per cent of Year 8 students attend schools in which the biggest problem reported was the lack of ICT skills among teachers" (Thomson 2015, p. 12). Consequently, there is evidence of increased attention, and research is evident in relation to TPACK in ITE programs and professional learning for teachers as technological knowledge (TK) is being considered important for teachers to develop and demonstrate, along with pedagogical knowledge (PK) and content knowledge (CK).

Trends, Challenges, and Technologies: New Zealand

Key trends, challenges, and technologies in schooling in New Zealand are summarized as being the development of learning spaces through redesigning physical spaces, Bring Your Own Device (BYOD) and mobile devices initiatives, the challenge of equity in relation to access to digital devices, implications for curriculum, and the use of data analytics.

As referred to in the *NMC/CoSN Horizon Report: 2016 K-12 Edition* (Adams Becker et al. 2016), the New Zealand government has prioritized modernizing of school classrooms across the country, due to the age of existing classrooms, population growth, and the Christchurch earthquakes of 2010 and 2011. The development of *learning spaces* as opposed to classrooms has been a focus since 2010, underpinned by the notion that schooling in a digital age should look different to schooling in an industrial age (Ministry of Education 2015a). The changes in physical learning spaces are underpinned by the notion that teaching and learning at school should be differentiated and responsive to the needs of the students, rather than focused on a teacher delivering a one-size-fits-all curriculum (Ministry of Education 2015a). Increasing access to resources through digital devices can enable the implementation of student-centered pedagogical practices (Hannafin et al. 1997). The central funding of new or altered physical spaces in which teachers collaboratively teach cohorts of up to 120 students reflects the aim that teaching will be more personalized for the students. This is a significant trend in primary schools, particularly for children aged 8–12, with walls being knocked down between existing classrooms and teachers developing ways to work collaboratively. A similar trend is occurring in some secondary schools, with a number exploring flexible timetabling with longer scheduled classes and open plan spaces. These policy directions have not yet been evaluated.

A current trend in New Zealand secondary schools is the introduction of BYOD policies. The majority of secondary schools either allow or require students to bring a device which connects with the school's Wi-Fi for learning and make use of tools such as Google Classroom and subject-specific tools for learning (Johnson et al. 2014). This is complemented by the current ICT focus in New Zealand on the infusion of mobile devices within teaching and learning. In primary schools in New Zealand, mobile digital devices are more likely to be purchased or leased by the school with touch screens being used by younger children and netbooks by older children (Johnson et al. 2014). While some schools have a dedicated one device per student policy, the majority provide access to shared devices that children can use for learning. Interactive whiteboards continue to be utilized in some primary classrooms, although these appear to be losing popularity with the evolving pedagogy and availability of large flat-screens with functions such as Chrome casting.

A significant challenge is equitable access to digital devices for learning. Primary schools in low socioeconomic contexts purchase fewer devices than those in higher socioeconomic contexts. In some low socioeconomic contexts, trusts, such as Manaiakalani (Jesson et al. 2015), have been established to assist families purchase or lease netbooks for learning at home and school. However, equitable access to devices and the Internet at home across the country is a challenge in the current context.

A further challenge is teaching a curriculum that enables students to become digitally competent. ICT are embedded in the technology learning area of the New Zealand Curriculum (Ministry of Education 2007). Each school develops their own curriculum from the national document and determines the extent that computing and digital technologies are taught across the school. The teaching of coding is not explicit or required in the existing flexible national curriculum, although this is being introduced in 2018 (Ministry of Education 2017). In recent years, coding clubs have been introduced to some primary schools as an option or extracurricular activity, and there has been a growth in robotics taught as part of the technology curriculum to 10–13-year-olds. Some primary schools have been exploring the teaching of computer programming, usually introduced by a teacher with a passion for coding (Falloon 2016).

Computing is offered as a subject in New Zealand secondary schools and can contribute to national qualifications for students in their final years at school. In 2015, out of 524 secondary schools, 79 taught computer science/programming, 242 taught computer studies, and 222 taught ICT. Less than 1% of students attending secondary school were studying computer science/programming (Education Counts 2016b). However, this may increase as a digital technologies strand within the national curriculum is being developed with an emphasis on computer programming for implementation in 2018 (Ministry of Education 2016b).

The use of data analytics is emerging in New Zealand schools. While data are predominantly used for accountability purposes, such as the evaluation of teacher and school effectiveness, the opportunities for broader use of digital data are being explored (Sutherland 2015). Teachers are increasingly using student achievement data to inform their teaching programs and pedagogical decisions, and principals are analyzing a range of digital data to inform school policy and decision-making. A challenge in developing the use of data is the availability of appropriate analytical tools and knowledge of how to maximize this resource.

Recent Developments in Policies on ICT in Australia and New Zealand

In this section, some of the recent developments in policies are discussed, within the context of understanding the contexts summarized earlier and the trends, challenges, and developments in technology.

ICT Policy Developments in Australia

ICT policy developments in Australia can be traced back to the 1980s as personal computers started to appear in schools and then revised as the Internet appeared during the mid-1990s. For example, in Queensland, Australia, the initial policy was *Computers in the Curriculum* (Department of Education, Queensland 1983) and was revised substantially with *Schooling 2001* (Education Qld 1997), which envisaged every classroom being connected to the Internet. More recent developments in that jurisdiction include the Smart Classrooms strategy designed to provide “direction for harnessing the learning and business potential of ICT now and into the future” (Qld Government 2016). That strategy is conceptualized according to four ICT eLearning drivers, i.e.:

- Working Digitally (e.g., OneSchool, OnePortal, Dream Factory) – outlines how schools use digital technology to move from traditional to transformational ways of working

- Developing Professionals (e.g., Digital Practice Guide, OneChannel) – articulates expectations for teacher and leader capabilities
- Enabling Learners (e.g., The Learning Place – Student Spaces and Staff Spaces) – focuses on addressing learners' needs through effective learning environments
- Harnessing the Enterprise Platform (e.g., Managed Internet Service, Websites for Schools, Computers for Teachers) – focuses on the processes, systems, and practices to develop and maintain effective learning and business productivity (Queensland Government 2016)

Similar examples can be identified within the other jurisdictions, and more recent policy responses have tended to reflect dynamic, and often disruptive, transformational technological changes, such as the emergence of laptop programs, mobile devices, social media, and BYOD initiatives. Many policies and curriculum have needed to ensure that the implications of learning *with* and *about* ICT are appropriately responding to those technological changes. Moreover, these challenges have required a collaborative approach at the national level. The *Digital Technologies Hub* (Education Services Australia 2017) is a tangible example of a national approach in providing "learning resources and services for teachers, students, school leaders and parents" (p. 1), support "the implementation of quality Digital Technologies programs and curriculum in schools" (p. 1), and to leverage "events and activities offered by education jurisdictions, industry and other providers" (p. 1).

To illustrate, all Australian education ministers were signatories of the *Melbourne Declaration on Educational Goals for Young Australians* (MCEETYA 2008). This declaration sought "to achieve the highest possible level of collaboration with the government, Catholic and independent school sectors and across and between all levels of government" (MCEETYA 2008, p. 5). That declaration stated that, "In this digital age, young people need to be highly skilled in the use of ICT. While schools already employ these technologies in learning, there is a need to increase their effectiveness significantly over the next decade" (MCEETYA 2008, p. 5).

Subsequently, Lloyd et al. (2016) have noted that the Melbourne Declaration has led directly to the development of *The Australian Curriculum* (ACARA 2016d), which includes the ICT capability to be developed across all learning areas (ACARA 2016e). As discussed earlier, *The Australian Curriculum: Technologies Learning Area* (ACARA 2016a) has become an approved curriculum and includes *Design and Technologies* (ACARA 2016b) and *Digital Technologies* (ACARA 2016c) subject areas. They also refer to the *Australian Professional Standards for Teachers* (AITSL 2011a), which outlines expectations across four career stages – graduate, proficient, highly accomplished, and lead teacher. In referring to those *Australian Professional Standards for Teachers*, they acknowledge that while there is "no formal nationally-accepted ICT Professional Development Strategy for Teachers in Australia… …many Standards can be demonstrated through the meaningful use of ICT in the classroom" (Lloyd et al. 2016, p. 25). Importantly, in relation to future teachers, all initial teacher education (ITE) programs in Australia must be approved and reviewed through program accreditation processes informed by those professional standards.

In summary, recent ICT policy developments in Australia find expression both at the national level and within jurisdictions, with significant implications for learning *with* ICT through the development of ICT capability across all learning areas and learning *about* digital technologies through the technologies learning area and its subjects, namely, Design and Technologies and Digital Technologies. In addition, informed by the *Australian Professional Standards for Teachers* (AITSL 2011a), there are expectations for current and future teachers to develop and demonstrate the efficacy to design and implement learning experiences for students to learn *with* and *about* ICT.

ICT Policy Developments in New Zealand

ICT policy developments in New Zealand have enabled technological innovation to overcome barriers of access to learning within rural New Zealand. Regional networks established in the 1990s, such as OtagoNet, have enabled the sharing of teachers and resources across schools for students attending rural schools (Barbour and Wenmoth 2013). This began as video-conferencing and has evolved to use a variety of ICT and a brokerage system whereby school networks can offer to teach a course and, in return, their students can access courses on the network. Urban networks such as the Wellington Loop have enabled the development of infrastructure and technical support across clusters of school (Barbour and Wenmoth 2013). These regional initiatives have informed current policy directions.

A national infrastructure development of laying fiber cable across the country included providing ultrafast broadband or rural broadband to every school in New Zealand by 2015 and the establishment of the *Network for Learning* (Crown Fibre Holdings n.d.). *Network for Learning* was established to manage the rollout of broadband to schools, and part of the function of this initiative has been to develop a repository or shared space, where teachers can share and evaluate digital resources. This innovation aimed to improve network capability and reduce geographical and socioeconomic inequities in Internet access between schools. Research suggests that the introduction of broadband is correlated to improved achievement in primary schools (Grimes and Townsend 2017). While the government developed the infrastructure to enable broadband access, the development of ICT policy for teaching and learning in New Zealand is the responsibility of the leadership or governance of individual schools; there are no national policies on how digital technologies should be used for teaching and learning apart from a brief statement in the national curriculum about how ICT can support teaching and learning (Ministry of Education 2007). The ICT policy developments are currently focused within and across groups of schools.

The devolved system of governance, introduced in 1989, included a model in which individual schools competed for student enrolments. This model sometimes skewed school-based decisions to consider the marketing potential or impact on the perceived image of the school to attract students and in some cases limited collaboration between schools who perceived themselves to be in competition (Wylie 2012). A current political direction in New Zealand is to increase collaboration across schools by encouraging networks of schools in a similar context to form communities of learning (Ministry of Education 2016a). This national policy direction has implications for the development of ICT policies and sharing of resources across clusters of schools in a way that supports and enhances the earlier regional initiatives.

Both Australia and New Zealand have a strong history in distance education for rural and isolated students. E-learning is an area that is rapidly evolving and provided some pioneering work within the use of technologies for learning at school. A policy change on the horizon in New Zealand is the introduction of communities of online learning (COOL) schools (Ministry of Education 2016c). Currently, there is one national distance education school that is fully funded by the government that was originally established for the education of rural and isolated students, but over time the students enrolled have changed to include a wider demographic (Barbour and Wenmoth 2013).

Cyber safety is taught in most schools under the Health or Hauora learning area of New Zealand Curriculum (Ministry of Education 2007). This is embedded within learning about personal safety such as the "keeping ourselves safe" program offered by the New Zealand Police (New Zealand Police n.d.) and through advice and resources developed by NetSafe, an independent national organization (Netsafe n.d.).

In contrast to Australia, New Zealand does not have explicit accountability requirements for teachers to use digital technologies or ICT in their teaching practice. The professional standards which guide primary and secondary teacher evaluation for certification purposes have one reference, i.e., that teachers will "select teaching approaches, resources, technologies and learning and assessment activities that are inclusive and effective for diverse ākonga (learners)" (Education Council 2015, Criteria 9ii). However, it would be difficult to meet the range of criteria without using the digital technologies that are infused into the work of a teacher. For example, the professional standards state that fully certified teachers are able to "analyse assessment information" (Criteria 11) which in most schools would include analyzing digital data integrated into a student management system. Therefore digital technologies while not explicit within professional standards are implicit.

Relevance of Cross-National and Worldwide Strategies and Plans for Australia and New Zealand

The discourse about education within Australia has increasingly been influenced by international and jurisdictional comparisons being conveyed through, in particular, analysis of the performance of Australian students in the 2015 *OECD Programme for International Student Assessment (PISA)* (OECD 2016), *Trends in International Mathematics and Science Study (TIMSS)* (see Thomson et al. 2016), *International Computer and Information Literacy Study (ICILS)* (see Fraillon et al. 2013), the *National Assessment Program – Literacy and Numeracy and the National Assessment Program – ICT Literacy* (ACARA 2012). These will continue to be important, but a wider agenda is needed that encompasses a broader and deeper curriculum for young Australians than these areas measured by these testing programs.

New Zealand national policies are also influenced by international trends including student achievement in PISA and TIMSS. The development of learning environment policy is attributed to OECD reports (2006, 2013). The introduction of the digital technologies curriculum drew on curriculum developed and implemented in Australia and England (Bell et al. 2014). Strategies and plans at a school level are influenced from regional experiences and can reflect the unique context of the schooling environment (Barbour and Wenmoth 2013).

Challenges and Relevance of Research for Policies on ICT in Education in Australia and New Zealand

The interface between research, policy, and practice underpins research for policies on ICT in education. Research can provide guidance for informing policies in Australia and New Zealand in a digital age.

Challenges and Recommendations for Policies on ICT in Australia

Thomson (2015) appropriately asks the central questions: Where to from here? and "Is Australia on track to realise the aims of almost a decade ago, to ensure that 'young people need to be highly skilled in the use of ICT'?" (Thomson 2015, p. 16). She highlights a range of comparative performances with other countries as well as historical data and trends to indicate that much has yet to be done to address differences in outcomes associated with socioeconomic disadvantage, challenges associated with attracting female students to ICT courses, and building student confidence in their ability to perform higher level ICT tasks. That is, Thomson uses research to critique policy in her suggestion that "Our education system could well be creating basically proficient ICT users but very few technicians, innovators or developers" (Thomson 2015, p. 16). In addition, she cited Livingstone (2015) who has argued that:

> . . .for Australia to succeed in a digital age, we should be starting the digital education of our students in the beginning years of primary school, introducing skills such as computational thinking, problem solving and computer coding. This is a giant leap from where Australia is now, and will require determined policy and a great deal of teacher professional development (Livingstone 2015, cited in Thomson 2015, p. 17)

The recent developments in terms of curriculum and expectations for future and current teachers appear to be largely "on track" to meet the challenges. For example, the Digital Technologies (ACARA 2016c) requires teachers to implement a project-based learning approach in which students from Prep to Year 10 (5–15-year-olds) develop systems thinking, computational thinking, and design thinking to create digital solutions to real-world problems. Thus, in Australia, there is momentum and an appetite for key stakeholders to collaboratively enable future and current teachers to develop the competencies with and dispositions about digital technologies needed in a digital age (Finger et al. 2016). The interface between research, policy, and practice in Australia requires focused attention on the role of research to inform both policy and practice, particularly in relation to ICT infrastructure and resourcing which provides guidance in relation to access and meaningful use of new and emerging digital technologies for teaching and learning, curriculum design, implementation and review, and building teacher capabilities for a digital age.

Challenges and Recommendations for Policies on ICT in New Zealand

A challenge and ideal in New Zealand is to have an equitable education system that narrows or closes digital divides (Starkey et al. 2017). While New Zealand students achieve comparatively well in the PISA research, there is a significant difference in academic achievement between advantaged and disadvantaged students (OECD 2016). These differences could widen given the current funding and devolved governance model within New Zealand (Wylie 2012).

While central policy has led to ultrafast broadband being made available to all schools, how this is used and the purchase of technology to access the Internet is decided independently at each school. Research has identified that schools with a higher proportion of disadvantaged students report spending more on digital technologies for student learning and less on teacher professional learning than those with a lower proportion of disadvantaged students (Johnson et al. 2014). The potential for digital divides to widen should be considered in educational policy and could be mitigated through targeted funding and curriculum design such as developing a profile of digital competence for learners and the deliberate teaching to enable all young people to leave school with the digital competence to be active participants in society (Starkey et al. 2017).

Perspectives for Developments in Australia and New Zealand and Emerging Themes/Perspectives

In Australia, learning *with* and *about* digital technologies is a useful conceptualization for understanding teaching and learning expectations for teachers and students and the design of curriculum discussed earlier in this chapter. Of direct relevance is *The Australian Curriculum: Technologies Learning Area* (ACARA 2016a), the *Design and Technologies* (ACARA 2016b) and *Digital Technologies* (ACARA 2016c) subject areas, and the ICT capability (ACARA 2016e) expected to be developed by students within all learning areas. It was established that these present new expectations for many teachers, as, for example, the *Digital Technologies* subject area is being introduced for the first time and is being mandated in Prep–Year 10. These developments in Australia are integral to the Science, Technology, Engineering and Mathematics (STEM) agenda in Australia. That STEM agenda and vision are being expanded to include digital literacy through concrete strategic planning, strategies, and funding support articulated in Australia's *National Innovation and Science Agenda* (Australian Government, Department of Education and Training 2016) termed *Inspiring all Australians in digital literacy and STEM* (Australian Government, Department of Education and Training 2016), which involves:

- Upskilling our teachers to be able to implement *The Australian Curriculum: Digital Technologies*
- Upskilling our students, through various computing and coding challenges, computer science summer school, and focusing on underrepresented students in STEM subjects, such as female students
- Facilitating partnerships with industry
- Digital Literacy School Grants, which schools and other organizations can apply for to facilitate the implementation of *The Australian Curriculum: Digital Technologies*
- Engaging in the early years, through providing funding of $14 million over 4 years to promote positive STEM learning experiences with children aged 3–5 years
- Funding of $112.2 million for *Inspiring all Australians in digital literacy and STEM* (Australian Government, Department of Education and Training 2016)

In New Zealand, all schools have reliable fast Internet access, and the focus is now on how digital technologies are integrated or infused into education (Ministry of Education 2015b). A review of STEM education and the resulting strategic plan (New Zealand Government 2014) has led to strengthening the place of digital technologies in the national curriculum which will place an emphasis on coding and computational thinking to be implemented in 2018–2019 (Ministry of Education 2017). The government has released contestable funding of 1 million dollars to support schools to pilot learning programs teaching coding to enable each school to consider how they might integrate this aspect of the curriculum into their technology programs. This places a significant challenge particularly within primary schools where teachers usually teach all aspects of a curriculum and have limited experience of computational thinking or coding.

Conclusion

To conclude this chapter, we emphasize the variation and similarities across the contexts within New Zealand and Australia and how this influences ICT policies. Both countries are influenced by international trends, and attention is given to their rankings within international tests, such as PISA and TIMMS. At the political and policy level, tensions and contradictions are evident in relation to this, for example, with some reductive policy advocacy more suited to an analogue world. Rather, we suggest that there are policy responses occurring in response to the dynamic opportunities and challenges presented by new and emerging ICT.

As outlined earlier, within Australia various national and jurisdiction policies are currently shaping how students learn *with* and *about* ICT. The last decade of curriculum developments in this regard has been largely informed by the *Melbourne Declaration on Educational Goals for Young Australians* (MCEETYA 2008), which involved collaboration between all education ministers and across all systems of schooling in Australia, i.e., state, catholic, and independent schools. Guided by that framework and within the context of competitive federalism, *The Australian Curriculum* (ACARA 2016d) has been developed with a new *Technologies Learning Area* (ACARA 2016a) developed, consisting of the two subject areas, namely, *Design and Technologies* (ACARA 2016b) and *Digital Technologies* (ACARA 2016c). The various state and territory jurisdictions in Australia are at varying phases of implementing this. Furthermore, within *The Australian Curriculum*, the ICT capability is a general capability to be developed across all learning areas. The policy and curriculum implications in Australia also are reflected appropriately in expectations for current and future teachers articulated in the *Australian Professional Standards for Teachers* (AITSL 2011a). There are significant implications for upskilling Australia's teachers and students explicitly articulated in Australia's *National Innovation and Science Agenda* (Australian Government, Department of Education and Training 2016).

In New Zealand, national policies guide the development of infrastructure and individual schooling policies to enable the development of the use of ICT within teaching, learning, and curriculum. For example, a national policy prioritized the provision of fast broadband Internet connection to schools across New Zealand which created the context for increasing the use of the Internet within learning programs. Evaluation of this policy identified a positive correlation between the introduction of fast broadband and student achievement within primary schools (Grimes and Townsend 2017).

National policies in New Zealand do not specify which ICTs should be used for teaching and learning or how they should be used although the national curriculum does outline why they should be used (Ministry of Education 2007). Likewise, ICT use is not explicit in teacher standards; instead it is implicit as it would be difficult for teachers to meet quality assurance measures without using digital technologies. Therefore it is the responsibility of the individual school to make the decision about the use of ICTs for teaching and learning and justify their policies to the Education Review Office. Research from New Zealand that explores policy and implementation is focused on access to technologies which reflects equity concerns.

A current development within both New Zealand and Australian policy is the introduction of computational thinking and coding named as “digital technologies” as part of technology learning across levels within the respective national curricular. This is in the early stages of implementation with Australia ahead of New Zealand. The need for teacher professional learning has been recognized in both countries, and this is being supported through allocated funding. The outcomes of this policy have not yet been evaluated.

Key ideas from ICT policies and implementation in Australia and New Zealand include the importance of context when considering whether ICT needs to be explicit or implicit within policy. The provision of broadband Internet access appears to make a difference to student learning at the primary school level. The changing expectations of teachers and school leaders to prepare students to be active and successful citizens in the world today and in the future present both challenges and opportunities which require active collaboration of research, policy, and practice within and across both countries.

When we consider, with increased life expectancies, that students entering schools in Australia and New Zealand in 2017 are likely to complete their schooling in 2029, and some might be alive beyond this century, this is critically important policy work. There are significant implications for curriculum, in relation to learning and teaching *with* and *about* digital technologies, and for the professional expertise of a teacher in a digital age.

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Information and Communication Technology and Educational Policies in the United States of America and Canada

84

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Abstract

This chapter reviews ICT and education policy in the United States and Canada; both countries have populations with diverse cultures, languages, socioeconomics, and ideologies. Generally local school authorities provide education, while state/territory and national bodies exert influence. Focus areas in this chapter include ICT infrastructure, protections for student data and privacy, data interoperability, personalized learning, online assessment, and updates to national technology standards and frameworks. In addition to evolving infrastructure, issues related to supporting "future-ready" learning, perhaps of equal importance, is the ongoing evidence-based evaluation of educational technology and effort to increase the pace and rigor of evidence associated with educational technology purchases and renewals by school districts. Some school systems are moving toward a competency-based education (CBE) model which often requires policy shifts. There is growing interest in exploring new models for teacher preparation and development as well as calls for increased personalization of student learning. Policy debates continue around the degree of equal access to technology that government should require, including whether parity should be required in terms of device age and availability, quality and availability of digital learning materials, and classroom bandwidth and whether the technology is being used actively or passively by students across all socioeconomic groups and across all schools. As policy makers grapple with the displacement of jobs and loss of employment due to advances in technology and continued growth in income inequality, they may turn to policies that encourage better alignment between K-12 education and the skills needed for future careers.

Keywords

Technology · Educational policies · United States · Canada

Introduction to ICT in Primary and Secondary Education in the United States and Canada

The socio-educational landscape in the United States and Canada can be characterized by geographically expansive countries comprised of states, provinces, or territories, whose educational realities and policies reflect socioeconomically, culturally, linguistically, and ideologically diverse perspectives. In Fall 2016, according to the National Center for Education Statistics, approximately 50.4 million students attended public elementary and secondary schools in the United States (NCES 2016). In the United States (US) decentralized education system, generally kindergarten through 12th grade (K-12) schools are run under local control of a school board that is responsible for setting policy and serves as the authority of the district (or diocese) of schools. However, each state does influence what happens in schools through policies and practices in critical areas such as teacher licensure, high school (secondary) graduation standards and requirements, funding patterns, and legislation (Anderson and Dexter 2009).

The federal government has very little direct control over the nation's schools; education is controlled entirely by the states. There is no national curriculum for education, and schools only receive a small percentage of funding from the federal government. This is especially true at the elementary and secondary level, where about 92% of the funds come from nonfederal sources (US Department of Education 2017b). That means the federal contribution to elementary and secondary education is about 8%, which includes funds not only from the US Department of Education (USDOE) but also from other federal agencies, such as the Department of Health and Human Services' Head Start program and the Department of Agriculture's School Lunch program.

The US Department of Education (USDOE) is influential by making additional funding available for national initiatives, with an emphasis on evolving high-need focus areas, and by developing and disseminating educational plans and national reports and making critical recommendations. ICT policies and practices in K-12 education at the state and national levels follow the same pattern of local control influenced by state and federal funding opportunities and policy recommendations (Anderson and Dexter 2009, p. 698). Federal grants support focus areas like high-poverty schools; teacher professional development; science, technology, engineering, and mathematics (STEM); and programs focusing on English language learners, students with special needs, etc. Generally, national large-scale assessments are administered annually in content areas like mathematics and reading.

While there are similarities in the education systems in states across the United States, there are generally differences in curriculum, large-scale assessment, and accountability policies. To date, 42 states, the District of Columbia, and four territories have adopted the Common Core State Standards. Launched in 2009 by state leaders through their membership in the National Governors Association Center for Best Practices (NGA Center) and the Council of Chief State School Officers (CCSSO), the Common Core State Standards (CCSS) provide a set of shared goals and expectations for the knowledge and skills students need in English language arts/literacy and mathematics at each grade level, including the use of technology and media, so that they can succeed in college, career, and life. Though the states of Alaska, Indiana, Nebraska, Oklahoma, South Carolina, Texas, and Virginia are not presently adopting the standards at a state level (Common Core State Standards Initiative 2017), many of these state standards are similar in content to the CCSS. An additional effect of the wide adoption of the CCSS and similar standards has been the ability to create digitally based assessments that allow results to be shared across state lines (ETS 2016, p. 4).

Canada constitutionally recognizes French and English as its two official languages. Canada's decentralized education system is the responsibility of the ten provincial and three territorial governments with approximately 4.74 million students attending public elementary and secondary schools in 2014–2015 (Statista n.d.). There is no federal department of education and no direct funding for public schools, with two exceptions: (1) the federal government does provide financial support for official minority language education in public schools. In the 12 provincial/territorial jurisdictions where English is the predominant and official language, this includes education in French and includes education in English in Québec where French is the official language. Under federal legislation, (2) the federal government is also responsible for funding the education of Aboriginal children of the First Nations living on reserves (Rich 2009, p. 120).

The differences in curriculum, assessment, and accountability policies in Canada's provincial and territorial education systems are influenced by the geography, culture, history, language, and specific needs of the diverse populations served. In the 13 jurisdictions, departments or ministries of education have curriculum departments and are responsible for the organization, delivery, and large-scale assessment of education at the elementary and secondary levels (Council of Ministers of Education Canada 2017). At the local level, elected school boards generally oversee the education system for districts, representing the interests of their constituents within the legal framework of the province or territory.

While there is not a federal department of education, the Council of Ministers of Education, Canada (CMEC) was formed in 1967 by the provincial and territorial ministers responsible for education, to undertake educational initiatives cooperatively and represent the interests of the provinces and territories with national and international organizations and federal and foreign governments. The CMEC provides a national voice for education, and, through the CMEC, the provinces and territories work collectively on a wide range of priorities at the elementary, secondary, and postsecondary levels (Council of Ministers of Education Canada 2017).

Recent Developments on ICT in the United States and Canada

Several recent developments in ICT in the United States and Canada focus on areas like infrastructure, protections for student data and privacy, data interoperability, personalized learning, online assessment, and updates to national technology standards and frameworks.

ICT Infrastructure in Schools

ICT infrastructure in the United States is supported by the federal E-Rate program, which was mandated by Congress in 1996 and implemented by the Federal

Communications Commission (FCC) in 1997, and has the goal of reducing the cost of Internet access for schools and libraries. Historically, the program was effective in providing basic connectivity to schools, but resulted in insufficient bandwidth in classrooms. Significant progress has been made in recent years in providing broadband to classrooms as a result of the modernization of the E-rate program (see section "Recent Developments on Policies on ICT in the United States and Canada").

A robust technology infrastructure is essential to "future-ready" learning environments (USDOE 2016, p. 41). Having adequate bandwidth is essential for teachers and students to utilize digital content. Low bandwidth is extremely problematic when trying to stream interactive or media-rich content, especially under the demands of a 1:1 classroom environment. The CoSN (2016) Annual E-Rate and Infrastructure Survey Report, which documents infrastructure changes in the United States, finds that school systems are making substantial progress toward meeting the FCC short-term goal of 100 Mbps per 1,000 students with more than two thirds (68%) of school systems reporting that all schools in their system fully meet the minimum Internet bandwidth recommendations. This number climbs to 80% of school systems having three fourths of their schools at this immediate connectivity goal, representing a significant improvement from 19% in just 4 years across urban, rural, and suburban districts.

Given that the education system in Canada is decentralized, national reports synthesizing ICT policies and practices are intermittent. Some cross-national or national profiles of ICT policies and practices in education in Canada have provided summary data and illustrative examples from select provinces (Milton 2015; USDOE 2011). The International Experiences with Technology in Education (IETE) Report, for example, includes the following findings for Canada: (a) improving Internet connectivity in primary and secondary schools is a top priority in national efforts to improve education (e.g., SuperNet high-speed network project in Alberta provides broadband connections to the Internet for all public institutions, including schools), (b) Canada is one of the seven countries to report national initiatives to deliver online instruction for students (e.g., the Alberta Distance Learning Centre serves 30,000 elementary and secondary students with distance learning services, including fully online courses, and manages the province's virtual school), (c) Canada is included in the eight participating countries to report the implementation of programs for using ICT for summative assessments, and (d) Canada was also one of the 17 of 21 countries that reported teacher technology standards in place in 2010 and also conducted some form of assessment of teacher ICT skills. Notably, Alberta was the participating province for this report (USDOE 2011, pp. viii–ix).

The British Columbia (2016) Education Plan also offers an illustrative example of efforts to improve infrastructure in Canadian schools. The Ministry continues to support quality technology-related learning through their next-generation network (NGN). "[The] initiative [is] transforming the Provincial Learning Network to a high-capacity, modern system that can grow and adapt to changing needs. The initiative will convert approximately 1,650 School District sites to the NGN over a period of three years" (p. 10).

Similarly, Ontario is improving access to high-speed broadband connectivity in schools across the province. In particular, infrastructure improvements focus on northern, rural, and remote schools to provide all students with reliable and equitable access to learning resources (Queen's Printer for Ontario 2017, para. 1). The $50M initiative will move Ontario's schools toward equitable access to adequate broadband speed in three waves over the next 4 years (para. 5).

Protections for Student Data and Privacy

Protections for student data and privacy have also become a growing priority and concern in the United States and Canada (Government of Canada 2017; Library of Congress 2015). According to the US National Educational Technology Plan, the use of student data is crucial for personalized learning and continuous improvement. As stewards, schools and districts have an obligation to inform students and families about the kind of student data the school or third parties (e.g., online educational service providers) are collecting and how the data can be used (USDOE 2017b, p. 79).

The US Department of Education, along with other organizations (Library of Congress 2015), offers schools and families resources and examples, training, and other assistance in navigating privacy concerns in the United States and Canada (USDOE 2017b; Government of Canada 2017).

Data Interoperability and Standards

Increasingly, educators and other stakeholders have the need to enable data sharing through an existing or custom application program interface (API) or through a data export option. In order to be useful, the data need to be in a common format, and rules must be applied to map common data fields across the systems. Data interoperability frameworks have been established to ensure data are presented in usable formats. There are several examples of existing frameworks, resources, and organizational alliances that address the issue of data interoperability:

- The Schools Interoperability Framework (SIF) is an open data sharing specification that includes Extensible Markup Language (XML) for modeling educational data and service-oriented architecture for sharing the data between institutions.
- The Ed-Fi Alliance supports the creation of a common data standard for communication among educational tools and systems. Ed-Fi technology aligns with the Common Education Data Standards (CEDS) established by the National Center for Education Statistics (NCES) and works closely with other entities such as the IMS Global Learning Consortium to expand interoperability.

- Project Unicorn, a grassroots effort to improve interoperability in K-12 education, works with school systems and vendors to create a demand for secure interoperability.

Personalized Learning

Educators in both the United States and Canada have given increased attention to personalized learning (USDOE 2016; Milton 2015) which refers to instruction in which the pace of learning and the instructional approach are optimized for the needs of each learner. Learning objectives, instructional approaches, and instructional content (and its sequencing) may all vary based on learner needs. Technology can enable personalized learning or experiences that are more engaging, relevant, and student-driven (USDOE 2016, p. 7).

Additionally, all students deserve equal access to (1) the Internet, high-quality content, and devices when they need them and (2) educators skilled at teaching in a technology-enabled learning environment. When this occurs, it increases the likelihood that learners have personalized learning experiences, choice in tools and activities, and access to adaptive assessments that identify their individual abilities, needs, and interests (USDOE 2016, p. 30).

Personalized Student Learning

- Technology enables personalized pathways for student learning through active and collaborative learning activities. Clearly defined sets of learning outcomes guide instruction. The outcomes, and the aligned curriculum, instruction, and assessment, reflect the multidisciplinary nature of knowledge, prepare students for our participatory culture through attention to digital literacy and citizenship, and attend to general skills and dispositions, such as reflection, critical thinking, persistence, and perseverance.
- Leaders ensure that policies and resources equip teachers with the right tools and ongoing support to personalize learning in their classrooms.
- Teachers collaborate to make instructional decisions based on a diverse data set, including student and teacher observations and reflections, student work, formative and summative assessment results, and data from analytics embedded within learning activities, and software aided by real-time availability of data and visualizations, such as information dashboards. Leadership policy and teacher methods support student voice and choice in the design of learning activities and the means of demonstrating learning. Students frequently complete a series of self-directed, collaborative, multidisciplinary projects and inquiries that are assessed through a profile or portfolio. Technology is integral to most learning designs, used daily within and beyond the classroom for collaboration, inquiry, and composition, as well as for connecting with others around the world. In the classroom, teachers serve as educational designers, coaches, and facilitators, guiding students through their personalized learning experiences (USDOE 2017b).

Personalized learning has been widely discussed and advocated for in Canada as well. Authors of the C21 Canada report argue:

> The well-tested methods of making change in education through incremental improvement are insufficient to the task of transforming schools into 21st century learning environments. We see the possibilities in many individual schools and classrooms – where personalization of the curriculum is the natural outgrowth of students' interests and aptitudes; where students communicate with subject experts worldwide; where classroom discipline and culture are established by students because their work is interesting and valued by themselves and those they connect to. (Milton 2015, p. 6)

Online Assessments

Recent developments in next-generation online assessments and performance-based tasks are attempting to measure a broader array of high-order skills and competencies that include critical thinking, problem solving, and socioemotional skills (ETS 2016, p. 3–5). Vander Ark and Schneider (2012) suggest that "the adoption of internationally benchmarked college- and career- ready standards in literacy and numeracy (Common Core or equivalent) and the move to online next-generation assessments are two key indicators that a national movement is building" (p. 3). Moreover, Vander Ark and Schneider and a number of stakeholders contend that students graduating into [an] increasingly global, technology-rich knowledge economy will need an expanded skill set to succeed (p. 3). In addition to the creation of digitally enhanced summative assessments, online formative assessments continue to be developed and adopted to inform daily instruction (Molnar 2017).

According to the Ontario Ministry of Education (2016), the Education Quality and Accountability Office (EQAO) is "exploring technology-enabled assessment, beginning with the use of computer-based assessments as an alternative to paper-and-pencil tests, with the hope of moving towards more transformative-based assessments in the future" (p. 41).

Increased Accessibility

As technology-enhanced tools and curricular materials become more widely adopted, demand increases for accessibility features to be built-in from inception in order to meet the needs of more students. Many of these tools and curricular materials are being built using principles of Universal Design for Learning, a framework for the design of materials and instructional methods that are usable by a wide range of students. Specifically, "UDL design principles take a holistic approach to learning in which curriculum, procurement, the LMS, and policy work together to support the needs of all learners" (Gronneberg and Johnston 2015). Gronneberg and Johnston (2015) argue that though the aim of UDL is to provide full access to students with special needs, the approach "offers significant affordances for all students, allowing them to benefit from learning presented through multiple sensory avenues and a variety of conceptual frameworks. Early research about the influence of UDL is positive, showing that it improves engagement and performance among all students" (p. 2).

Updates to Technology Standards, Competencies, and Frameworks

Significant work has been done to develop and update technology standards, competencies, and frameworks in recent years. There is now widespread consistency on the twenty-first-century competency foci (e.g., critical thinking, problem solving, digital literacy, digital citizenship) needed for students to be successful (e.g., CMEC 2011; ISTE 2007, 2016; Ontario Ministry of Education 2016). The widely used set of International Society for Technology in Education (ISTE) standards, for example, "emphasize ways that technology can be used to amplify and even transform learning and teaching," rather than focusing on education technology tools, and work in concert to support key stakeholders (e.g., students, teachers, administrators) with clear guidelines as they rethink education and adapt to a constantly changing technological landscape" (ISTE 2016). The ISTE standards are student-driven and focus on student agency across respective focus areas, standard statements, and indicators. The focus areas are (a) empowered learner, (b) digital citizen, (c) knowledge constructor, (d) innovative designer, (e) computational thinker, (f) creative communicator, and (g) global collaborator. The recently updated ISTE Standards for Students (2016) provide an aspirational framework to leverage technology for learning transformation. A recent focus on digital citizenship is also evinced across ICT frameworks and standards (e.g., ISTE 2016; Hoechsmann and DeWaard 2015). In unpacking the ISTE Digital Citizenship focus, the standard "Students recognize the rights, responsibilities and opportunities of living, learning and working in an interconnected digital world, and they act and model in ways that are safe, legal and ethical" maps to four indicators (e.g., *students cultivate and manage their digital identity and reputation and are aware of the permanence of their actions in the digital world*).

Similarly, Hoechsmann and DeWaard (2015) describe digital citizenship as one of six core digital literacy competencies adopted by British Columbia from the ISTE Standards (Digital Literacy Competencies). In the Draft Digital Literacy Framework, this definition of digital citizenship is broken down into ten specific outcomes relating to (a) Internet safety, (b) privacy and security, (c) relationships and communication, (d) cyberbullying, (e) digital footprint and reputation, (f) self-image and identity, (g) creative credit and copyright, (h) legal and ethical aspects, (i) balanced attitudes toward technology, and (j) understanding and awareness of the role of ICT in society.

Additionally, the Council of Ministers of Education, Canada (2011) discussed how "provinces and territories are addressing the broad range of skills that [students] will need to be fully engaged workers and citizens in the knowledge society of the 21st century" (para. 9). Skills include critical thinking, information literacy, collaborative learning, and new modes of civic engagement. The C21 Canada (2012) seminal report, *Shifting Minds 1.0: A 21st Century Vision of Public Education for Canada*, also offers a vision for education, guiding principles for the vision, seven competencies (the 7 C's) that all students need to succeed in the twenty-first century, and priorities for redesigning the public education system. The 7 Cs are (1) creativity, innovation, and entrepreneurship, (2) critical thinking, (3) collaboration, (4) communication, (5) character, (6) culture and ethical citizenship, and (7) computer and digital technology. The authors explain the focus of the paper "is systemic transformation. It explores the critical question facing school district leaders and government policy makers: How can innovative models of teaching that are emerging in some places become the new norm in all schools?" (Milton 2015 p. 8). The "shift" described proposes a shift away "from hierarchical policy-driven systems toward networks of strong, responsive, schools . . .[In] these transformed systems, leaders at the top empower leadership at all levels . . . The dual strategies of school improvement and innovation work together to hold the system in balance" (p. 8).

Recent Developments on Policies on ICT in the United States and Canada

In 2011, the US Congress defunded the Enhancing Education Through Technology (EETT) provision of the Elementary and Secondary Education Act (ESEA), which was the only dedicated federal funding source for educational technology. This program has provided states more than $3.5B in dedicated funding of educational technology since 2002. This negatively impacted the ability for states to maintain educational technology expertise and capacity on the state level, leading to the elimination of a number of state level educational technology director positions, or the combining of those positions with other responsibilities. It also negatively impacted districts around the country who relied on these funds for district level personnel and support.

In 2015, with the passage of the Every Student Succeeds Act (ESSA), Congress reauthorized the *Elementary and Secondary Education Act of 1965* (*ESEA*), the primary legislation governing elementary and secondary education in the United States. In this law, EETT was consolidated and combined with 49 other programs into a single program called the Student Support and Academic Enrichment (SSAE) program. This program provides state block grants aimed at (a) providing all students with access to a well-rounded education, (b) improving school conditions for student learning, and (c) improving the use of technology in order to improve the academic achievement and digital literacy of all students. It is important to note that this program is focused on building educator capacity to use educational technology effectively and caps the dollars that can be spent on the direct purchases of hardware and software at 15% of total educational technology spending.

It is also important to note that, as clarified in a Dear Colleague letter issued by the Office of Educational Technology at the US Department of Education, funding from other provisions of the law may be used by states and school districts to pay for educational technology in many cases as long as the purpose of those purchases is in direct support of the goals of those provisions of the law and abides by the particular rules associated with those programs (USDOE 2017a).

Another major recent development in federal policy in the United States is the modernization of the E-Rate program. In 2014, this program was updated to increase the overall spending cap to $3.9B per year and also increase the priority of internal connections (i.e., WiFi in schools) while phasing out support for some services (i.e., pagers and voice). As a result, from a baseline level of 30% of school districts meeting the targeted bandwidth in 2013, as of January 2017, between 81% and 88% of school districts now meet the bandwidth goal. This dramatic change lays the foundation for widespread, reliable digital learning in US classrooms.

Through the National Educational Technology Plan (2017), the United States also seeks to provide a vision and a call to action to US schools for how they use technology for learning including calling for using technology to reduce equity gaps in both access and achievement. It also calls for a focus on the active use of technology by students as tools for them to explore, to create, to communicate, and to solve rather than more passive uses of technology (USDOE 2017b).

The US Department of Education and the US Department of Health and Human Services also issued a joint policy brief in 2016 on the use of technology by early learners. This brief differentiates between different kinds of technology use for early learners, going beyond "screen time" to discuss the purpose and manner in which the child engages. It encourages overall limits, but also encourages active learning with others, especially underscoring the importance of adults' co-viewing with children to provide context and reinforce learning (USDOE & US Department of Health and Human Services 2016).

Alberta Learning and Technology Policy Framework

It is difficult to apply a broad brush stroke in the review of ICT policies and practices across Canada. Rather, reports have highlighted illustrative policies and practices from provinces like Alberta. Alberta's updated (2013) Learning and Technology Policy Framework provides a roadmap that delineates five interdependent policy directions and respective outcomes (for students, teachers, administrators, and other school professionals) and actions at both the school authorities and Ministry of Education levels (Alberta Ministry of Education 2013):

- Policy Direction 1: Student-Centered Learning – Technology is used to support student-centered, personalized, authentic learning for all students.
- Policy Direction 2: Research and Innovation – Teachers, administrators, and other education professionals read, review, participate in, share, and apply research and evidence-based practices to sustain and advance innovation in education.
- Policy Direction 3: Professional Learning – Teachers, administrators, and other education professionals develop, maintain, and apply the knowledge, skills, and attributes that enable them to use technology effectively, efficiently, and innovatively in support of learning and teaching.

- Policy Direction 4: Leadership – Education leaders establish policy and governance.
- Policy Direction 5: Access, Infrastructure, and Digital Learning Environments – All students, teachers, and administrators and other education professionals have access to appropriate devices, reliable infrastructure, high-speed networks, and digital learning environments.

Relevance of Cross-National and Worldwide Strategies and Plans for the United States and Canada

Although educational plans and frameworks established at the global level have highlighted the need for generating ICT policies in education, such as the Organisation for Economic Co-operation and Development (OECD), this influence has not been enacted formally or fully in the United States and Canada perhaps due, in part, to a lack of comparable structures and coordination of ICT policies and structures (▶ Chap. 88, "Information and Communications Technology and Educational Policies in Latin America and the Caribbean" by Valenzuela and Miranda) in both of these countries. However, the United States and Canada have participated in developing promising frameworks like those described in the OECD study and attended the UNESCO (2015) Conference.

Innovation Imperative

OECD (2015) research from the Teaching and Learning International Survey (TALIS) found that an average of two thirds of teachers across the participating countries consider the school where they work "an innovation hostile environment." This tracks with innovative learning environments being the exception rather than the rule in most education systems. They underscore, "a powerful learning environment and learning system will constantly be creating synergies and finding new ways to enhance professional, social and cultural capital with others" (p. 4).

Economic critique and educational critique, evinced in international discourse (OECD 2015), make a strong case for both innovation in and an urgency for systemic change in schools. When focusing on learning systems and innovation, OECD (2015) suggests many conventional frameworks are inadequate by themselves. OECD researchers conducted an international Innovative Learning Environments (ILE) study. The underpinnings of the study included three interrelated strands: "(1) research about the fundamentals of learning using international expert knowledge, (2) the study of a range of cases across many countries and education systems, and (3) the search for effective practices for change management and policy implementation" (p. 4).

The ILE study authors discuss the wide variety of contexts in the initiatives highlighted (e.g., some were organized or just supported by national ministries, some cover a small network of schools, some were based on digital technology, others addressed particular groups of learners). Despite the widely different contexts, there were some common threads shared: (a) culture change, (b) clarifying focus,

(c) capacity creation, (d) collaboration and cooperation, (e) communication technologies and platforms, and (f) change agents.

There are further examples of cross-national synergies and work with the United Nations Educational, Scientific, and Cultural Organization (UNESCO). The UNESCO (2015) Conference Report of the Canadian Delegation (2015) outlined several issues addressed. A delegation, comprised of close collaboration between the Government of Quebec, CMEC, Canada's Permanent Delegation to UNESCO, and Confederation of Canadian Unions (CCU), took an active part in the conference and achieved several objectives. The main issues addressed included:

- UNESCO's leadership role in implementing the new Education 2030 agenda
- The promotion of inclusive, quality education
- The promotion of global citizenship education
- The development of cross-sectoral policies and the engagement of all parties in the process, including youth
- Consideration of the various different forms of learning and the promotion of information technology
- The importance of promoting lifelong learning in education
- The use of existing structures such as national commissions, ASP.NET, and UNESCO chairs in the promotion and implementation of UNESCO *activities* (p. xx)

Challenges and Relevance of Research for Policies on ICT in Education in the United States and Canada

Equity and Access

Similar to the United States, Canada is geographically vast and has a tendency to have a concentrated population in large urban centers (Rich 2009). According to Rich, "this situation leaves a rural and often remote population located in coastal regions, mountain areas, the northern regions of the central provinces, and the Arctic" (p. 128). Canada's population is also culturally diverse encompassing the

> original First Nation and Inuit inhabitants along with residents from successive waves of immigration (Rich, p. 128). Rich maintains that several factors – the vast geography of the country, the mix of large urban concentration and remote towns, and a linguistically diverse and multicultural population – present challenges for maintaining quality educational services. Rich further asserts these contexts position ICT as both a promise and a challenge. While technologies may help in removing some barriers (e.g., geographic), they can present a challenge "in terms of demonstrating that equity of access to and use of ICT enhances learning. (p. 129)

Notably, one can draw parallels from this context, to help unpack digital equity issues in the United States (Davis et al. 2007). Additional concerns in Canada include infrastructure issues (e.g., less access to high-speed Internet/broadband for rural schools).

While use of ICT in Canadian schools has been purported as a solution to some equity issues, far-reaching results have not been completely realized. Looker and Thiessen (2003) found that access at home and the level of skill in using ICT were lowest for Inuit, Mi'kmaq (a First Nation group in eastern Canada), and Black students in Canada and highest for Asian and White students (as cited in Rich 2009). More recently, "the CMEC reviewed results from OECD's 2009 Programme for International Student Assessment (PISA). Canada remains one of the few countries in the world where high PISA scores and high equity go together. Canadian students not only score in the top tier of participants; the gap between the highest- and lowest-performing students is relatively small (CMEC 2011). Additionally, according to the International Experiences with Technology in Education Report, Canada is exploring ways to better serve students at risk of not completing high school and English- or French-language learners (USDOE 2011).

Competency-Based Education

Some school systems are moving toward a competency-based education (CBE) model which often requires policy shifts. Competency-based education, as defined by the Council of Chief State School Officers and the International Association for K-12 Online Learning (Patrick and Sturgeis 2013), incorporates the following:

1. Students advance upon mastery, not seat time.
2. Competencies include explicit, measurable, transferable learning objectives that empower students.
3. Assessment is a meaningful and positive learning experience for students.
4. Students receive timely, differentiated support based on their individual learning needs.
5. Learning outcomes emphasize competencies that include application and creation of knowledge, along with the development of important skills and dispositions (p. 6).

According to a policy and political landscape published by KnowledgeWorks (Pace et al. 2015), many current accountability measures create barriers to full adoption of competency-based education such as state seat time requirements, lack of consensus on what constitutes proficiency, required assessments designed to measure grade-level knowledge rather than competency, and limited opportunities for students to demonstrate mastery in multiple formats.

Evidence-Based Evaluation of Education Technology

In addition to evolving infrastructure, issues related to supporting "future-ready" learning, perhaps of equal importance, is the ongoing evidence-based evaluation of educational technology. Research by Digital Promise shows that school districts rely more upon peer recommendations than rigorous evidence when making educational technology purchases (Digital Promise 2014).

In a Digital Promise (2014) report, authors suggest that procurement, the process for discovering, evaluating, and acquiring classroom resources, processes can become a barrier to selecting and implementing high-quality ICT solutions, particularly when these practices were designed for print-based resources rather than modern technology. Several recommendations were made as a result of the survey findings:

> a) Better guidelines for conducting needs assessments and including end users in the process, b) Faster methods of evaluating products and better ways of sharing results, c) Simplified Request for Proposal (RFP) processes to ensure a level playing field and high-quality results, d) Pilot approaches that increase rigor and drive purchasing decisions without overburdening teachers, e) Incentives for providers to get results and show evidence, such as performance-based contracting and prizes, f) Websites with trusted information about edtech tools and district procurement policies and better ways to match providers and products with educators, and g) More research about funding strategies for acquiring ed-tech products. (para. 7)

Also worth noting, rapid-cycle technology evaluations have been effective for some school leaders. According to the Office of Educational Technology (OET), at the US Department of Education, “rapid-cycle tech evaluations are designed to assist school leaders in making evidence-based decisions regarding educational technology acquisitions. Traditional research approaches do not meet the needs of evaluating rapidly changing education technology. They 1) take too long, 2) cost too much 3) cannot keep up with speed of development, 4) are not iterative, and 5) serve a different purpose than most school leaders need. By the time a traditional research project is complete, new iterations of the app can make the research outdated before it is even published” (USDOE n.d., para. 1).

A number of commercial and open source tools have emerged to assist districts and schools with conducting rigorous rapid-cycle evaluations to collect essential evidence to use technology more effectively in teaching and learning (USDOE, OET n.d.). This is part of a larger effort to increase the pace and rigor of evidence associated with educational technology purchases and renewals by school districts.

Comprehensive Landscape Analysis Needed

A recommendation that came out of the National Educational Technology Plan (USDOE 2017b) in the United States is to create a comprehensive map and database of connectivity, device access, use of openly licensed educational resources, and their uses across the country. To understand the digital divide better and progress toward bridging it, researchers, state and local officials, and district administrators should work in concert with one another to test connectivity speeds in schools and homes and to identify the kinds of devices to which educators and students have access and the ratios of devices to users within education institutions. The building of such a map and database would allow for the visualization of inequities of access and targeted interventions to alleviate them. In addition, the level of engagement with openly licensed learning materials should be made transparent as an indicator of progress toward equitable structures, cultivate innovation, and build capacity within the system to leverage technology in support of student-centered learning and system efficiencies.

Given that the responsibility for setting education policy resides at the provincial and territorial levels, it is not surprising that there is considerable variance across the 13 jurisdictions and geographic regions across Canada in terms of digital literacy policies and implementation programs. Hoechsmann and DeWaard (2015) explicate that approaches to implementing digital literacy and digital citizenship education differ across the country. They identify four main approaches used in implementation strategies: infusion, cross-curricular competencies, integration, and dispersion (p. 15). Table 1 highlights digital literacy and digital citizenship frameworks across the five geographic regions in Canada.

Perspectives for Developments in the United States and Canada and Emerging Themes/Perspectives

Deeper Learning

Vander Ark and Schneider (2012) suggest that great teachers and innovative schools are discovering ways to foster deeper learning for their students. But along with other scholars, they caution that it will not be possible to bring these opportunities to scale, without the necessary technology (Vander Ark and Schneider 2012; Dede 2014). They further assert that the adoption of college- and career-ready standards and the coordination of next-generation assessments create an unprecedented opportunity to advance readiness that can be realized by linking digital learning and deeper learning (p. 2). Among other insights, Vander Ark and Schneider identify three primary ways that digital learning promotes deeper learning:

- Personalized skill building in preparation for deeper learning (e.g., adaptive learning)
- Schools and tools that foster deeper learning (e.g., project-based learning networks)
- Extended access (e.g., access to quality courses and teachers online) (p. 1)

Dede (2014) also positions that we are now seeing digital technologies used in ways that promote deeper learning. Dede highlights two promising technologies in detail that have been widely researched in empirical studies: digital teaching platforms and immersive authentic simulations. He offers that an extensive series of

Table 1 Select digital literacy and digital citizenship frameworks in Canada

Geographic region	Digital literacy and digital citizenship framework
In the North	"Northwest Territories based their vision on five core competencies drawn into a holistic circle that unites community, home, workplace and school, and also individual life trajectories that include psychological (self), social (others) and spiritual dimensions as well as an acknowledgement of the physical context (the land). Brief explanations of each of the five core competencies set the directions of this twenty-first Century curriculum" (Hoechsmann and DeWaard 2015, p. 17)
To the East	"In Newfoundland and Labrador, twenty-first Century learning is oriented towards a strong vocational focus based on changing work futures. The [curriculum map includes] three domains: literacy; life and career skills; and learning and innovations skills. Significantly, "literacy" combines the traditional "three Rs" with ICT literacy. [The] direction for digital skill sets and mindsets are holistic and oriented to students' needs in the classroom, community, and future workplace" (Hoechsmann and DeWaard 2015, p. 20)
Central Canada	"A growing trend in Canadian education is to move away from content knowledge curriculum outcomes in favour of competency-based outcomes. While this trend is not unique to Quebec (for example, Saskatchewan and BC have similar orientations), the Quebec Education Program (QEP) was the result of a major rethinking and reworking of the province's curriculum and teaching guidelines. The QEP is based on a three-pronged vision: to provide instruction in a knowledge-based world; to socialize students in a pluralistic world; and to provide qualifications in a changing world" (Hoechsmann and DeWaard 2015, p. 15)
Out West	"Manitoba's Literacy with ICT (LwICT) is a holistic and pedagogy-focused approach to integrating digital literacy into and across the curriculum that recognizes the fundamental shift that has occurred in communication and learning with digital tools, but makes a very explicit connection between traditional and digital literacy practices. "The meaning of literacy evolves with the times. Literacy is not only about reading, writing, listening, speaking, viewing and representing. It is also about developing literacy with information and communication technology (ICT). . . [which] means thinking critically and creatively, about information and about communication, as citizens of the global community, while using ICT responsibly and ethically" (Literacy with ICT Across the Curriculum: Definition and Purpose)" (Hoechsmann and DeWaard 2015, p. 24)
On the Pacific	"Adopted from the six competencies articulated in the 2007 ISTE Standards for Students, British Columbia's Digital Literacy Framework provides another model for the development of a digital literacy curriculum that is comprehensive and concise. It includes: research and information literacy, critical thinking, creativity and innovation, digital citizenship, communication and collaboration, and technology operations and concepts" (Hoechsmann and DeWaard 2015, p. 26)

research studies have been conducted on their effectiveness and practicality. Dede proffers three recommendations: stay focused on reducing achievement gaps, build professional capacity to use digital tools effectively, and invest in research and development.

Building Professional Capacity

In addition, there is growing interest in exploring new models for teacher preparation and development to build professional capacity. Discourse has centered around how to best prepare and equip educators with the transformative skills and experiences needed to empower learners to use technology to its fullest potential and reduce equity gaps in achievement. Calls for increased personalization of student learning have been amplified in cross-national and national discourse in both the United States and Canada (USDOE 2017b; Milton 2015). Cator et al. (2014) remind us, "new adult learning models are creating the potential for personalized preparation and development pathways for teachers. As student roles change in a personalized learning environment, teacher preparation and professional learning should evolve accordingly" (p. ii).

Digital Use Divide

The digital use divide has been a growing concern. According to the 2017 NETP, "[c]losing the digital divide alone will not transform learning. We must also close the digital use divide by ensuring all students understand how to use technology as a tool to engage in creative, productive, life-long learning rather than simply consuming passive content" (USDOE 2017b, p. 21). Essentially, though there are notable exceptions, technology exposure for most students still needs to move from a focus on passive consumption to creation.

Augmented and Virtual Reality

Augmented reality (AR) is expected to take a more prominent role in education, as is virtual reality to a lesser degree. According to review of studies on AR (Bacca et al. 2014), augmented reality has been shown to improve learning gains, to increase motivation and student engagement, and to foster stronger collaboration skills. However, AR is still often considered an intrusive technology; students can pay too much attention to virtual information (p. 146). In addition to increased use of AR and VR for learning experiences, students will also likely need to learn how to create and manipulate augmented experiences themselves.

Scaling Out and Scaling Up

Both the United States and Canada face significant challenges in scaling innovation both out and up. Fullan and Donnelly (2013) in their discussion on the challenges in research on digital innovations recognize, for example, that the "field is currently characterized by either weak or undeveloped pedagogy, or strong technology and pedagogy connected to a small number of schools; that is, the best examples tend to be small–scale exceptions that are not representative of the main body of schools" (p. 11). Further, they argue that "pushing the envelope in the direction of larger–scale reform will require the integration of technology, pedagogy, and system change" (p. 11).

OECD (2015) discusses micro-, meso-, and meta-levels that must be addressed when focusing on learning systems and innovation. According to a C21 Report, Canada faces challenges of scaling out and up as school districts pursuing "a change agenda along an improvement and innovation trajectory start where the opportunity presents itself because there is not a single (or simple) approach to create innovative schools across a whole system.... Leaders watch for the fine balance between the need for autonomy to innovate at the school level and the desire for systemic and sustainable improvement" (Milton 2015, p. 12). Milton (2015) discusses innovation further:

> [c]reating the conditions for local innovations is relatively easy. Sustaining the innovations over time, and scaling them out to other schools, is much harder. Schools may, for example, get better at using technologies and may for limited subjects and time periods support interdisciplinary studies or facilitate collaborative projects. But without a disciplined approach to transformation, these innovations will not likely add up to a new way to do school every day for all students in every class. (p. 13)

Looking to the Future

As Canada and the United States expand their support of educational technology in schools, policy makers will encounter both challenges and opportunities. These include determining the proper safeguards for protecting the privacy of student data and determining the propriety of allowing private entities with profit motives to access and use this data, even when authorized by school officials and limited to specific purposes related to improving student outcomes. Also challenging will be constructing policies governing student assessments, including whether computer-based assessments should be a required format for gathering national data. Policy debates will also continue around the degree of equal access to technology that government should require, including whether parity should be required in terms of device age and availability, quality and availability of digital learning materials, and classroom bandwidth and whether the technology is being used actively or passively by students across all socioeconomic groups and across all schools in a given geography. Even as technology is used in more effective ways for learning, the debate will continue about whether policies should limit the amount of overall screen time students experience in school and, if so, by how much.

Some opportunities for policy makers include supporting expanded interoperability standards to make it easier for educators to gather data from multiple products into a single learning dashboard; reforming educational technology procurement policies to support the procurement of digital resources in lieu of paper textbooks and to require a demonstrated evidence-based for educational technology solutions before purchases are approved or renewed; supporting for the systematic use and vetting of high-quality open educational resources (OER) in schools; expanding the applications of data systems at the national and regional level that provide comparative longitudinal information on learning gains across schools and demographics; supporting teaching approaches that elicit active learning, rather than passive learning, with technology; and implementing policies that help prepare learners to be responsible digital citizens in both digital workspaces and social realms.

Both Canada and the United States face particular economic challenges in the upcoming years that education technology could play a role in addressing. As policy makers grapple with the displacement of jobs and loss of employment due to advances in technology and continued growth in income inequality, they may turn to policies that encourage better alignment between K-12 education and the skills needed for future careers. Educational technology can support the necessary data, learning, and credentialing to create pathways from K-12 to college and career that align with long-term employment stability. Further, if personalized learning approaches can be designed to provide experiences that help students not only learn required material but also explore their personal interests, passion, and purpose, educational technology can be a powerful force in enabling a lifetime of learning and fulfilment.

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Information and Communication Technology and Educational Policies in the Sub-Saharan African Region

85

Frank Tilya

Contents

Abstract

This chapter refers to policies toward integrating ICT in primary and secondary education from the perspective of Sub-Saharan Africa region. This chapter explores how recent development in ICT policy facilitates the integration of ICT in teaching and learning in primary and secondary education in the region. Varieties of strategies are in progress to ensure the technology is integrated into primary and secondary education. These strategies focus mainly ICT professional development for management and teaching and learning; electronic content resource development and distribution; access to ICT infrastructure; connectivity, community engagement; and research and development, though the emphasis vary from country to country. Moreover, trends show that different countries are at different stages of ICT adoption and use (UNESCO. (2004). *Integrating IT into*

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education: A collective case study of six Asian countries. Bangkok: UNESCO). Majority countries are at emerging and applying stages in ICT adoption and use in education, with only Seychelles, Mauritius, and South Africa at infusing stage. The main challenges facing the region include lack of sufficient budget to sustain ICTs in schools, inadequate ICT infrastructure, untrained teachers and technicians on ICT integration, and ineffective coordination of ICT initiatives, which leads to unfriendly curriculum which does not specify where, how, and when to use ICT for educational purpose. However, low cost and proliferation of mobile technologies in the region have enormous potential to improve ICT use in education. In many countries, mobiles are the only channel for effectively distributing reading material, given the high cost of books and their distribution, especially in rural areas. In addition, mobiles offer interactivity, connectivity, and personalized content.

Keywords

ICT in sub-Sahara · ICT in basic education · ICT policies in sub-Sahara · ICT integration in sub-Saharan education · Mobile phones in sub-Sahara · Innovations in education sub-Sahara

Introduction of ICT in Primary and Secondary Education in Sub-Saharan Africa

This chapter presents an overview of information and communication technology (ICT) and education policies in sub-Saharan Africa (the African countries south of the Sahara desert). The focus is on sub-Saharan Africa (SSA), not Africa in total, as Northern Africa is similar in many ways to the Middle East, and it is discussed in one of the chapters of this volume. According to the UN, SSA region consists of all African countries that are fully or partially located south of the Sahara. The region is full of tremendous promise as it is emerging out of decades of stagnation and now is the home of fastest-growing economies of the world. Since 2000, GDP per capita in SSA has grown by almost 5% per year, compared with 2.4% in the two preceding decades despite being one of the poorest regions in the world (Leke et al. 2010).

Given sub-Saharan Africa's historical legacy, most of the region's educational systems have been modeled largely on their European counterparts. Although sub-Saharan educational institutions have been modified partially to respond to local conditions, by and large, formal educational programs reflect the basic primary, secondary, and higher education structures and standards found in European countries. For most sub-Saharan countries, this meant that educational policy and the allocation of resources to education have taken place essentially through the public sector rather than through the private sector, at the national level rather than at the local level, and frequently through the coordination of educational policy targets with national development planning of one form or another (LeBel 2000).

Although all countries in SSA have education policies to guide how the provision of education throughout the country, not all countries in SSA have ICT policy in education. Most sub-Saharan African countries with ICT in education policies are progressively integrating information and communication technologies (ICTs) into their education systems especially in primary and secondary schools with a particular emphasis on improving the quality of subject teaching and learning.

A recent report from the UNESCO Institute for Statistics (UIS) has found that, despite the development of ICT in education policies, the integration of technology in classrooms across sub-Saharan Africa remains insufficient to meet the needs of the twenty-first-century labor market (UNESCO 2015).

ICT in education is widely accepted as both enabling learning and preparing students for employment in a technology-rich workplace. But in sub-Saharan Africa, barriers – including a lack of effective policies, basic infrastructure (i.e., electricity, the Internet, computers, and mobile devices), financing, and teacher training – mean that the use of ICT in education is still at an embryonic stage in most countries (UNESCO 2015).

In the UNESCO report, the most pervasive barrier is the lack of electricity, especially in remote, rural areas where most of the primary schools are. ICTs are more likely to be found in urban schools, where access to electricity and the Internet enable computer-assisted instruction and online learning. In addition, Hennessy et al. (2010a) concluded that a primary barrier to ICT integration in SSA is teachers' "readiness and confidence" in using ICT.

Recent Developments on ICT in Sub-Saharan Countries

Although ICT integration in education is facing many challenges in SSA, the use of ICT, especially of mobile communications, has increased exponentially in other sectors of society in the past decade (Etzo and Collender 2010). Mobile communications are seen as the fastest-growing market, and the outlooks show large potential (World Resources Institute [WRI] 2007). Unavailability of electricity has been the biggest hindrance to the growth of ICT in the region, especially in remote and rural areas. It is becoming common to talk of a "mobile revolution" sweeping the region, with mobile phone use spreading quickly, geographically, and socially, accompanied by novel applications, impacting on other areas of economic life. The quick spread to some extent is caused by easy means to charge mobile devices without depending on electricity supply from the national grid. The percentage of the population having access to a mobile phone is already bigger than the share of the population having access to electricity. Mobile phones have spread quickly, not only addressing the huge demand for communication but also substituting for products like bank accounts, newspapers, entertainment, medical advice, and training, to which many people previously had no access (Aker and Mbiti 2010). Building the necessary connection infrastructure has considerably advanced, and digital devices are becoming more affordable. In 2009, sub-Saharan Africa began to see its first international submarine fiber-optic cable connections. They brought with them much faster and a bit cheaper, the Internet. The Internet still has to catch up with the mobile sector, but there are encouraging signs that it will do so. The whole continent is ranked the last in Internet use, and most Internet access takes place on mobile phones (ITU 2016).

However, general literacy and digital skills across the population are generally low, and it needs to be improved in order for countries in the region to fully reap the benefits of the digitalization, and this is a more difficult challenge to tackle.

Albimana et al. (2016) found that mobile phone and the Internet have triggered economic growth in SSA region. They also found that except for financial development, human capital, institutional quality, and domestic investment were the main growth-enhancing transmission channels of ICTs use in the economy. Other studies have shown that there a number of initiatives to ensure ICTs are having an impact on many sectors of the economy, from access to basic amenities like electricity supply and clean water to financial transactions.

In SSA, few people have a bank account, and this gap has been filled by mobile transactions. In Kenya, for example, more than two-thirds of adult population use m-banking for transferring money, making payments in stores, paying bills, and making online purchases. Similar mobile money services have proliferated in SSA with varying degrees of success, but SSA remains the region in which mobile money is most widely spread (Aker and Mbiti 2010).

Agriculture is the largest sector of the SSA economy, the use of new digital applications has hugely benefited the farmers. Farmers' organizations are using a text message service or a mobile communication platform, to inform farmers about market prices and link them with potential buyers. Digital platforms are also used to provide practical information about growing methods, market trends, weather information, and warnings and advice about plant and animal diseases and in financial transactions related to agriculture (Aker and Mbiti 2010).

Mobile technology is hugely transforming the way health care is delivered in SSA, considering the region has an acute shortage of medical staff. Numerous projects have been developed, providing health information for pregnant women, advice to youth on sexuality, helping identify counterfeit medicine, helping with self-diagnosis and the search for a physician, and even in providing an e-learning and communication platform for medical staff (Fayoyin 2016).

Digital communications, especially social media and news platforms, are used to help improve governance, by enabling access to public information online, increasing transparency and accountability, and promoting better interaction between citizens and government to improve efficiency through provision and their services to citizens online, for example, tax collection and safely reporting cases of corruption. More and more SSA countries are using an electronic system of voter registration based on biometric identification (UNDP 2010).

e-Learning initiatives are certainly underway in many sub-Saharan African countries, particularly in higher education institutions. However, access to ICT remains deficient in many parts of SSA. Many schools are still not connected to the electricity grid, and digital devices are unaffordable to many children. Even when digital devices are made available to schools, they are not always used effectively as very few trained teachers with ICT pedagogy are available. ICT can provide a solution to the problem of shortage of teachers in schools, through the use of digital devices and platforms and by overcoming physical distance. The mobile phones can improve access to education in the region, though promoting new learning is yet questionable (Valk et al. 2010).

The potential uses of ICT promise a transformative impact on economic, social, and political life, spurring development in numerous areas. If current trends continue, more and more people will see their life touched by these new technologies. It is also important to remain aware of the potential limitations of the new technologies, which cannot fully substitute, for example, for other major drivers of economic growth or for real teachers and schools.

Recent Developments on Policies on ICT in SSA Region

Efforts of reforms in sub-Saharan education systems are geared toward achieving United Nations millennium development goals (MDGs) and *Education for All (EFA).* Neither the MDGs nor EFA provided concrete objectives or goals related to the role of ICT in education. Despite some progress, universal attainment of the goals remains distant. Nonetheless, education is the key to sub-Sahara's future, and if it is to do what is expected of it, technology has to be at the heart of it. The continent's education ministers adopted a 10-year plan in which science and technology teaching was to undergo reform at all levels of sub-Saharan educational systems (African Union [AU] 2006). The plan aimed at improving learning outcomes, promoting the use of indigenous knowledge, and encouraging more girls to pursue scientific careers. Science and technology education is seen as the most important tool in existence for addressing challenges to development and poverty eradication and for participating in the global economy. Technologies such as ICT are perceived and therefore employed to bring the plan to success.

In all regions of the world, the penetration of ICT in schools has led to a major transformation of the education landscape which brought about increase in economic productivity through digital economies, enhancing the delivery of public and private services and achieving broad socioeconomic goals in education, health care, employment, and social development.

The task for the education sector in SSA is therefore to identify ways of creating necessary conditions within the education system to maximize the benefits of ICT and thus support development. Proper acquisition of skills for productively transforming knowledge and information into innovative products and services will define successful knowledge economies and societies. Because knowledge and information have become the most important currency for productivity, competitiveness, and increased wealth and prosperity, nations of the region have placed greater priority on developing their human capital. The sub-Saharan governments at different levels are thus focusing on strategies to increase access to and improve the quality of education through ICT (United Nations Economic Commission for Africa [UNECA] 2003).

Mansel and Wehn (1998) noted that knowledge and human capital are essential to all aspects of development. They further observed that key to this form of development is to ensure that all people in a country have the ability to acquire and generate knowledge. This is where information technologies become vital. They are the primary tools to enable the acquisition, generation, access, and use of knowledge that forms the bedrock of effective development. ICT needs to be enhanced by an ICT policy that ensures people are capable of using it to source and assimilate information and transform it into useful knowledge. ICT policy often defines broad strategies and approaches to issues; sometimes policies establish more specific actions. The rapid integration of ICT into learning environments raises many issues that demand the development of effective ICT policy. ICT policy issues are particularly diverse and challenging, in part because the rapid rate of change in the technology continues to create new possibilities for use and the need to find the best ways to implement them.

Zlotnikova and van der Weide (2011) proposed a framework for developing and improving ICT educational policies in countries of sub-Saharan Africa, as well as a tool for evaluation of ongoing ICT educational projects and success forecasting of future projects. The model has components and parameters. Components proposed are influenced by numerous parameters (economic, political, demographic, technological, and cultural).

Development and implementation of ICT policy in education have started in SSA though vary in emphasis and dimension from country to country. Some countries piloted ICT use in schools and trained teachers without an ICT in education policy, for example, Kenya, Uganda, and Tanzania, and later developed one. Others, for example, Mauritius, find it important to have the policy to serve as a framework and guide. Better economic advantages made South Africa spearhead developing and implementing ICT policies in its education system. Integration of ICT is a low priority when compared to other educational objectives in most SSA countries. Despite the development of ICT in education policies, use of ICT in education is still at an embryonic stage in most countries; the integration of technology in classrooms across SSA remains insufficient to meet the needs of the twenty-first-century labor market.

Relevance of Cross-National and Worldwide Strategies and Plans for SSA

Studies of ICT development in both developed and developing countries identify at least four broad approaches through which educational systems and individual institutions typically proceed in their adoption and use of ICT (Anderson and Van Weert 2002). Sometimes, the number of stages identified varies. However, there is a consensus that the introduction and use of ICT in education proceed in broad stages that may be conceived as a series of steps. These steps, termed emerging, applying, infusing, and transforming, are elaborated in Fig. 1:

– *Emerging*: In this initial phase, administrators and teachers are just starting to explore the possibilities and consequences of using ICT for school management and adding ICT to the curriculum. In this phase, ICT infrastructure is either donated or purchased by the school authority.

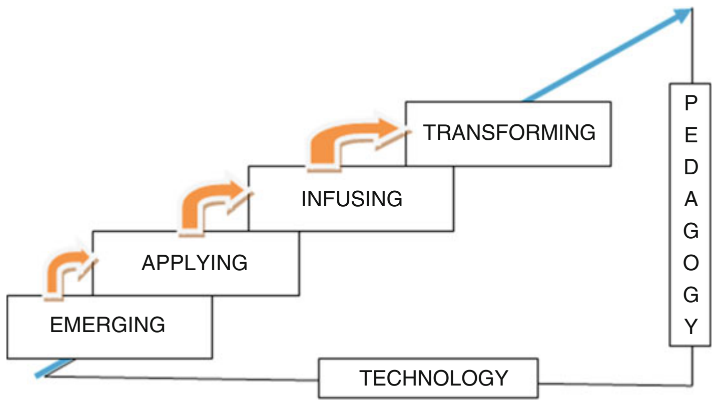

Fig. 1 Stages of IT development

– *Applying*: In this step, administrators and teachers use ICT for tasks already carried out in school management and in the curriculum. For example, schools adapt the curriculum in order to increase the use of ICT in various subject areas with specific tools and software such as drawing, designing, modeling, and application-specific tools.
– *Infusing*: It involves integrating or embedding ICT across the curriculum and is seen in those schools that employ a range of computer-based technologies in laboratories, classrooms, and administrative offices. ICT infuses all aspects of teachers' professional lives in such ways as to improve student learning and the management of learning processes.
– *Transforming*: In the final stage, ICT becomes an integral though invisible part of daily personal productivity and professional practice. The focus of the curriculum is now learner centered and integrates subject areas in real-world applications.

The steps represent a continuum of approaches to ICT development. The continuum model presented can be mapped onto two interwoven tracks for the development of teachers' capacity in harnessing information and communication technology with regard to (a) stages of ICT usages and (b) pedagogical usages of ICT as shown in Fig. 2.

Figure 2 shows the stages of ICT usages in terms of awareness, learning how, understanding how and when, and specializing in the use of ICT tools according to the stages of the proposed model:

In becoming aware of ICT – Teachers and learners become aware of ICT tools and their general functions and uses. Usually, the emphasis is on ICT literacy and basic skills.

Learning how to use ICT – It involves the use of general or particular applications of ICT and is linked with the *applying stage* in the ICT development model.

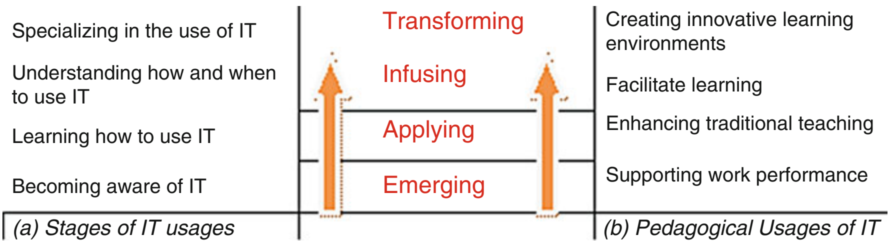

Fig. 2 Mapping the model

Understanding how and when to use ICT – It implies the ability to recognize situations where ICT will be helpful, choosing the most appropriate tools for a particular task and using these tools in combination to solve real problems.

Specializing in the use of ICT – It demands specializing in the use of ICT tools which occurs when one enters more deeply into the learning environment that creates and transforms the learning situation with the help of ICT.

Studies of teaching and learning in schools around the world identify four broad stages in the way the teachers and learners use ICT as a support for teaching and learning that have been broadly classified as supporting work performance, enhancing traditional teaching, facilitating learning using multimodal instruction, and creating innovative environments, according to the stages of the proposed model:

Supporting work performance – In this initial stage, teachers use productivity tools such as word processor, visual presentation software, spreadsheet, database, email, etc. to support their daily work performance.

Enhancing teaching – It entails techniques for integrating computer-based learning in the traditional instructional process through use and developing computer-assisted learning software and beginning to make use of such software in different disciplines.

Facilitating learning – It indicates the ability to recognize situations where various multimedia, simulation, and modeling software can be utilized for teaching and learning. Teachers learn how to choose the most appropriate tools to solve real-life problems.

Creating innovative learning environments – It involves specializing in the use of network-based resources to create a meaningful environment with rich and affordable innovative learning models. This occurs when one enters more deeply into the shared learning environment that creates and transforms the learning situation.

Countries in the sub-Saharan region are at different stages of ICT policy implementation, in terms of infrastructure, curriculum, content development, technical support, and usage of ICT in the teaching and learning process. In the typical sub-Saharan schools equipped with ICT, computers are often secondhand and are more frequently available for secondary education; electricity supplies are unreliable; access to computer rooms is limited by the competing demands of teachers, students, and administrators; and Internet availability ranges substantially within the region. Owing to lack of training and familiarity with computers, teachers do not know how to browse effectively and find Internet materials and are not familiar with the educational software. These differences are not only varying from country to country but even within the individual countries. There are uneven developments from region to region, area to area, and even from institution to institution. National priorities and strategies for ICT implementation in education differ widely from system to system. Although there is variation in terms of the structure of education systems and other aspects of the economic and social context, there are also strong similarities in the pathways of change in terms of the goals of introducing ICT in education. Most countries have established formal recommendations to integrate ICT in at least some subject areas; the level and grades recommended for integrating ICT in curricula vary. For example, in South Africa recommendations for integrating ICT begin in primary education and cover all subjects and grades, whereas in Côte d'Ivoire and Zambia formal, recommendations exist for some grades in primary education and then all grades in secondary education. In Tanzania, ICT is offered as a subject from primary to tertiary levels, while integration in a subject is mostly at secondary school level. Integrating ICT in curricula is least common in Gambia, Madagascar, and Sao Tome and Principe where they begin only at the upper secondary level. In Burkina Faso, Comoros, Guinea, Niger, and Togo, there are no formal recommendations at all for integrating ICT across subjects or education levels (UNESCO 2015).

In view of the abovementioned observations, a framework to be able to situate a country in its development of ICT in education policy is helpful. The framework might also be useful to show the interrelationship of various components of ICT implementation and in portraying how complex systems operate. The framework (see Table 1) provided by Moonen (2008) is used to situate the ICT in education policies of sub-Saharan countries. The status of ICT in African countries information to fill in the framework was gleaned from a variety of sources (Farrel and Shafika 2007; GESCI 2011; UNESCO 2015).

From Table 1 it is clear that only three countries in the region are without ICT policy. Equatorial Guinea and Guinea Bissau have a lot of uncoordinated ICT in education activities going on, initiated mostly by the private sector and civil society. Somalia has been without a stable government for the past 25 years. Since the transitional federal government (TFG) came into power, a lot of effort through various international organizations, notably UNICEF and the UNESCO, has been to increase primary school enrolment and improve access to postprimary education including technical, vocational, and higher. The seemingly healthy ICT infrastructure in the urban centers supports the use of ICT in schools (ITU 2006).

Almost all sub-Saharan countries currently have either ICT policies or ICT educational policies or both and have started to implement the policies either on an ad hoc or small project basis. In Botswana, for example, they have a revised national policy on education that emphasizes the importance of proficiency in computer use by students and their teachers. Also, the Ministry of Education has

Table 1 A summary of ICT implementation in sub-Saharan countries

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy
National/subnational policy document for IT in education	Eq, Gw, So	Cm, Co, Cg, Ls, Mg	Bj, Bf, Bi, Cv, Km, Cg, Ci, Dj, Et, Gh, Gm, Si, Sz, Zm, Zw, Gn, Ke, Mg, Mw, Ml, Mz, Na, Ng, Rw, Sn, Sd, Tz, Ug	Mr, Sc, Za	
Master plan with a time frame			Bj, Bf, Cv, Km, Cg, Ci, Dj, Et, Gh, Mg, Ml, Mz, Na, Ng, Rw, Sn	Mr, Sc, Za	
Budget plan and appropriations			Na, Rw	Mr, Sc, Za	
Organizational structure responsible for implementing the master plan		Cm, Co, Gw Cg, Ls, Mg	Bj, Bf, Cv, Km, Cg, Ci, Dj, Et, Gh, Mg, Ml, Mz, Na, Ng, Rw, Sn	Mr, Sc, Za	
Monitoring and evaluation scheme or mechanism implementing the master plan		Bj, Bf, Bi, Cv, Km, Cg, Ci, Dj, Et, Gh, Gm, Si, Sz, Zm, Zw, Gn, Ke, Mg, Mw, Ml, Mz,Na, Ng, Rw, Sn, Sd, Tz, Ug	Mr, Sc, Za		
Statement of inclusion of women, minorities, and those with special needs in IT policy			Bj, Bf, Cv, Km, Cg, Ci, Dj, Et, Gh, Mg, Ml, Mz, Na, Ng, Rw, Sn, Zm	Mr, Sc, Za	

(*continued*)

Table 1 (continued)

	No policy yet	Emerging policy	Applying policy	Infusing policy	Transforming education by policy
Manner by which the country and schools implement IT for education if no IT policy exists		Cm, Co, Gw, Cg, Ls, Mg	Ao, Bw, Ga, Ls, Sw, Zm		

Abbreviations of countries: *Ao* Angola, *Bf* Burkina Faso, *Bi* Burundi, *Bj* Benin, *Bw* Botswana, *Cd* DRC, *Cf* Central Africa Republic, *Ch* Chad, *Cg* Congo, *Ci* Cote D'Voire, *Cm* Cameroon, *Cv* Cape Verde, *Co* Comoro, *Dj* Djibouti, *Eq* Equatorial Guinea, *Er* Eritrea, *Et* Ethiopia, *Ga* Gabon, *Gm* Gambia, *Gh* Ghana, *Gn* Guinea, *Gw* Guinea Bissau, *Ke* Kenya, *Lr* Liberia, *Ls* Lesotho, *Mg* Madagascar, *Ml* Mali, *Mw* Malawi, *Ma* Mauritania, *Mr* Mauritius, *Mz* Mozambique, *Na* Namibia, *Ni* Niger, *Ng* Nigeria, *Rw* Rwanda, *Sc* Seychelles, *Sd* Sudan, *Si* Sierra Leone, *Sn* Senegal, *So* Somalia *St* Sao Tome and Principe, *Sz* Swaziland, *Tg* Togo, *Tz* Tanzania, *Ug* Uganda, *Za* South Africa, *Zm* Zambia, *Zw* Zimbabwe

pursued an aggressive roll-out campaign to equip all secondary schools with a fully networked computer laboratory with at least 20 computers and access to the Internet. Teachers are prepared for the integration ICT into, and across, the curriculum; heads of schools are also trained to support resourcing initiatives. In addition, computer-integration support officers are trained to pass ICT skills to their colleagues at the school level. ICT is taught as a subject and but is not examinable (Garegea and Moalosi 2011).

Tanzania started by ensuring teachers' colleges gets equipped with basic ICT infrastructure, and all graduates from the colleges are ICT literate and have basic skills to integrate ICT in the curriculum (Mendes et al. 2003; Hennessy et al. 2010b). The college's curriculum also supports the integration. Few public primary schools have ICT integrated into the curriculum though the curriculum has ICT as a subject. Few public secondary schools are supported with ICT infrastructure and the Internet. In Kenya, the government launched a multimillion ICT Trust Fund and committed to providing 2500 of the 3500 public secondary schools in Kenya with computers, but the challenge is employing the technology to improve student learning (Mwangi 2014; Hennessy et al. 2010b). In Nigeria, several initiatives by government, civil society, and the private sector managed to acquire hardware, but the challenge is its integration into the curriculum to benefit learners (Oshionebo and Ashang 2011). Similar stories are evident in other sub-Saharan countries.

Only Mauritius, Seychelles, and South Africa are barely in the infusing stage of policy implementation. The two islands are more advanced because of their small population and the more dynamic nature of the ethnic composition of the population. The main resource of Mauritius Island is human capital; the government is committed to making ICT the fifth pillar of its economy and also intends to convert the island into a "cyber island" (Eastmond 2006; Lincoln 2006), and ICT is used in most schools from primary level. For Seychelles, the Ministry of Education has developed an ICT master plan (Ministry of Education [MOE] 2000) since the year 2000 with goals and strategies to use ICT. There are policies promoting the use of ICT across the system at both organizational and capacity building levels. The use of ICT in educational processes at schools and at higher education levels has become a main priority for the Seychelles government (Chisholm et al. 2004). South Africa, on the other hand, is a much bigger country, and her economic muscle enables integration of ICT in the curriculum to quite a high number of schools. The South Africa in e-education white paper (Department of Education [DOE] 2004) emphasized support ICT integration in teaching and learning and improved management and administration, competencies for teacher development in the integration of ICTs into the curriculum, connectivity, and high-quality content. The challenge that the country is facing is a digital divide between rural and urban schools.

Challenges and Relevance of Research for Policies on ICT in Education in SSA

At the beginning of 2006, 28 of the sub-Saharan countries had developed national ICT policies aimed at ameliorating the realization of national development goals (UNECA 2006). These policies were general in the sense that it was at the discretion of each government ministry to develop appropriate implementation strategies. ICT policy for education implementation strategy is vital for it to impact societies in the region by revolutionizing the learning and teaching processes, opening new learning opportunities and access to educational resources well beyond those traditionally available, and impacting curriculum development and delivery.

However several challenges impede the revolution. These challenges include inadequate ICT infrastructure, unskilled manpower, resistance to change by teachers, underfunding of the overall education system, over-dependence on the government for everything, ineffective coordination of ICT initiatives, and sustainability (Grant 2004; Tearle 2003).

In view of the abovementioned challenges, the ICT policies in education in sub-Saharan Africa must address at least five strategic objectives: ICT professional development for management and teaching and learning; electronic content resource development and distribution; access to ICT infrastructure; connectivity, community engagement; and research and development (UNESCO 2004).

Naidoo (2003) noted that attempts to integrate ICT into the education system entail the leadership of the government and the education ministry, working together with other relevant ministries. Leadership must have a clear vision of the mechanism that the government intends to use and to implement ICT. This vision then needs to be integrated with national policies. Walker (1989) observed three preconditions for a successful introduction of new information technologies into an education system, these being an appreciation by the government of the financial, resource, and operational requirements and the resulting consequences; a commitment by the government to give time and take responsibility for decision-making and implementation strategies; and commitment to an integrated support service encompassing teacher and technician training, curriculum, and assessment, together with software and hardware provision. Such an approach helps to build ICT within a broader environmental context of the education system, covering economic and social infrastructure and policies and global market conditions.

Also reflecting this broad context, UNESCO (2004) proposed generic elements that any policy on ICT in education should cover. These are a careful analysis of the current context that the country finds itself in with respect to the type of society and economy that is being built and the education system necessary to contribute to it, research and analysis of international developments and trends in ICT use in education, and an outline of the key issues that need to be addressed, together with proposed methods of doing so.

From experiences in Asian countries, UNESCO recommends a holistic approach to ICT in education policy implementation. This considers crucial aspects such as the curriculum, assessment, ICT resources, professional development of teachers, research and development, and fund generation. Once policy and an implementation strategy for using ICT in the education system are developed, the next step is ensuring that the policy is integrated into the general education policy and other related policies.

The challenge of providing ICTs to sub-Saharan schools in order to enhance the quality of learning and teaching requires a significant investment. Research contribution in providing solutions on how to prepare school to accept ICT; procure and install technology; train teachers to use ICT; integrate it into the curriculum, content development, and management; and plan for continuous evaluation and research, provision of curriculum, and technical support and developing partnership is necessary.

There are success stories of ICT in education which research has contributed much and SSA can emulate. The Dutch Kennisnet Four in Balance model is one example. According to the model, introducing ICT for educational purposes has a greater chance of success if four basic elements – vision (how an educational institution envisages qualitatively sound and efficient education, how it intends to achieve it, and what ICT's role will be), expertise (the competencies that staff must have to make satisfactory use of ICT), digital learning materials (the information, educational content, and software used in an educational institution), and ICT infrastructure (the availability and quality of hardware, networks, and connectivity within the institution's education system) – are in balance (Ict op School 2004). In essence, successful introduction of ICT in education involves striking the right balance between vision, expertise, content and applications, and infrastructure. Having better technical facilities does not automatically lead to more computer use. Considering the human elements alone (e.g., making a vision explicit in a policy plan or receiving training) will not lead to the long-term use of ICT if the necessary technical facilities are not available at the same time. It is possible to strike the right balance between the human and technical elements of the stakeholders – teachers, school managers, and school boards – that work together. Since its creation, the model has proven its added value in the implementation of ICT in Dutch schools.

Another example is Enlaces network, a national information and communication technologies and education initiative designed as part of a series of programs to overcome inequity and quality issues of public education in Chile, by integrating teachers and learners into the knowledge society. It has provided basic infrastructure tools, connectivity, ICTs, and teacher training to a huge number of schools (Sanchez and Salinas 2008). Though the network results are limited in classroom learning, there are plenty of lessons to learn from it.

Perspectives for Developments in SSA and Emerging Themes/ Perspectives

According to Cambridge dictionary, development is the process in which someone or something grows or changes and becomes more advanced. Many SSA countries have seen some of the world's highest economic growth rates in the past decade, which has led to high levels of economic optimism for the future. The growth of economy should have been a sign of development, but real income growth has failed to keep pace with population growth and other related areas such as education, health care, poverty, etc. World poverty has decreased over the last few decades. However, in sub-Saharan Africa, the situation has not improved: In 1981 half the population lived on less than 1 USD a day, and in 2005 this was still the case. Today, the percentage of people living on less than $1.25 a day in SSA (41%) is more than twice as high as any other region (such as Southern Asia, with 17%). Of all sub-Saharan African countries, just Mauritius saw a consistent drop in poverty rates between 1970 and 2003. In all other sub-Saharan African countries, poverty only improved in one or two aspects regarding chronic poverty or not at all (de Haan 2010).

Perhaps more surprising, however, sub-Saharan African countries perform poorly when it comes to converting their limited wealth into well-being (better life for their citizens), too. Although few countries like Ethiopia are doing very well in the conversion of economic growth into the improvement of the well-being of citizens, most are not doing so. Poor governance and corruption seem to be the stumbling blocks in achieving conversion of wealth to well-being. Africa is widely considered among the world's most corrupt places; a factor is seen as contributing to the stunted development and impoverishment of many African states. Of the 20 countries considered most corrupt in the world, 10 are in sub-Saharan Africa, according to Transparency International (2016), a leading global watchdog on corruption.

Though generally, the situation is SSA sound bleak, the region is full of tremendous development promises. Emerging out of decades of stagnation, the region is now home to seven of the world's ten fastest-growing economies. The significant strides in sub-Saharan Africa's socioeconomic progress have helped to grow a vibrant middle class and propel technological advancements at a rapid pace. Lessons learned from countries performing well in the region clearly show that success in raising standards of living relies in large measure on a combination of four critical factors: strong political commitment, disciplined prioritization of key objectives, well-crafted policies that reflect local realities, and effective systems for delivering change. In the landlocked nation of Ethiopia, novel approaches are driving significant improvements in providing primary health care for rural populations. At the same time, government policies in Ghana have made that country one of the region's most attractive investment centers and are contributing to the emergence of a robust information technology industry. And political stabilization in resource-rich Angola after decades of war has fostered major progress, including the rebuilding of the nation's infrastructure. These improvements illustrate an inescapable truth: governance matters. In fact, advances in governance constitute the single largest differentiator between the sub-Saharan African countries with the greatest improvement (Africa Economic Outlook [AEO] 2016).

The region has a potential which if well planned can be harnessed for future development. Africa is the world's most youthful continent. Today, nearly 50% of sub-Saharan Africans are under age 15. Africa's young people are the future leaders and will be the driving force behind sustainable growth across the continent. Over the next 20 years, as both infant mortality and fertility rates decline, sub-Saharan Africa will become the main source of new entrants into the global labor force. This is a trend with significant ramifications for both the region and the global economy. Under the right policies, the region could indeed benefit from a substantial demographic dividend, but the magnitude of that dividend will depend critically on the speed of decline in fertility rates and on the strength of accompanying policies. Hence, investment in education and training is essential in building an educated and skilled workforce and to encourage innovation (Africa-America Institute [AAI] 2015).

Education required in SSA region need to cater for local needs such as the provision of clean and safe water, health care, agriculture, etc. (which will eventually eradicate poverty) in addition to fulfilling twenty-first-century skills (Kamehameha Schools Research & Evaluation 2010) to be successful. This type of education will produce individuals who are critical thinkers, problem solvers, and skilled in information literacy, with mastery in a different kind of knowledge required in changing economies worldwide. The success of graduates from this education lies in being able to communicate, share, and use the information to solve complex problems, in being able to adapt and innovate in response to new demands and changing circumstances, in being able to command and expand the power of technology to create new knowledge. ICT will play a key role in this; hence good ICT policy in education and investment in ICT integration and teacher education is necessary.

Other possibilities to augment or complement education also exist. Rodríguez-Pose and Tijmstra (2005) proposed local economic development (LED) as an alternative approach to economic development in SSA region. LED is an approach toward economic development which allows and encourages local people to work together to achieve sustainable economic growth and development**.** LED helps to build up the economic capacity of a local area to improve its economic future and the quality of life for all. It is a process by which public, business, and nongovernmental sector partners work collectively to create better conditions for economic growth and employment generation.

Reflections and Future Steps to Improve the Introduction of ICT in Education

A phased implementation of ICT policy in education ensures that the implementation process is manageable and the development of best practices and lessons learned is gradual. The following factors are worth considering.

ICT infrastructure is the backbone of the ICT venture in education. Therefore it is important that sub-Saharan African governments mobilize support from telecommunications and ICT organizations and industry to promote affordable Internet connectivity and computer hardware and software. High costs of telecommunications prohibit schools from adopting ICT, especially in the rural areas. But technological innovation and the decreasing costs of wireless and other technologies, combined with progressive policy and regulatory environments, have resulted in the provision of telecommunication services to remote areas in Latin America, Central Europe, and Asia (UNESCO 2004). This is also possible for sub-Saharan Africa. In addition, the proliferation of mobile phone networks has transformed communications in sub-Saharan Africa. The mobile phone is fast becoming the PC of Africa. In many countries, mobiles are the only channel for effectively distributing reading material, given the high cost of books and their distribution, especially in rural areas. Mobile devices offer interactivity, the ability for readers to comment on content, to connect with other readers, and to publicly ask questions and receive support, and can deliver appropriate and personalized content, in ways that print books cannot.

The sub-Saharan governments need to be careful to avoid past failures of investment in computers and connectivity that emphasize on quantitative benchmarking based on rough indicators such as pupils per computer or investment in the technological infrastructure, investing in ICT infrastructure solely while forgetting developments in teacher training, content, partnership, and organizational and regulatory frameworks to promote participation of private providers in the development of ICT in education (Robertson 2003).

Having a comprehensive ICT policy in each of the sub-Saharan countries is something unavoidable if the region is serious about preparing future generations for a knowledge economy. On contemplating what is required of policymakers, the following ideas are put forward:

- The educational transformations associated with technology are that technology is not a mere ingredient that “boosts” teaching and learning. Rather, it is part of a collective project of educational communities, and the outcomes of that undertaking depend on a multitude of decisions at the local (schools) as well as the national and global level.
- Research input into the implementation process is important, but we need to reconfigure the systems of educational research and teaching so that we can respond more quickly and establish a more dynamic knowledge base on questions of ICT use in education. Through research, justification of continued investment of funds for ICT in education can then be

made, and educators, policymakers, educational researchers, and the public will know what can be gained by using technology in schools and at what costs.

- ICT has the potential to enhance access, quality, and effectiveness in education in general and to enable the development of more and better teachers in sub-Saharan Africa. Capacity building of the key transformers in this process, namely, teachers, is paramount to the success of ICT integration in the curriculum. Also, the focus needs to be on the integration of well-designed technologies in the context of meaningful, mindful inquiry projects, nonpresentational pedagogies, access to resources and tools, and adequate support for technological maintenance and pedagogical renewal.
- One of the phenomena of recent times has been the enthusiasm with which Africans have adopted mobile phone technology (BBC 2014). Lower smartphone prices are driving a digital revolution in Africa, allowing mobile phone users to access the Internet at unprecedented levels. In many countries, mobile phones are the only channel for effectively distributing reading material, given the high cost of books and their distribution, especially in rural areas. Nokia capitalized on the growing popularity of social networking in South Africa to launch MoMath, a mathematics teaching tool that targets users of the instant messaging platform Mxit in South Africa (SchoolNet South Africa 2012). The potential for transforming the continent's dysfunctional educational system is immense, as mobile phones – cheaper to own and easier to run than PCs – gain ground as tools for delivering teaching content. It is hoped that mediating education through social networking will help reduce the significant numbers of school-age African children who are not receiving any formal education. However, the mobile phone can be disruption to teaching and learning, hence a need to promote responsible phone use in school. It is important to have a clear school policy on pupil phone use, to inform parents about this, and to explain the reasoning behind it. Policymakers need to seriously think about how to fuel the demand for ICT in their educational systems through mobile phone-facilitated learning in contributing to improving learning outcomes.

Conclusion

The level of development and culture in North Africa is more or less the same as Middle East countries.

Cross-References

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Information and Communication Technology and Educational Policies in Primary and Secondary Education in the Middle East and North African (MENA) Region

86

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Abstract

The chapter refers to policies toward information and communication technology (ICT) in primary and secondary education from the perspective of Middle East and North African region (MENA). The MENA region includes countries that vary in culture, language, religion and resources. Since it is quite difficult to cover the whole region, the researchers excluded some countries (i.e. Cyprus, Iran, Israel, & Turkey) that only share the geographical location with the other countries in the region. The analytical approach had been used to provide information on how policy deals with integrating ICT in teaching and learning in primary and secondary education in MENA region. Trends and developments are identified by analysing policy plans and strategies. Six main trends were identified in the region. The trends include using ICT in primary and secondary education to increase access to formal education, using ICT to improve teaching and to prepare students for future jobs, using data to align learning with job market, analysing performance for personalize learning, and utilizing online learning for learning and skills development. The most important finding of this section is that countries in the MENA region are willing to move forward the adoption of ICT in education by increasing their spending on planning and implementing ICT in education. However, the process of planning and implementation is not always successful due to different factors. The main challenges were: financial challenge, less attention given for the pedagogy behind ICT integration, resistance from actors, lack of cooperation, contextual challenges, technical challenges, and social and political challenges.

Keywords

ICT · MENA region · ICT policy · Primary education · Secondary education · K12 education · ICT integration in education

Introduction to ICT in Primary and Secondary Education in the Middle East and North African (MENA) Region

This chapter discusses information and communication technology (ICT) in primary and secondary education in 23 countries (Table 1) from the Middle East and North Africa, known as the MENA region. Some countries in the region share similar characteristics (e.g., language, culture, and religion), while other countries only have the geographical location as a common feature with the others. The aim of this

Table 1 MENA region

Number	Countries of the Middle East (ME)	Subregion	Countries of North Africa (NAR)
1.	Cyprus	Omitted	Algeria
2.	Iran		Egypt
3.	Israel		Libya
4.	Turkey		Morocco
5.	Bahrain	Arabian Peninsula	Sudan
6.	KSA		Tunisia
7.	Kuwait		Western Sahara
8.	Oman		
9.	Qatar		
10.	UAE		
11.	Yemen		
12.	Iraq	Fertile Crescent	
13.	Jordan		
14.	Lebanon		
15.	Palestine		
16.	Syria		

chapter is to cover ICT policies in education in MENA; since it is quite difficult to cover the whole region, we offer some guidelines and notes below to provide an overview of the region.

First, we excluded some countries as being part of MENA since their only connection is through their geographical location; these countries are Cyprus, Iran, Israel, and Turkey. Second, the remaining countries were grouped into three main regions based on similar characteristics such as sharing the same culture and geographical status. Those three regions, presented in Table 1, are (1) Arabian Peninsula countries (Bahrain, Kingdom of Saudi Arabia [KSA], Kuwait, Oman, Qatar, United Arab Emirates [UAE], and Yemen), (2) Fertile Crescent (Iraq, Jordan, Lebanon, Palestine, and Syria), and (3) North Africa (Algeria, Egypt, Libya, Morocco, Sudan, Tunisia, and Western Sahara).

Throughout the chapter, we tried to include various examples from MENA to support our claims. At the same time, the limited articles and research conducted in many of these countries limited our option of including examples of all countries in the region. So, we tried our best to include a variety of examples that represent different countries as much as possible.

Information and communication technology (ICT) in education was introduced in the MENA region as a result of national policies adopted by the governments with the help of international organizations (UNESCO 2013). Generally, in any educational reform, certain contextual challenges must be taken into consideration to effect any real change (Al Dakkak 2010). The MENA region possesses contextual factors which are unique to the region and which can affect ICT reform.

For any reform to work, there should be a strong commitment from the governmental leadership about the direction that needs to be taken (Al Dakkak 2010). The administrators must implement a long-term (5, 10, or 20 years) state-owned strategy regardless of the changes that may take place in the government and ministry (Al Dakkak 2010). Also, there should be clear plans to review, evaluate, and redesign the ICT policy and conduct real assessment and monitoring of what is happening inside the classroom. In addition, the decision-makers should address implementation steps or a road map of how ICT policy will be implemented inside the classroom. The involvements of the community's stakeholders, businesses, and parents in the reform process are important factors, and they help offer a clear vision and set standards and expectations that should be considered (Al Dakkak 2010).

The implementation and use of ICT in education lag behind in the MENA region (Chapman and Miric 2009). At the same time, in many MENA countries, children and youth learn more about how to use various ICT tools informally outside of the school system (UNESCO 2013). An example of mass usage of ICT that surpasses current capacity within the educational system and schools is the case of Egypt during the Arab Spring of 2011, when the youth efficiently used mobile devices and the Internet to communicate and organize the protest.

Recent Development of ICT in the MENA Region

Over the years, the MENA region countries have gone through many significant changes. One of these changes is the development and implementation of ICT. In this section, we consider the ICT implementations in the MENA region and present examples from specific countries in the region.

Introducing ICT/Computer Literacy as a Separate Subject

Kuwait, Jordan, Oman, and Qatar have specific objectives or courses at all three levels of primary and secondary education regarding the inclusion of basic computer skills (or computing) in their curricula (Alayyar 2011; UNESCO 2013). However, this is not the case in KSA, Egypt, and Palestine, where courses that cover basic computer skills are lacking in primary education. They are only introduced in secondary education (UNESCO 2013; Al Mofarreh 2016). While many children in KSA, Egypt, and Palestine may be learning informally how to use ICT, children who are the most disadvantaged economically or geographically will likely continue to be deprived.

ICT Infrastructure and Models for Incorporating ICT in Schools

In the case of Jordan, the first technological project, Education Reform for Knowledge Economy (ERfKE), is a 10-year project that was launched in Jordan in 2003 by the World Economic Forum. The schools and technology component of ERfKE has been managed by the Jordanian Education Initiative (JEI) which has been operating to support and develop ICT integration in 100 Discovery Schools situated in and around Amman, the Jordanian capital (Ministry of ICT, 2012). In these schools, staff and students were introduced to an electronic curriculum delivered via an Internet-based learning platform called "EduWave." In addition, schools were equipped with new computers, several Smart Boards, and data projectors that were installed in the classrooms (Abuloum and Qablan 2008).

In Bahrain, the King Hamad School of the Future (KHSF) project started in 2003 with 11 schools spread all over the 5 districts, and by 2010 all the schools in Bahrain became part of the project (Eqab 2003). Today, all schools in Bahrain have broadband Internet connections, equipped with at least one ICT suite. They also have data projectors and/or interactive electronic whiteboards in many classrooms (Lightfoot 2012).

Since 1999, all primary and secondary schools in Kuwait were equipped with at least 2 computer labs containing about 25–35 computers each, to teach computer literacy courses with Internet connection and data show (MoE 2008). The Ministry of Education (MoE) required all primary and secondary schools in Kuwait to have an accessible website on the MoE portal. Also, most schools have at least one computer in each classroom connected to the Internet with data shows, while some schools are equipped with a Smart Board and more recently with Wi-Fi connections in the school (moe.edu.kw 2015).

According to the National ICT Policy in education plan, primary and secondary schools in Egypt are required to have computer labs at the rate of 1 lab for every 15 classes and 1 computer, data show, and wide screen connected to the Internet for each class (Farid 2016).

The United Arab Emirates Department of Education has undertaken the UAE Vision 2021 for implementing computer-assisted learning. Part of this vision, the "Mohammad Bin Rashid Smart Learning Initiative," will be introduced in four stages over 5 years. The initiative is designed to provide a single digital platform to support teachers, students, and parents (Galil 2014).

Use of ICT by Teachers and Students

To better evaluate ICT use in primary and secondary schools, it is important to look at the students and teachers' access to technology. A good indicator of ICT use is the student-computer ratio in the classroom. According to a report published by UNESCO, the average number of students to computers at the primary school level in Egypt is 120 students to 1 computer, and in secondary school the number of students decreases to 25 students per computer, while in other countries such as Jordan, Oman, and Qatar, the average student-computer access is between 7 and 19 students per computer at the primary level, and it drops to 5 students per computer at the secondary level. The gap between Egypt and the other countries regarding students' computer access shows how the MENA region is widely different in characteristics and resources. The disparity between the previous countries and

Egypt is enhanced when looking at the number of students who have access to computers connected to the Internet. In primary education in Egypt, every 441 students share 1 computer with Internet connection (Stamboliyska 2013).

In Egypt, it is obvious that the technology is not easily accessible in schools, which means that students' practice time is limited. On the other hand, countries like Jordan, Qatar, and Oman provide more initiatives to their students and teachers, encouraging them to be proficient in using ICT. Less or lack of access to technology leads to less practice for students, which leads to less experience with using the technology. It is also a sign that every teacher is responsible for teaching a large number of students with limited resources. Even though teachers may be interested in implementing and using ICT while teaching, it could be a challenge to do so with large numbers of students and limited access to technology.

Despite substantial success at creating and providing e-learning resources to schools, the common uses of these new resources do not yet align with the vision of use desired. The misalignment could be attributed to the fact that the traditional teacher-centered approach is still predominant in most schools in the region (UNESCO 2011a). For example, in 2011 in Kuwait, the use of ICT by teachers within the classroom was very limited. Computers were used predominantly for slide shows and YouTube to reinforce teaching. This practice is due to lack of teachers' training on how to integrate ICT into the classroom (Alayyar 2011; Alharbi 2012). However, Kuwaiti students are still able to acquire a high level of ICT due to the presence of computers and connection to the Internet in most homes (Alharbi 2012).

Teachers and students can achieve greater ICT skills when teachers integrate the ICT hands-on session into their classes so that students don't learn the skills in isolation. Integrating ICT skills into mathematics, science, Arabic, EFL, geography, and other subjects can help to provide a context for teaching these subjects (UNESCO 2011a, b).

Teacher Training About ICT

ICT training must be a central component in teacher preparation programs. The ideal teacher in a globalized world must be an expert in a subject area as well as an expert in the use of ICT in teaching and learning situations. Such teachers must be prepared to be active participants in integrated communities of learners (Misra 2012). In some developing countries, ICT training for teachers is based on developing computer literacy, which is considered an important component for integrating ICT in education. However, it is noteworthy that effective training should not stop at computer literacy, but should model effective teaching practices (Infodev Annual Report 2015). According to the literature, training that focuses only on ICT skills is insufficient for preparing teachers to integrate ICT in their lessons; thus, training should be more focused on the integration and use of ICT for certain contents with different pedagogy within a certain context (e.g., Koehler and Mishra 2005).

In Kuwait, for example, during the academic year 2000–2001, the Ministry of Education started facilitating and providing the International Computer Driving

License (ICDL) training course for in-service teachers to equip them with the practical skills needed for ICDL qualification. Later on, the MoE started to use incentives for teachers to encourage them to obtain the ICDL qualification or diploma (Alayyar 2011). Today, the ICDL diploma is a prerequisite for employment in public schools. The teachers suggested that ICT training should focus more on how to use ICT as a teaching aid and not only focus on acquiring ICT skills (Alharbi 2012).

The Jordanian education system adopted different strategies to prepare their teachers to meet the ICT educational policy by offering courses to improve the use of ICT in classrooms. Some of the offered courses are Word Links, Intel Teach to the Future ICDL, CADER, and iEARN. These courses are also aimed to improve teachers' ICT experience at three levels, which include ICT skills, pedagogical skills, and curriculum training (Alutaibi 2003).

In Egypt, most teachers need to earn the ICDL. They were trained to use ICT in preparing and conducting lessons by setting agreements with international companies such as Microsoft, Cisco, Intel, and Oracle. The agreement was made to help enhance the educational process through upgrading the programs and training teachers to use modern technology (Farid 2016).

Many educational systems considered ICT training courses as prerequisites for teachers' promotion and reward. However, there are no follow-up and monitoring efforts to gauge real practices. ICT policies and programs related to teacher training should be structured in a way that connects to specific classroom practices or engages teachers in a community of professional practice and ongoing development, policies that have proven to be effective in school reform (Cohen and Hill 2001). In the early phases of ICT introduction, teachers need training in the operation of hardware, software, and, to some extent, networking. As ICT use by teachers becomes more common, professional development shifts to pedagogical integration, creation of content, and development of shared knowledge and practice (Kozma 2011).

Recent Developments of ICT Policies in the MENA

ICT educational policy was defined by Kozma (2008) as "a rationale, a set of goals, and a vision for how education systems might [work] with the introduction of ICT and how students, teachers, parents, and the general population might benefit from its use in schools" (p. 1084).

In the MENA region, the first decade of the new millennium has seen policy initiatives which have promoted the use of ICT in schools in several countries (Chapman and Miric 2009). Policy makers in the region believe, like other policy makers around the globe, that access to ICT in education will help enhance learning and provide students with new sets of skills, will reach students in rural and remote regions, will facilitate and improve the training of teachers, and will minimize costs associated with the delivery of traditional instruction. These benefits will in turn help to create a skilled work force for the twenty-first century and enhance social mobility (UNESCO 2013).

The Jordanian education policy's main objective is to provide its citizens with the appropriate knowledge and skills to create a competitive economy in the global marketplace. Another goal is to maintain and extend the Jordanian society's security and stability. To fulfil the mentioned goals, Jordan has set the following objectives for its educational and strategic plan:

- Ensuring lifelong learning by restructuring the educational system
- Ensuring responsiveness of the educational system to the knowledge-based nation
- Accessing and utilizing ICT to maintain successful learning and system management
- Ensuring high-quality learning experiences

The ICT policy of Jordan focuses on incorporating both e-content and e-learning into several disciplines in all K-12 education. The Jordanian Educational Initiative is the foundation of innovation in expanding ICT through the curriculum for all grade levels in Jordan (UNESCO 2011a). The JEI has adopted policy for the use of open educational resources (OER), where it offers the public educational materials that can be accessed, used, and redistributed with an open license, at no cost, and with few or no restrictions (UNESCO 2013).

The Kuwaiti government believes that the controlled deployment of ICT in schools will create exciting possibilities for learners and teachers to engage in new ways of information acquisition and analysis, as well as new opportunities to create knowledge. ICT will enhance access to education and will improve the quality of education delivery in a more equitable way across the country. The government is therefore committed to a comprehensive program of rapid deployment and utilization of ICT within schools to transform the education system and improve the lives of Kuwaitis (National ICT in Education Strategy 2008).

In 2004, Kuwait developed "Kuwait's Strategy for Developing Education, KSDE, 2005–2025." This strategy was intended to improve the quality of public education by providing strategic guidelines for anticipating and managing existing and future concerns, challenges, and issues facing Kuwait's educational system in the twenty-first century. Among other principles, the strategy emphasized updating the curriculum to ensure the country's objectives and principles and incorporating advances in ICT in the education process. It is worth noting that the strategic document did not advise the MoE to undertake any sort of operational framework. Also, the fulfilment of the strategy was left up to the judgment of appointed ministers (AL-Refai et al. 2015).

The KSDE strategy was followed by a large total quality management (TQM) project by the MoE in 2009. The project was a result of the 2008 National Conference on Educational Development which recommended the reform of preuniversity public school education using TQM principles (AL-Refai et al. 2015). In 2008, the MoE issued the strategy of e-learning and, in 2009, started its implementation. The blended learning mode of e-learning was adopted through the e-learning strategy of the MoE in Kuwait, whose main objectives were to improve teaching and learning by introducing ICT, to increase student-centered learning, to create an environment for immediate interactions between learners and the teacher, to overcome the limits of time and place in the educational process, and to avoid the emergence of new generations suffering from technological illiteracy (moe.edu.kw 2015).

In 1999, Egypt adopted a National ICT Policy by the Ministry of Communication and Information Technology (MCIT). This policy concluded that the number one priority in Egypt is education. Both MCIT and the MoE are responsible for conducting the National ICT Policy in the area of education. The Egyptian policy uses ICT as a lever to reduce illiteracy and improve the education of its citizens by providing equal opportunities for learning regardless of age, gender, class, or geographical location (Stahl 2008). The ICT policy in education was formulated to a working plan that includes seven major points (Farid 2016), as follows:

- Integrating technology in schools.
- Introducing developed educational software.
- Providing electronic educational services, such as e-content for K12, and virtual classes for effective transmission.
- Establishing the infrastructure of the information technology by which information could be exchanged among schools, education directors, administration, and the ministry.
- Distance-training national net: Upgrading the use of videoconferencing and video streaming and equipping some classrooms with videoconferencing tools. Distance interactive learning is encouraged to test the abilities of those attending the videoconference training sessions.
- Training the educational cadres.
- Co-projects with donors, by using local or foreign loans and grants and setting agreements with international companies such as Microsoft, Cisco, and Intel to constantly upgrade the programs and regularly train teachers to use the ICT. Cooperating with the European Union, World Bank, US Aid, etc., to equip schools with technological equipment that will help in improving the educational process.

In the Kingdom of Saudi Arabia, there is a prolific list of implied rules/policies regarding educational policy in KSA. In addition, a variety of annual documents are released in relation to the implementation of ICT such as ministerial resolutions, administrative declarations, school memos, and curricular letters (Al Mofarreh 2016). However, there is neither a stand-alone policy for ICT nor a syllabus that incorporates ICT. Implementation at the school level is through pedagogy that relies predominantly on textbook use. There is neither a fundamental document nor an article that completely covers or strictly defines ICT policy. Rather, information regarding ICT is distributed through a general board of educational policy (Al Mofarreh 2016).

ICT Initiatives

In this section, the ICT initiatives that are emerging as new and potentially complementary ways to reform education in the MENA region are presented. The Brookings Institution (2016) identified six initiatives that are emerging in the MENA region, as follows:

Increasing Access to Formal Education

Countries in the MENA region have made great effort to increase access to formal education. However, in countries with limited budgets, governments are unable to effectively serve their populations, leaving youth with worse prospects than the previous generations. ICT can present an opportunity to complement the governments' efforts to scale up access to education. For example, Tabshoura is a free, interactive trilingual e-learning platform that intends to offer the complete Lebanese curriculum from kindergarten to grade 12 (The Brookings Institution 2016). Another initiative is Nafham ("We Understand"), a free online K-12 educational video platform launched in Egypt in 2012, on which teachers and users can post 5–15 min of educational videos on any topic covered in the public-school curriculum (The Brookings Institution 2016). Also, in Saudi Arabia, Khan Academy's videos were translated and made available to over 350 million users in the Arab world (Friedman 2015).

Using New Media

Most classes in MENA countries are still teacher centered, memorization based, and assessment focused. Using ICT tools for educational purposes has opened the space for students to be more active in the learning process (The Brookings Institution 2016). ICT also allows the learning process to be more customized to the needs of students through differentiated learning, thereby improving teaching and learning inside and outside the classroom.

> The first such initiative to use new media in the MENA region was the Jordanian Educational Initiative in 2003 (The Brookings Institution 2016). Through partnerships with key global and local actors in the fields of technology and education, one of the JEI's goals was to integrate ICT in schools to improve students' outcomes and capabilities and better prepare them for the knowledge economy. The JEI's model involves improving schools' ICT readiness through providing hardware and software, training for teachers and school leaders, changing management, and offering digitized content and enrichment materials to improve student learning. JEI pilots a range of programs, applications, and games across K-12, focusing on English and Arabic literacy, math and sciences, computer programming, critical thinking, and other soft skills. (The Brookings Institution 2016)

Preparing Learners for Future Jobs

Youth in the MENA region need to be prepared to compete in the global market. They need to develop other skills, besides the core-subject knowledge, that are in demand among employers, such as collaboration, creativity, flexibility, communication, and foreign language skills (IFTF 2011). Today, high school graduates in the MENA region are weak in communicating in either or both Arabic and

English languages, which limits their ability to perform effectively and professionally at work. One way in which these skills can be strengthened is through the use of more creative, engaging, and personalized technological mobile and web application tools to develop their language learning. For example, Little Thinking Minds (Jordan), an interactive digital Arabic literacy program for young learners, is accessible via digital books and mobile applications. Another is Josoor Arabia (Egypt), a program that aims to promote Arabic-language content on the Internet. The program is implemented in collaboration with SchoolNet Africa and AGENT Consulting. A third example is AlHudHod (Jordan), a program for early learners that is taught using smartphone and interactive boards, facilitating Arabic literacy and teaching numeracy in ways that promote imagination and creativity.

Another skill that is critical to develop in the next generation of youth besides digital literacy is computer programming. Computer programming has grown in popularity across schools in parts of the MENA region, like Lebanon, Jordan, the UAE, and Kuwait (Knight 2015). Other similar private initiatives have also been launched, such as The Coding Circle in the UAE, Hello World Kids in Jordan, and Coded in Kuwait, which offer software coding courses to a variety of ages of children and youth.

Using Large Data to Align Learning with the Job Market

The ability to digitize information provides more comprehensive data for more effective decision-making and policy formulation by government, educational institutions, and industry leaders. Hence, the developed policies and programs aligned with the needs of the job market that can ease the transition for youth from education to work. This trend is primitive in the MENA region. However, given the high unemployment rates of youth in the region, technology could be used to leverage such data in creating medium- to long-term strategies to provide youth with better work prospects. Doroob, a new initiative in KSA, started in 2015. Based on the needs of the job market, Doroob offers training opportunities to unemployed youth who are not sufficiently trained to fulfil future jobs. It offers a range of free online accredited professional development certificates to prepare youth at three levels: (1) career readiness (ICT and English language classes), (2) job-specific training (in hospitality, accounting, retail, information technology, fashion, and more), and (3) on-the-job training.

Adopting New Metrics and Performance Analytics

When it comes to assessing and personalizing learning, ICT can provide formative assessments to ensure that students and teachers identify learning gaps of each individual in real time. ICT can help administrators and teachers monitor students regularly and provide opportunities for remedy if they are failing. In the context of the classroom, it offers teachers the flexibility to alter online content or incorporate new innovative materials and programs that provide personalized support to address the specific learning needs of students at different academic levels. There is a growing investment in learning management systems – online platforms for administering, documenting, tracking, reporting, and communicating within schools. In 2012, the government of UAE launched the Mohammed Bin Rashid Smart Learning Program, the most ambitious effort in the region, which aims to integrate technology across most of the country's public schools, giving students from grades 6 to 12 their own tablets (The Brookings Institution 2016).

Offering Open Online and Blended Learning

There is a great demand for lifelong learning, including up-skilling and on-the-job training that can be facilitated by using ICT. Introducing blended online learning for students in primary and secondary education helps prepare them to integrate this technology in the future. Examples of blended online learning initiatives are the Nafham, Tahrir Academy (Egypt), and Tabshoura (Lebanon), which complement the national curricula in their respective countries by providing lessons using online media.

Relevance of Cross-National and Worldwide Strategies and Plans

The whole world is connected somehow; whenever something happens in one part of the world, it affects the other parts of it. The influences could be small or big, economic or political, and social or environmental. Globalization influences education quality and decisions; especially ICT has a huge influence on schools' curricula, planning, and implementation. Educators and ICT planners must be able to "think globally and act locally" when planning education due to the influence of the international culture on education (Misra 2012).

The integration of ICT in education through policy brings change into the learning environment. Research has shown that a connection exists between innovation and national policies that advance ICT use (Jones 2003). An impressive case of successful ICT policies and adoption can be seen in Jordan, which was recognized as a model in the Arab world and in international literature. Jordan's ICT initiative has served as a leader in ICT infrastructure and developed that can improve human capital, promote economic growth, and decrease poverty (UNESCO 2011a, 2013). Jordan's successful adoption of ICT has relied heavily on continuous development and updates to the policy documents that were initiated in 2004 and were updated to an overall policy framework for 2007–2011 and again for 2009–2013 (UNESCO 2011a).

In addition, the call for increasing ICT in education from developed countries has encouraged some countries in the MENA region to spend more on planning, buying, and implementing ICT in the education sector. Within the Arab world, KSA has invested greatly in developing ICT in the public education sector. The Saudi government was interested in improving education reform and implementing modern technologies and invested over $2,500,000 (almost £2 billion) in 2007 (Tatweer 2015). It also sought to improve the public education through revising the curriculum and by introducing technology to facilitate teaching. Furthermore, this improvement included development and training sessions for the educators to guarantee the success of the educators' ICT adoption. Over time, the Saudi government increased its budget for the education sector in 2015 to reach about $47 billion (more than £36 billion). A considerable amount of the budget goes to funding the implementation of technology in schools' curricula and to enhancing the ICT facilities (Ministry of Finance 2015).

It is clear that countries in the MENA region are being influenced by the developed countries in the field of ICT in education. At the same time, the increased budget and planning in the MENA countries is evidence that they are willing to move forward in their adoption of ICT. However, we cannot conclude that all influences were successful and the spending and adoption were right on point. There are other issues surrounding the adoption process – whether it is before, during, or after adoption – that decision-makers should consider. From a global viewpoint, studies in developed countries have shown that neither the abundance of technology implementation nor the great investment in technology resources in the classroom directly contribute to academic achievement and improved learning outcomes (European Schoolnet 2006; Ungerleider and Burns 2002; Wozney et al. 2006).

Challenges and Relevance of Research for Education Policies on ICT

MENA countries are trying their best to have a successful ICT implementation by increasing their spending, but it has proven to be worthless without considering other factors that influence ICT success. Many factors need to be considered when planning to develop policies toward implementing ICT in education.

Financial Challenge

Some countries in the MENA region lack the financial support to add to or advance on the technologies needed to adopt ICT in education, while other countries can afford to do so. In the region, KSA is considered the biggest market for ICT, as the government has invested almost $7 billion, and Qatar is considered the fastest growing, while Egypt is spending less than the amounts it used to spend in 2007 and 2008 (Hamid 2013). The countries that can afford the adoption and implementation must keep in mind that it is not a one-shot investment; it requires ongoing maintenance expenses, updating the system in use, and training and supporting the users.

Less Attention Given to Goals of ICT in Education

It is important for the governments in the MENA region to understand that installing ICT will not automatically improve learning standards. The "goals of using ICT" and the actual accompanying pedagogy must not be overlooked (Abuloum and Qablan 2008). Policy makers in the MENA region do not offer a pedagogical model or pedagogical vision toward the ICT implementation process. This lack of focus and interest has contributed to the absence of strategic directions on how to implement ICT policy and use ICT in the classrooms (Alkhezzi and Abdelmagid 2011; Alsharija et al. 2012). As Ghazal (2014) stated regarding ICT use in primary and secondary education in Jordan, the "absence of a focused strategy on the integration of ICT into schools is hampering the spread of the JEI, a public-private partnership that envisions accelerated education reform through technology integration, according to its CEO" (para. 1).

Resistance from Actors

The resistance of the actors in the educational system – principles, school managers, teachers, students, and parents and other stakeholders – can also hamper the use of ICT in schools. The lack of communication between the administrator and the user can cause a disconnect in vision, mission, and implementation. The disconnect in turn can lead the actors within the system to resist the ICT initiatives because they may not understand where the system is heading and why. They may thus question the sufficiency of their old skill sets and methods of assessment and whether it is needed or not.

Also, other countries have managed to counteract the resistance of integrating technology into education by partnering multi-stakeholders. The partnership initiative was promoted by the World Economic Forum and started by launching the JEI (UNESCO 2012a, b). The efforts toward having multiple partners involved in the learning process, including the stakeholders, teachers, and students, promote shared understanding and build a common vision that connects all players in the learning environment.

Lack of Cooperation

Teachers, students, and parents fail to cooperate and coordinate their efforts not only because they're unaware of or do not understand the current reform efforts but also because they are unable to plan for ICT integration. They fail to contribute to the efforts because they are not equipped with the right skills and tools to enable them to enact the reform measures. Countries in the region still rely on the teacher-centered approach, a traditional teaching method that contradicts with the policy of ICT integration and decreases its benefits (UNESCO 2015). In other words, it is unreasonable to ask teachers to switch to a student-centered approach in teaching, while they are not trained to do so; nor is it fair to ask students to answer critical thinking questions when their teachers themselves are not capable of teaching them how to think critically.

Contextual Challenge

An example of this challenge is lack of fluency in the English language. Poor English language, especially in K-12 education, among both students and teachers increases resistance to ICT use. The new ICT interface design uses English as the main navigation language; this causes confusion to the users since they are not fluent users of the English language. The absence of suitable and easy-to-use learning management system that fully or partly supports Arabic is still not an available option for Arabic-speaking users of ICT (Alfelaij 2016).

Technical Challenges

Countries in the MENA region are faced with technical challenges when they implement a technology that does not enhance the users' technical or thinking skills. In Kuwait, K-12 ICT education curriculum books (e-books) can be found online; however, they do not add to the students' skills or knowledge, since they are no different than the printed books (Al-Hunaiyyan et al. 2008). The K-12 e-books lack the interactive part, the extra activity related to the lesson learned, and the extra knowledge the student may benefit from.

Social and Political Challenges

Unstable governments in the MENA region lead to instability in the Ministries of Education of the affected countries due to frequent changes in education ministers. According to UNESCO (2015), the repeated change of administration alters the ICT educational policy status or the implementation process of the policy.

ICT Developments in the MENA

Infrastructure, Hardware, and Content

The enhancement of the Internet and networking technologies significantly impacts teaching and learning. Students and teachers use a variety of ICT tools in the technology-mediated learning environment to engage in learning opportunities anytime anywhere. They use these tools to communicate, collaborate, and share resources associated with the learning experiences. Table 2 below presents a selection (pertaining to the MENA countries) of the Networked Readiness Index (NRI)

Table 2 Networked readiness index 2015

Rank (out of 143 countries)	Country	NRI value	Income level
23	UAE	5.3	HI
27	Qatar	5.1	HI
30	Bahrain	4.9	HI
35	KSA	4.7	HI
42	Oman	4.5	HI
52	Jordan	4.3	UM
72	Kuwait	4	HI
78	Morocco	3.9	LM
81	Tunisia	3.9	UM
94	Egypt	3.6	LM
99	Lebanon	3.5	UM
120	Algeria	3.1	UM
131	Libya	2.9	UM
136	Yemen	2.5	LM

Income level: *HI* high-income economies, *UM* upper-middle-income economies, *LM* lower-middle-income according

2015 of 143 countries around the world (Schwab and Sala-i-Martín 2014). The NRI reveals that mostly rich countries benefit from the ICT revolution; that means ICTs have opened up a new digital divide. Although Internet access is expanding and schools increasingly have access to the Internet, the skills required to leverage ICTs remain inadequate in many countries.

The ICT divide within the MENA region is the largest among all regions. The UAE (23rd, moved up one) and Qatar (27th, moved down four) continue to lead, ahead of Bahrain (30th), KSA (35th), and Oman (42nd), which are all countries of the Arabian Peninsula. All owe their success to a very strong commitment to ICT development by their respective governments. On the other hand, Kuwait's performance (72nd) stands at odds with its peers, even though Kuwait has the financial resources to implement ICT in its schools. In the rest of the MENA region, only Jordan (52nd) features in the top half of the rankings. Morocco follows at a middling 78th, but it is the country that has improved the most (move 21 places up) over the past year. Yemen (136th) remains the region's worst-performing country, 115 places behind the UAE.

Pedagogical Practices and Conditions for Change

Just like countries with bigger budgets, some MENA countries have invested in computers in schools despite their limited educational budget. Their investment stemmed from the belief that the technology will change the "what and how teachers teach and learners learn" (Lightfoot 2012). Educational amendments associated with the advancement of the twenty-first century learning skills have become a trigger for investment in the ICT foundation in schools.

Table 3 shows that Kuwait and Jordan recommend the use of ICT in all subjects for every level, kindergarten through 12th grade. However, Egypt's policy recommendation for ICT integration does not cover all subject areas.

Conclusion and Recommendations

This chapter provides information concerning ICT and educational policies in primary and secondary education in the MENA region. The MENA region includes countries that vary in culture, language, religion, distribution, and resources. These factors contribute, directly or indirectly, to the adoption of ICT in any given country. In addition, the degree of political stability in the region contributes to the adoption process, the success of adoption, and the recent development of ICT. It influences ICT literacy in schools, the ICT infrastructure, the students and teachers' use of ICT, and teachers' ICT training.

Policies concerning ICT have been influenced differently according to each region's specific characteristics and educational goals. Six initiatives were developed based on the new policies. These initiatives included increased access to formal education, using media to improve teaching, preparing students for jobs, using data to align learning with the job market, analyzing performance to assess and personalize learning, and utilizing online learning for learning and developing skills.

Our research in the use of ICT in the MENA region highlighted the challenges facing ICT research on policy. Among the critical challenges that faced the researchers while reviewing the literature related to ICT educational policy in the MENA region is the lack of sufficient literature. It was difficult to locate studies, books, reports, or peer-reviewed articles discussing the efficiency and effectiveness of ICT policy and implementation. The majority of the literature available on ICT discusses the new ICT innovations in classrooms. However, the literature is missing the documentation of the ICT implementation process, from start to finish, and the follow-up part, including challenges, effectiveness, and analysis. It is an urgent matter in the field of education, development of ICT, and human development to have available information and documents dealing with the implementation process in the field of ICT.

Thus, we conclude our study with the following recommendations that may lead to a better understanding of the relationship between ICT educational policies in the MENA region and the real status of ICT integration within K-12 public schools. First, we recommend the cooperation of educators and education ministers from each of the countries in the MENA region. Second, we recommend to compile an information bank that contains studies and statistics and that can recommend new research topics in the area of ICT for those who are interested. Third, we recommend developing rules and regulations governing the adoption of ICT specific to each country. The involvement of stakeholders, especially educators, will help develop better rounded rules that fit each region specifically when formulating ICT policy in education. Fourth, a change in teaching approach is highly recommended in the MENA region to help teachers, educators, and policy makers move from traditional

Table 3 The status of ICT integration within the K-12 curriculum

	Kuwait			Jordan			Egypt		
	Primary	Intermediate (lower secondary)	Secondary	Primary	Intermediate (lower secondary)	Secondary	Primary	Intermediate (lower secondary)	Secondary
Science	√	√	√	√	√	√	√	√	√
Math	√	√	√	√	√	√			
Arabic language	√	√	√	√	√	√			
English language (second language)	√	√	√	√	√	√		√	√
Quran and Islamic studies	√	√	√	√	√	√			
Social studies	√	√	√	√	√	√			

Notes: Data for Egypt reflect the academic year ending in 2010
Data for Jordan reflect the academic year 2011
Source: UIS database
Data of Kuwait reflect the academic year 2015 and adopted from national curriculum

teaching methods (i.e., from the teacher as presenter of information and knowledge to students as empty vessels) to modern learning approaches that allow students to play a more active role in their own learning and that help them be co-facilitators of knowledge.

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87 Information and Communication Technology Policy in Primary and Secondary Education in Europe

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Abstract

The chapter draws attention to ICT policies in primary and secondary education in Europe. The authors explore a selection of policy initiatives and policy developments at regional and local levels considered to be significant for primary and secondary education in the region. Policy trends and early history of different national and European policy initiatives are highlighted, with a particular focus on the role of the European Union on the matter. The chapter addresses an increased differentiation between policies that: a) promote pedagogical use of ICT for improving subject-specific learning, b) promote fostering of learners' digital competence, and c) express initiatives related to the field of computer science. Cross-national and national examples provide a rich base of examples that showcase the variety of policy initiatives in the European region as well as recent trends and challenges with regard to educational ICT policies. The authors call for a stronger evidence-base in the field, and underline the need to utilise evidence to greater extent when designing pedagogical approaches, methods and tools involving ICT. The most pertinent challenges found are related to teachers' professional digital competence, changes in the world of work such as automation and the importance of lifelong learning and finally the increased emphasis on digital citizenship and digital responsibility.

Keywords

Digital competence · Professional Digital Competence · Digitalization · ICT · Europe · Primary and Secondary Education · Digital Citizenship

Introduction to ICT in Primary and Secondary Education in Europe

Europe is a diverse compilation of countries, regions, political unions, and partnerships. Theregion encompasses some of the world's most densely populated and some of the most desolated. Europe contains the world's largest trading bloc, the European Union (EU), and is also host to a wide range of bilateral and multilateral partnerships regulating economic, social, and political alliances between countries and regions.

The European region has been characterized by the term *variable geometry* (Delrio and Dondi 2008), which seeks to capture not only the area's diversity in culture, economy, politics, and demographics but also the somewhat fluid definitions through which countries or regions are included in the alliance. A United Nations list of European countries comprises 53 sovereign states, including Vatican City and the island of Sark. For the sake of consistency, this chapter will use the United Nations Statistic Division's list, as was used in a previous edition of this handbook. This list suggests that Europe is divided into four major regions based on environmental, cultural, and economic similarities. Eastern Europe consists of Belarus, Bulgaria, the Czech Republic, Hungary, Poland, Moldova, Romania, the Russian Federation, Slovakia, and Ukraine. Western Europe consists of Austria, Belgium, France, Germany, Lichtenstein, Luxembourg, Monaco, the Netherlands, and Switzerland. Northern Europe includes the Åland Islands, the Channel Islands, Denmark, Estonia, the Faroe Islands, Finland, Guernsey, Iceland, Ireland, the Isle of Man, Jersey, Latvia, Lithuania, Norway, Northern Ireland, Sark, the Svalbard and Jan Mayen Islands, Sweden, and the United Kingdom. Finally, Southern Europe consists of Albania, Andorra, Bosnia and Herzegovina, Croatia, Gibraltar, Greece, Vatican City, Italy, Malta, Montenegro, Portugal, San Marino, Serbia, Slovenia, Spain, and Macedonia [Note 1].

Since each European country develops its education policies within a national context, content and structures vary widely. The aim of this chapter, *ICT Policy in Primary and Secondary Education in Europe*, is to provide an overview of ICT policies that illustrate some of the variety in the European region and the trends and challenges facing such policies as they relate to primary and secondary education. This chapter is not exhaustive and cannot cover the entire range and variety of policies in Europe. Instead, we will discuss a selection of policy initiatives and policy developments at the regional and local levels that we consider to be relevant and of interest to a wider audience both within and outside the region. In general, policies for economic, social, and political developments in European countries are increasingly geared toward recognizing the impact and importance of a digitized society, including for the educational sector. European countries were early to integrate information and communications technology (ICT) into primary and secondary education. Some countries developed policies for ICT in education throughout the 1990s, such as **Germany's** Schulen ans Netz [Note 2] and the **United Kingdom's** National Grid for Learning (BECTA 1998). Then, in the early 2000s, **Italy** released its Action Plan for the Information Technology Society (2001–2003), and **Finland** introduced its program for Education, Training, and Research in the Information Society, the National Strategy for 2000–2004 (Delrio and Dondi 2008).

The early phases of ICT integration in primary and secondary education often focused on teaching computing as a subject with limited additional curriculum integration. The early 1990s witnessed the advent of the multimedia computer as a possible learning resource within curricula (Plomp et al. 2009). With the introduction of the Internet, national governments began to develop policies for ICT as a tool for expanding learning in both content and topics (BECTA 1998). Then, in the mid- to late 1990s, several EU initiatives emerged for integrating ICT in primary and secondary education, representing an elevation of these priorities to the cross-national level. Lately, the use of ICT in primary and secondary education has been strongly connected to the general strengthening of knowledge, skills, and competences necessary for European citizens. Examples of this connection can be found, for instance, in the EU's definition of Key Competences for Lifelong Learning (European Parliament and Council 2006) and in the frameworks of the recent OECD PISA studies (OECD 2010a, 2013, 2016a).

In the following section, we will present some of the most recent and influential policy efforts at the EU level, look at current cross-national implementation strategies endorsed and implemented by European countries, and describe examples of extraordinary efforts at the country and local levels.

Recent Developments in ICT in the European Region

In this section, we will elaborate on recent developments and initiatives in different countries in the European region, focusing primarily on the topics of uptake of ICT in education, the concept of digitization in schools, and the use of ICT for student assessment.

Recent Findings on the Uptake of ICT in Education in European Countries

An important metric for the integration of computers into European schools has been the relationship between the number of students and availability of computers, aggregated at the national level. This metric is reported in, among other studies, the IEA studies SITES Module 1 (Pelgrum and Anderson 1999), SITES 2006 (Law et al. 2008), and ICILS 2013 (Fraillon et al. 2014), as well as in the OECD PISA studies from 2006 and onward (OECD 2006, 2010b, 2014a, 2016b). Though this metric is rough in the sense that it does not explore actual pedagogical usage in classrooms, it still provides an indicator of educational systems' capacities for investment and priorities concerning the integration of ICT in schools.

The latest PISA 2015 results (OECD 2016b) show that the median number of computers available per student aggregated at the country level is 0.66 for the 40 European educational systems participating in the study [Note 3], ranging from 0.14 in Kosovo to 1.49 in Iceland. Comparing countries, a median of 97.8% of computers are connected to the Internet, again with huge variations, ranging from 29.2% in Kosovo to 100% in Malta.

The results from IEA TIMSS 2015 [Note 4, 5] (Mullis et al. 2016) show that, of the 11 participating European countries [Note 6] that reported on the availability of computers for mathematics lessons in grade 8, the average coverage was 32% of students, ranging from 4% in Malta to 65% in Sweden. For grade 4, the average coverage among the 23 participating European countries [Note 7] was 40%, ranging from 13% in Serbia to 84% in Denmark.

Digitization of Schools and BYOD Initiatives

A wide range of parameters can be used to describe the uptake of ICT or, in a wider sense, the digitization of schools. According to a report from the European Schoolnet based on a survey of school IT administrators in Europe, countries vary widely with respect to their levels of digitization. The report states that six countries can be grouped together according to the extent of digitization:

- Highly digitized schools [Note 8] Denmark, Norway, and Sweden
- Digitally developing schools [Note 9] Poland, Romania, and Turkey

In addition, there are two Linux countries, Italy and Spain, with high levels of equipment and above-average Linux OS penetration (European Schoolnet 2015b, p. 24).

Educational authorities and school owners are increasingly supporting one-to-one learning environments for their students and teachers in primary and secondary schools. Due to considerable costs and maintenance demands, a growing interest in BYOD (bring your own device) or BYOT (bring your own technology) approaches rises. Such approaches to meet greater access needs also increase demands on teachers, who need to be ready to assist their students with a range of different digital tools (European Schoolnet 2015c). An example of BYOD implementation can be found in **Austria**, where two national initiatives are helping to drive eLearning, mobile learning, and BYOD (European Schoolnet 2015c).

The degree of digitization indicates an access divide, such that countries in Northern Europe seem to be better off in terms of equipment levels and policies supporting a diversity of technologies than Eastern and Southern European countries. However, this only indicates the potentials or opportunities teachers and students have to use ICT in school and does not reveal anything about the *extent* or *ways of use* of technology in schools.

Assessment and Digital Exams

Assessment practices influence and guide student learning in many ways. Efforts to digitalize matriculation exams are on the agenda in several European countries. Such interventions can have huge influences on digitalization and the overall implementation of ICT in schools. In **Finland**, the Finnish National Matriculation Examination Board is digitalizing the matriculation examination through the digitalization project DigiAbi (2016–2019) [Note 10]. This project will allow Finnish students to use the most common office applications, including multimodal text (including text, pictures, audio, and video), to respond to questions in the matriculation exam. Of all European countries, **Denmark** is likely the most advanced in terms of online exams in upper secondary schools. In 2013, Denmark adopted the Strategy for Digital Welfare, including an initiative for digital written tests in upper secondary education. The initiative also includes digital support for giving marks on academically relevant assignments and tests in primary and secondary schools (European Schoolnet 2015d).

Recent Developments on Policies on ICT in the European Region

Cross-national policies and, to a varying degree, national policies throughout Europe posit policy expectations that concern both the school and the education system as a whole. This is done in order to prepare students for further studies and their professional lives, which, to a great extent, will include the use of ICT (Balanskat and Gertsch 2010; Binkley et al. 2012).

A general observation on the development of policies for ICT in primary and secondary education in Europe is the move toward a more fine-grained understanding of different strands of applications of digital technologies. Initiatives concerning supporting ICT to improve subject-specific learning processes and general learning outcomes are increasingly being separated from initiatives supporting the fostering of digital competence. In this chapter, these two issues are treated under the heading "National-Level Policies" in the next section.

In addition, a separate strand of initiatives integrating "new" subjects or topics directly related to the field of computer science has also gained traction. These topics are labeled differently between countries but are commonly described in this chapter as the integration of ICT, technology, and coding within the curriculum. Recent developments see the use of the growing evidence base on ICT in schools, digital competence, and curricular operationalization as the foundation for evidence-informed policymaking at the national level (see section "Integration of ICT, Technology and Coding in the Curriculum").

National-Level Policies

At the national level, we see a range of initiatives being implemented or emerging based on specific national educational contexts. Here, we introduce a few examples showcasing a variety of different policy approaches and related actions.

A concrete example of how research evidence is being utilized to shape national educational policies can be found in **Germany**, where the division of responsibilities between the federal and the regional (Länder) levels creates a complex context for policymaking. Based on, among other findings, results from the IEA ICILS 2013 study (Fraillon et al. 2014), in which German students performed lower than anticipated on measured ICT competences, German policy makers at the federal level took action by citing the study in an official 2014 decision (Bundesministerium für Bildung und Forschung 2016). Official exchanges between policy makers and experts in the field have been arranged, and the recent release of the national strategy for Education in a Digital World (Bildung in der digitalen Welt 2016) laid the foundation for systematic capacity-building for the inclusion of digital competences in Länder's educational systems, including primary and secondary education, VET, and higher education. The Education in a Digital World strategy encompasses actions for digitalization within the fields of educational plans and curricular developments, CPD for educators and teachers, infrastructure, educational media and content, educational administration at all levels, and necessary actions within legal and functional frameworks. The strategy also promotes a strong focus on fostering digital competence as transversal competence for learning in all subjects.

Austria introduced a computer-based school-leaving exam in 2014/2015 and launched digital versions of schoolbooks in 2016. It has also initiated funding schemes for interactive whiteboards and mobile applications. Secondary school reforms aim to develop school policies that resonate with modern society, focusing on transversal key competences as their primary outcomes. Under the umbrella agenda “eFit 21,” the Ministry of Education has collected strategic aims, measures, and concrete projects. The main strategic objectives are to use ICT in schools to enhance the quality and efficiency of teaching and learning and to foster digital competences and social inclusion. An example of tangible output is the LMS (Learning Management Systems) project, which provides teachers learning modules for competence-oriented teaching (European Schoolnet 2015e). The www.digikomp.at initiative in Austria is also worth noticing as it provides a digital competence framework for learners and teachers in grades 1–12. It emphasizes the importance of digital competence in subject teaching but has not been integrated as a part of teacher education.

The 21 German-speaking or multilingual Cantons in **Switzerland** have published the curriculum “Lehrplan 21.” It covers a new curriculum for all subjects including a new module called Media and Informatics “Medien und Informatik.” It derives from the existing ICT module and defines competence in the areas of media education and informatics and is obligatory for all students. Lehrplan 21 structures topics along seven fields of action [Note 11], and these provide schools with guidance on the implementation of the curriculum. All Cantons have to develop competence framework and websites for schools and teachers with examples for lessons and projects and provide new textbooks on the issue.

In 2012, **Flemish Belgium** implemented a new policy plan for ICT and media literacy, putting forward a comprehensive action plan and implementation policies. The main goals are to support the development of a competence-based curriculum and frameworks, to increase spending on ICT infrastructure in schools, to fund open digital educational resources (including serious games, in-service teacher training on digital competences, and media literacy), and to boost research and innovation in the field. A specific outcome is a personalized digital platform for students in primary and secondary education for integrating data, knowledge, and information across all relevant school actors. This system will be incrementally developed to support capabilities in learning analytics (European Schoolnet 2015f).

The **Czech Republic** has devised a strategy for educational policies for the period from 2014 to 2020. The strategy has three main priorities: to reduce inequality in education, to support quality teacher training, and to support the responsible and efficient management of the educational system. The strategy links to ICT in primary and secondary schools through a general recognition of the importance of the role of digital technologies in teaching and learning. The initiative also includes a separate strategy for digital education, with a strong focus on modernizing the Czech educational system and enabling students to become lifelong learners in a digital society and a digitized labor market. The digital education strategy has three priority objectives for interventions: new digital teaching and learning methods, students’ school-related digital competences, and the development of computational thinking. Concrete initiatives are operational programs focusing on the purchase of ICT equipment and teacher training in the field of ICT (European Schoolnet 2015g).

For the period 2011–2017, **Denmark** is pushing forward a comprehensive initiative for public schools addressing the structure of the school day, funding for teacher and headmaster training, and a nationwide system of learning consultants.

Boosting the use of ICT in public schools remains a high priority and is facilitated by a state initiative to develop a national market for digital learning resources by supporting 50% of school owners' purchases, providing funding to developers, and delivering an innovative quality framework. Capacity-building efforts involve building networks of digitally competent teachers, digital learning resource developers, and school principals involved in leading digital change. Beginning in 2013, the initiative has been followed-up with an extensive research program and a reform of teacher education (European Schoolnet 2015d).

An extensive strategy for lifelong learning between 2014 and 2020 guides efforts to modernize the educational system in **Estonia**. The strategy seeks to change the learning approach from teacher-led to student-driven and to accomplish personalization through the application of ICT. It also focuses on digitally competent school leadership and aligning lifelong learning opportunities with labor market needs. Estonia aims to foster digital skills and equal opportunities for learning in the long term. Responsibilities for fostering digital skills are shared between the state (e.g., through curricula, frameworks, and specific programs, such as digital learning resources) and school owners (e.g., through digital infrastructure, connectivity, and virtual learning environments) (Kerb 2015). A specific large-scale initiative at the school level is the 1:1 mobile learning initiative, which was organized according to a BYOD model. Together with university and business partners, Estonian authorities have also established the Information Technology Foundation for Education (HITSA) [Note 12], with a mission to "…ensure that the graduates at all levels of education have obtained digital skills necessary for the development of economy and society [and that] the possibilities offered by ICT are skilfully used in teaching and learning" (European Schoolnet 2015h, p. 6).

Integration of ICT, Technology, and Coding in the Curriculum

European education systems also take different approaches to relate to and integrate digital technology in their curricula and pedagogical use of ICT. This section explores countries that have introduced ICT as a separate subject taught either based on specific curriculum goals or as a general competence across disciplines. For instance, of the European countries participating in the ICILS 2013 study, ICT is a compulsory subject in secondary schools in the Czech Republic, Lithuania, Poland, Russia, and Slovenia and an optional subject in secondary schools in Germany and Slovenia (Fraillon et al. 2014). Based on a review of national instruction time, the Eurydice network monitors the national implementation of ICT and technology as separate subject domains in European countries (European Commission/EACEA/Eurydice 2016).

ICT is taught as an independent theme or subject in several EU member states. Some allocate a prescribed number of hours to the subject each year (Bosnia and Herzegovina, Bulgaria, Cyprus, Germany, Greece, Spain, Hungary, Lichtenstein, Latvia, Montenegro, FYROM/Macedonia, Malta, Portugal, Romania, Slovakia, and Turkey). Most countries in this group (except Greece, Slovakia, Spain, and Macedonia) allocate time only at the secondary level. Overall, Greece dedicates the most hours to ICT at all grade levels, and Bulgaria dedicates the most hours to ICT in upper secondary classes. Denmark, the Netherlands, and the United Kingdom give schools and teachers the flexibility to allocate time across curriculum subjects as they see fit. A third group of countries incorporates ICT into instruction time for other subjects or as a flexible option (Switzerland, the Czech Republic, Denmark, Estonia, Ireland, Iceland, France, Lithuania, Austria, Poland, Serbia, Slovenia, and the United Kingdom), with varying degrees of implementation. Combinations of these three modes are also present in several countries (European Commission/EACEA/Eurydice 2016).

Technology is taught as an independent theme or subject in 19 member states (Bosnia and Herzegovina, Belgium [French-speaking and Flemish parts], Bulgaria, Cyprus, the Czech Republic, Germany, Estonia, Greece, Spain, France, Croatia, Hungary, Italy, Lithuania, Montenegro, the Netherlands, Poland, Portugal, Romania, Serbia, Slovenia, the United Kingdom, and Turkey). Of these, only three countries (Lithuania, the Netherlands, and the United Kingdom [Scotland and Northern Ireland]) offer technology education in upper secondary schools. Slovenia dedicates the most hours to technology, allocating a total of 319 h across grades 1–9. A variety of European countries also either integrate technology into other parts of the curriculum or offer a mix of the two modes of integration (European Commission/EACEA/Eurydice 2016).

Computer Programming, Computational Thinking, and Coding

As a part of the digital transformation in Europe and to strengthen students' competence, skills, and employability for the twenty-first-century job market, computer programming, computational thinking, and coding have been central to recent developments within European schools. Curriculum studies from European Schoolnet (2014, 2015a) show that among the European countries explored in the study, 15 (Austria, Bulgaria, the Czech Republic, Denmark, England, Estonia, France, Hungary, Ireland, Lithuania, Malta, Poland, Portugal, Slovakia, and Spain) include computer programming or coding as part of their national or local curricula, while Finland and the Flanders region of Belgium have plans to introduce these subjects. Countries offer multiple rationales for the integration of coding; however, the three most prominent involve this subject's ability to foster logical thinking skills, coding and programming skills, and problem-solving skills. Improving the ICT sector and increasing the number of students in computer science are also priorities for ten of the surveyed countries (European Schoolnet 2014, 2015a).

It is notable that the forthcoming IEA ICILS 2018 study includes a module for the direct assessment of computational thinking skills as an international option for participating countries [Note 13]. Though computational thinking is not directly analogous to programming or coding, the concepts are related. According to the IEA, computational thinking for working out how computers can help solve problems entails such processes as problem-solving, design, and relating basic concepts of computer science to human behavior. This signifies a breakthrough in terms of the objective assessment of this particular skill, and the results can also be used for national or cross-national educational policymaking.

Relevance of Cross-National and Worldwide Strategies and Plans for the European Region

For most European countries, the EU's systems for cooperation for educational development are the most important international frameworks for national policymaking. EU member states and other countries in Europe are included in both EU standardized statistical monitoring of educational systems (Eurostat 2016) and the EU-funded Erasmus + program for education, training, youth, and sport [Note 14]. The following section examines the common goals and frameworks put forward at the EU level.

Relevance of Cross-National Policies Under EU Frameworks

The EU has a long history in developing policies for including digital technologies in primary and secondary education. Current efforts in the field are closely tied to overarching cross-sectorial goals and strategic planning designed to tackle the combined ongoing effects of the financial crisis, youth unemployment, increased immigration, and the recent wave of terrorist attacks and threats. These efforts are also related to more proactive issues, such as the modernization of education, the fostering of skills in education that harmonize with labor market needs, and the wish for a civic intercultural dialogue across all layers of society (European Commission 2010, 2015a). In general, broad overarching policies for education at the EU level have usually been developed as cross-national intentional papers in the form of communications developed by the European Commission and debated and ratified by member states in the council. Given their abstract and intentional character, such overarching policy documents must be adapted and operationalized into more concrete measures, aims, and strategies that take local educational and political contexts into consideration.

Cross-national educational policies concerning ICT in education can be divided into (1) top-level cross-national policies targeting society at large, where education is one of many societal aspects addressed, and (2) operational policies specifically targeting the education and training sector. In the following sections, we will explore some specific examples of these two different modes of policymaking to better understand the dynamics in the discourse on educational developments and reform in Europe. The cases in question are the top-level cross-national policy goals of the EU 2020 strategy (European Commission 2010) and the Key Competences for Lifelong Learning framework (European Parliament and Council 2006). At the operational level, the ET 2020 cooperation framework (European Commission 2015a), the cross-ministerial European Schoolnet network, and the European Commission's newly developed framework for digital competence (Vuorikari et al. 2016), all geared toward improving the quality of national educational systems by increasing digitalization in education, will be used as examples.

Top-Level Cross-National Policies

Top-level cross-national policies tend to link rationales for educational developments to gains in other societal areas, mainly labor market outcomes. Such policies do not focus primarily on improving the educational system per se but rather seek to strengthen the output of education relevant to other sectors in society, including labor market outcomes, economic productivity gains through innovation and entrepreneurship, social cohesion through active citizenship and integration, and well-being perspectives.

The Europe 2020 Strategy (European Commission 2010) acknowledges that education and training play a strategic role in Europe's ability to remain competitive, overcome the current economic crisis, and grasp new opportunities. The digital transformation of education and training systems is, hence, a theme in several Europe 2020 flagship initiatives. Moreover, the European Commission's Opening Up Education initiative (European Commission 2015a) emphasizes the need for educational institutions to review their strategies in order to integrate digital technologies into teaching, learning, and organizational practices.

Recently, the New Skills Agenda for Europe (European Commission 2016) [Note 15] aims to align the skills available in the labor force with the actual skills demanded by the labor market. The Skills Agenda emphasizes that the digitization of society is an important backdrop for understanding the growing skills gap. As a consequence, digital transformation in society raises new demands for fostering skills inside the formal educational system, in adult learning and reskilling, and at the workplace. Thus, to increase the digital skills of European citizens, the Skills Agenda calls for specific actions mainstreaming and underlining the impact of digitization [Note 16]. To ensure that individuals are equipped with adequate digital skills, in this communication, the Commission stresses that digital skills and competences must be developed at all levels of education and training. Furthermore, it acknowledges that teachers and educators need to support best practices in bringing digital tools into the classroom. The Skills Agenda is also aligned with the educational sector through one of its main actions: the ongoing revision of the Key Competences for Lifelong Learning (European Parliament and Council 2006) [Note 17].

The Key Competences for Lifelong Learning were launched in 2006. They were originally devised as a framework for describing key competences across all sectors of society; however, evidence shows that the use of the framework in member states has been most pertinent in the educational sector (Gordon et al. 2009). The Key Competences framework originally defined the eight key competences as "…a combination of knowledge, skills and attitudes appropriate to the context. Key competences are those which all individuals need for personal fulfilment and development, social inclusion, active citizenship and employment" (European Parliament and Council 2006, p. 13). Furthermore, the framework defines digital competence as involving "the confident and critical use of information society technology (IST) and thus basic skills in information and communication technology (ICT)" (European Parliament and Council 2006, p. 15).

Operational Policies

An in-depth analysis based on PISA 2012 (OECD 2015) underlines that merely increasing access to digital technologies in schools does not yield higher learning outcomes, although specific and targeted use with clear pedagogical aims might do so. In pedagogical terms, digital technologies should ideally yield profound changes in learning contents and pedagogical practices and should lead to more immersive, connected, and natural learning processes. Digital technologies also hold the potential to increase institutional efficiency, data consistency, and interinstitutional connectedness (European Commission 2015b). At the cross-national level, there is limited mutual learning on best practices and/or failures in the process of integration and effective use of digital learning technologies, increasing the chances of cooperation opportunities being lost, work being duplicated, and mistakes or suboptimal implementations being repeated.

To address this situation, several cross-national mechanisms have been implemented. The current European Framework for Cooperation in Education and Training 2020 (European Commission 2015a) emphasizes the importance of developing transversal skills and key competences, particularly in the realm of digital competence. Specific actions include raising the skill levels of pupils and the workforce by improving the effectiveness of education and training systems. In line with this goal, the development of digital competence is a relevant priority area within the development of high-quality skills. Under the umbrella of the ET2020 cooperation framework, thematic working groups [Note 18] have been established, including a group on digital skills and competences, in which experts from national administrations in EU member states benefit from mutual discussion on the policy level and in situ peer learning activities on relevant issues.

The European Schoolnet (EUN) [Note 19] is, in itself, an example of and a mechanism for defining and implementing operational policies. The EUN is a network of 30 European Ministries of Education that aim to bring innovation to teaching and learning across schools, teachers, researchers, industry partners, and the ministries themselves.

Another good example of an operational policy developed in the EU is the Digital Competence Framework for Citizens (DigComp), first published in 2013 by the European Commission (Ferrari 2013) and updated in 2016 (Vuorikari et al. 2016). This framework is primarily a tool to develop policies that support digital competence building and to plan education and training initiatives to improve the digital competence of specific target groups.

Although the DigComp framework was designed to be of universal use for all sectors of society, the most prominent uptake has been within the educational sector. Successful examples of the use of DigComp as a backdrop for overarching school policies and a tool for revising instructional planning and designing self-assessment tools of digital competence for pupils can be found in several European countries. Examples of national and regional initiatives using DigComp for policy planning include the **Italian** National Plan for Digital School (Il Piano Nazionale Scuola Digitale) [Note 20] launched in late 2015; the **Maltese** "Green Paper: Digital

Literacy" [Note 21] launched in 2015; and the 2016/2017 work in **Navarra**, **Spain**, where DigComp is used for strategic planning in the regional Department of Education.

For instructional design purposes, prominent examples of the uptake of DigComp can be found in **Spain**, where a continuous professional development (CPD) program for teachers includes strong support for teachers' digital competence building and the development of digital training material. Both **Portugal** and **Lithuania** have implemented similar CPD initiatives, while in **Norway**, DigComp is used as an inspiration for a new national digital competence framework for teachers targeting both initial and in-service teacher training. A more holistic approach is taken in **Croatia**, where the "e-schools project" uses the DigComp framework to build its understanding of teachers' digital competence in digitally mature schools.

Another interesting use of the framework is as a background for designing assessment tools. In **Estonia**, starting in 2017, ninth graders will be assessed on their digital competence, an initiative that follows up on the inclusion of digital competence in the national curriculum in 2014. A similar project targeting teachers can be seen in **Croatia**, where an international research consortium has initiated a DigiComp [Note 22] project to facilitate hands-on understanding of the framework's competence areas by designing an online course platform to train teachers in confidently and critically using ICT in teaching, including cooperation, communication, and content-making.

Other notable EU-level frameworks aimed to support the fostering of digital competences in schools are the forthcoming European Commission Digital Competence Framework for Teachers (DigCompTeach), which highlights the specific need to understand digital competences in the teaching profession, and the European Framework for Digitally Competent Educational Organizations [Note 23] (DigCompOrg) (Kampylis et al. 2015), which complements other frameworks, such as the DIGCOMP framework.

Challenges and Developments in the European Region

When considering further developments in the region, it is appropriate to explore some of the pertinent challenges. We have already touched upon some of the major struggles the region is currently facing, such as increased immigration and terrorist threats. Furthermore, at the school level, we see other types of challenges related to curriculum integration, the professional digital competence of teachers, digital divides, and a weak association between the use of ICT and pupils' learning outcomes. The PISA 2012 results show that increased access to ICT is not synchronous with better learning outcomes in mathematics and reading (OECD 2015), and one reason may be that the potential of technology is not yet fully utilized.

The quantitative focus of (more) access to infrastructure, technological tools, and Internet connectivity supersedes the focus on a better pedagogical use of technology to optimize students' learning outcomes. Technology does not transform education by itself; rather, it facilitates innovative, multimodal, and flexible learning. Moreover, technology adaption in schools needs to be viewed together with other aspects of school improvement and quality, such as school leadership, continuous professional development/lifelong learning of teachers, and assessment/evaluation systems.

Looking ahead, it is likely that the importance of lifelong learning and the continuous development of both learners and teachers over the course of their working lives will become the norm. Education systems will be informed by detailed and timely evidence through big data and developments in artificial intelligence. Pupils and teachers will be able to transport and combine education from various modes of formal and informal learning platforms. These shifts will lead to the development of formal qualifications, digital badges, ePortfolios, etc. (European Commission 2017).

However, though the European region is home to great disparities in access to technology and infrastructure, the user divide is even more prominent. We see great differences in teachers' competence when it comes to using technology within primary and secondary schools. Teachers claim that they need more training to gain the competence necessary to use technology in the classroom (OECD 2014b; European Commission 2013). Moreover, it is important to connect existing policies with actual practices and to understand that, despite good policy intentions, transferring them into practice is not an easy task. In addition to supporting good access and infrastructure, we also need school leaders and teachers to integrate policy intentions into local curricula. In accomplishing these objectives, we are dependent upon those school leaders and teachers who see the potential of ICT use for improving students' learning processes.

Professional Development of Teachers

In addition to primary and secondary education policies themselves, teachers' professional digital competence can also greatly influence the use and integration of policies at the school level. Therefore, we discuss this competence as an emerging theme in the region. Policy visions can be supported both by the provision of in-service training and by efforts to address the pedagogical use of ICT during the preservice training of primary and secondary school teachers.

The TALIS reports (OECD 2009, 2014b) reveals that teachers in primary and secondary education require more training in the use and integration of ICT into their practice. Teachers' professional digital competence is an important factor in ensuring the effective implementation of ICT education policies in primary and secondary education. Assisting teachers in developing their professional practice, knowledge, and skills in integrating ICT is an emerging theme in many European countries.

Professional digital competence refers to teachers' competence using ICT (i) as general basic tools, (ii) within the subject matter, and (iii) as a profession-oriented practice (e.g., to improve home-school communication, class leadership, relational competence, and teachers' own continuous professional development). Teachers require both basic digital skills and critical skills to assess when it is (or is not) appropriate to use technology to teach their subject matter. Teachers, therefore, need to have knowledge and skills in technology, pedagogy, and content, as well as in the many possible combinations of these three, in order to embed ICT effectively into their teaching practice.

Competency frameworks focusing on the digital competence of teachers are being developed in several European countries in order to further assist teachers in integrating ICTs into their teaching and learning (see also section "Operational Policies" and the discussion on the DigComp framework). The UNESCO competence framework for teachers has been adapted and used to define teachers' competence in **Ireland** (Department of Education and Skills 2015). Similarly, in **Norway**, researchers and policy makers have developed a competence framework that provides structure for ICT integration in the teaching and professional learning of primary and secondary teachers as well as in teacher education [Note 24].

Job Automation and Youth Unemployment

Demographic changes and ICT have influenced what kinds of work and career paths are needed in the future. Following the 2007 financial crisis, millions of people in Europe lost their jobs, and young people with limited work experience were often hit the hardest. Youth unemployment is still high in several European countries. In addition, ICT is changing the ways in which we work. Artificial intelligence, the Internet of things, and big data are all influencing how we work, when we work, and where we work. Against a backdrop of rising inequality and shrinking job security, demands for entrepreneurship and the innovative and effective use of ICT are growing.

There is, therefore, a need to better coordinate education with the needs of the labor market in order to enable youth to gain necessary skills, reduce mismatches between job requirements and competence, and cope with challenges of increased competence and economic and social demands. Curricula must bridge boundaries between subjects and "cross the borders between subjects, between 'academic' and 'vocational' learning, and between the worlds of adults and students" (Hampson et al. 2016, p. 15). Such steps will enable youth to personalize their career choices and gain the competences necessary for their future careers.

Digital Citizenship

Learners in primary and secondary education today are born into a digital world. Though many call this generation "digital natives," it is important to remember that students who are familiar with technology do not necessarily know how to use educational resources and ICT for learning. For this reason, issues of digital citizenship are and will be of great importance both globally and within the European region. The challenges teachers face concerning distracted students in technology-rich classrooms need to be addressed with strategies for class management (pedagogical, organizational, and technological). Challenges regarding online bullying and disrespectful communication and issues of privacy and copyrights are also of continuous concern within primary and secondary education in Europe. In this regard, efforts to incorporate policies promoting digital citizenship across the curriculum are critical. This message is underscored by research findings from the EU Kids Online project, which reported that children's chances of being exposed to hate messages and cyberbullying on the Internet rose significantly between 2010 and 2014 (EU Kids Online 2014).

Conclusion and the Way Forward

We have now discussed some of the policy initiatives targeting primary and secondary education in Europe. In so doing, we have identified several national and local initiatives and more holistic policy plans involving the EU and the European region as a whole. However, needless to say, the limitations of this chapter are abundant, and it is impossible to cover all the positive initiatives that are worth mentioning.

It is difficult to forecast developments and upcoming challenges within the field of ICT. One way to address future developments is to describe or predict some of the technological changes and developments that are likely to occur. Instead of taking this route, we chose instead to focus on some of the qualitative and pedagogical aspects influencing technology adoption. Therefore, we discussed three challenges that we are already facing: (i) teachers' professional digital competence, (ii) changes in the world of work and the importance of lifelong learning processes, and (iii) the increased focus on digital citizenship and digital responsibility.

The European region faces several challenges involving the integration of ICT in primary and secondary education. Some of these have been briefly mentioned in this chapter. However, supplementing teaching methods with ICT is only as effective as the teacher leading the teaching/learning process. In other words, ICT will never replace "traditional" teaching methods and/or teachers. The biggest challenge is, perhaps, how we assess empirical and research-based evidence to determine what works and when and to learn how the variety of pedagogical approaches and methods/tools in the classroom can lead to better learning for students. This challenge applies not only to ICTs but also to every method or means teachers use in the classroom. It can, in short, be defined as the challenge of leveraging evidence-based practices and policies to further develop education.

End Notes

1. See further http://unstats.un.org/unsd/methods/m49/m49regin.htm#europe
2. See, e.g., http://www.dw.com/de/das-aus-f%C3%BCr-schulen-ans-netz/a-16481641

3. These are Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kosovo, Latvia, Lithuania, Luxembourg, Macedonia, Malta, Moldova, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Russia, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.
4. Calculations based on TIMSS 2015 exhibit 9.5 and 9.6 (http://timssandpirls.bc.edu/timss2015/international-results/timss-2015/mathematics/classroom-instruction/computer-activities-during-mathematics-lessons/)
5. PISA results are based on data on 15-year-old students, a population usually assigned to upper secondary schools in European countries. TIMSS covers the populations of both fourth graders (typically in primary schools) and eighth graders (typically in lower secondary schools). TIMSS 2015 was released at the same time as PISA 2015; thus, the studies are chronologically comparable.
6. These are England, Hungary, Ireland, Italy, Lithuania, Malta, Norway (grade 9), the Russian Federation, Sweden, Slovenia, and Turkey.
7. These are Denmark, Netherlands, Sweden, Norway (grade 5), England, Germany, Finland, Cyprus, Ireland, Belgium (Flemish), Italy, Spain, Poland, Lithuania, Turkey, the Czech Republic, Hungary, Bulgaria, the Slovak Republic, Portugal, France, Slovenia and Serbia.
8. With high equipment levels, large numbers of network access points, routers and switches, highly Wi-Fi connected classrooms, high use of cloud for hosting, BYOD policy and BYOD support.
9. With relatively low levels of equipment, low classroom Wi-Fi provision and services hosted in school.
10. https://digabi.fi/?lang=en_US
11. See further www.mi4u.ch
12. See further http://hitsa.ee/about-us
13. See further http://www.iea.nl/fileadmin/user_upload/Studies/ICILS_2018/IEA_ICILS_2018_Computational_Thinking_Leaflet.pdf
14. See further http://ec.europa.eu/programmes/erasmus-plus/node_en
15. See further http://ec.europa.eu/social/main.jsp?catId=1223
16. See further http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:JOC_2016_484_R_0001
17. See further http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006H0962
18. See further https://ec.europa.eu/education/policy/strategic-framework/expert-groups_en
19. http://www.eun.org/
20. http://www.istruzione.it/scuola_digitale/allegati/Materiali/pnsd-layout-30.10-WEB.pdf
21. https://education.gov.mt/elearning/Documents/Green%20Paper%20Digital%20Literacy%20v6.pdf
22. http://www.digital-competences-for-teachers.eu/
23. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC98209/jrc98209_r_digcomporg_final.pdf

24. See further https://www.udir.no/globalassets/filer/in-english/pfdk_framework_en_low2.pdf

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88 Information and Communications Technology and Educational Policies in Latin America and the Caribbean

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Abstract

The chapter refers to policies towards ICT in primary and secondary education from the perspective of the Latin American and The Caribbean region. These policies show different levels of progress, maturity and consolidation which reflect the heterogeneity and social inequity that persist in the region. Analysis of these characteristics and differences are made by considering pedagogical models, teacher training issues, student access to technology for inside and out of school use and evaluation on the impact of technology within this context. A more detailed analysis is offered to some recent initiatives, such as the one-to-one model and the development of digital content for open educational practices. From the analysis of the global, regional and local ICT development policy for education, the short, medium and long term future challenges in training trends and technological innovations are pointed out. The main challenges still are related to decisions regarding technological infrastructure, conditions for pedagogical change, development of capacities in teachers and students, policies evaluation and research development.

Keywords

Digital Infrastructure · ICT Policies in Education · Innovation with ICT · Teacher Training · Policy Evaluation · Pedagogical practices · Quality assurance · Digital Skills · Open Educational Practices

Introduction to ICT in Primary and Secondary Education in Latin America and the Caribbean

The socio-educational reality of Latin America and the Caribbean is characterized by the coexistence of different realities resulting from social, ethnic, and/or geographical differences existing in the population. On the one hand, and coinciding with the last cycle of economic growth, the region as a whole shows important improvements regarding the fulfillment of the Education for All (EFA) goals set up in 2000, in Dakar; however, there are geographical areas and/or sociocultural groups which experience enormous educational inequalities keeping them far from meeting these goals (OREALC 2014a; UNESCO, IIPE & OEI 2014). Therefore, in order to analyze ICT policies in education in the region, we need to consider different levels of progress, achievements, and urgencies.

The introduction of ICT in education in the region has been the product of national policies implemented by the Ministries of Education and financed by international organizations such as the World Bank or the Inter-American Development Bank. In a first stage, the main objectives of the policies were to institutionalize an ICT policy in the education area to expand the coverage and access to technological infrastructure in schools and reduce the differences caused by the "first" digital divide (Attewell 2001). At the end of the twentieth century, it is possible to see a few pioneers in addressing these challenges: Costa Rica and its National

Program for Educational Informatics (1988); Mexico and its Red Escolar (1990); Chile and the Red Enlaces (1992); Brazil with the National Programme for Educational Technology, ProInfo (1997); and Argentina with the Programa Educar (2000) (UNESCO, IIPE & OEI 2014).

During the first and a half decade of the twenty-first century, governments in the region continued with the expansion and institutionalization of this policy. Since 2006, governments reinforced the expansion of infrastructure, including Internet connectivity and teacher training, thanks to the growing availability of resources, as well as the expansion of commodities with the consequent increment of the gross domestic product (GDP) and the implementation of social redistribution policies which was beneficial for the whole population (OREALC 2014b). During this period, two main challenges for ICT policies in education emerged: to use ICT to help develop the cognitive and social skills demanded by the information society (Ananiadou and Claro 2009) and to improve the results of teaching and home practices, including improving the ICT skills of socially and culturally disadvantaged students (Kuhlemeier and Hemker 2007).

Then, a second phase in ICT policies in education emerged which focused the attention on three main issues: renewed teaching and learning processes, the distribution of ICT equipment to students, and the implementation of more efficient school management procedures. Some initiatives of this period are Uruguay's Plan Ceibal (2007), Argentina's Conectar Igualdad Programme (2010), Colombia's National System for Innovation in Education with the Use of ICT, Peru's One Laptop per Child Project, and Mexico's Digital Skills for All Project (UNESCO, IIPE & OEI 2014; OREALC 2014a).

In spite of the lack of evidence regarding the impact and results of these policies, the information available shows that the region has made great improvements; but these are uneven with profound differences, within and between countries, in the incorporation of ICT showing, thereby, the existence of multiple divides produced by a heterogeneous and unequal social reality (Hinostroza and Labbé 2011; Lugo and Kelly 2010; Lugo and Brito 2015; Sunkel and Trucco 2014).

Recent Developments on ICT in Latin America and the Caribbean

In order to understand recent developments on ICT in the region, one has to consider three levels of development based on how the countries have been able to solve different barriers involved in closing the digital divide.

In the *emergent* stage, which is characterized by scarce infrastructure, lack of financial resources, or policies that have not been able to institutionalize, are countries such as Guatemala, Paraguay, and Bolivia; then in the *application* stage, in which pilot projects become laboratories whose purpose is to demonstrate the effects of long-term innovations but implemented at a small scale within the limits of the school context, are countries such as El Salvador, Jamaica, Peru, the Dominican Republic, and Trinidad and Tobago. Lastly, in the *integration* stage, where policies have been institutionalized and show ample coverage in the school system with a strong coordination to face the digital divide, are countries such as Chile, Uruguay, Argentina, Mexico, Brazil, Colombia, Cuba, and Costa Rica (Lugo and Kelly 2010; Sunkel 2006).

ICT Infrastructure and Models for Incorporating ICT in Schools

The region confronts four main divides in its efforts to overcome differences in access to equipment and connectivity: the *socioeconomic* gap, which impinges upon households and is reproduced in the school system, except in countries where integration tends to disappear; the *geographic* gap or the difference produced by the geographical place of residence, which is predominant in rural areas and has increased in Peru and Mexico, but declined in Uruguay; the *educational* gap, or difference in access to ICT depending on the type of school the students attend, with private schools being the most advantageous; and lastly, the *social* gap which affects disadvantaged social groups including indigenous students and groups with special educational needs (Sunkel et al. 2013; Sunkel and Trucco 2011; UNESCO 2013).

In this context, half or more than half of the students in the region does not have access to a computer or Internet connectivity in the home; however, variations by country show that 60% of students in Uruguay, Argentina, and Chile have access to equipment; in Peru, Colombia, Mexico, and Brazil, this amounts to 40% and, in the rest of the countries, less than 40%. Similarly, 40% of the students in the region have access to computers connected to the Internet with variations in Brazil, Uruguay, Argentina, and Chile where connectivity exceeds 50% and can reach 90%, falling to less than 40% in countries such as Mexico, Colombia, and Peru (Fraillon et al. 2014; Claro et al. 2011). These data indicate that the region is well below the Organisation for Economic Co-operation and Development (OECD) rate, where the average for both types of access reaches 80%.

The availability of computer equipment in schools has increased in the last decade, approaching the average values of OECD countries. In 2000, 62% of 15-year-old students had at least one computer available for academic use, a figure that increased to 93% in 2009 in countries such as Chile, Colombia, Trinidad and Tobago, and Uruguay (UNESCO 2013). Meanwhile, the student-computer ratio, which was 56 in the region in the year 2000, decreased to 21 in 2009 with great disparities ranging from 1/1 in Uruguay to 122/1 in the Dominican Republic. Thus, the availability of computers and/or Internet connection in schools reaches or exceeds 92% in Chile, Brazil, Cuba, and Uruguay; in Colombia, Mexico, Argentina, Ecuador, and Panama, the rate is above 75%, but in Guatemala and the Dominican Republic, it is well below 30%. Only Brazil and Chile reach or exceed the average 90% of the OECD countries; Mexico and Panama have an average of over 70%, and Paraguay, the Dominican Republic, Guatemala, and Cuba have rates below 30% (OECD 2015; Román and Murillo 2014). On the other hand, Caribbean countries (particularly Anglophone ones) have significantly higher levels of ICT access and use than most South American and Central American countries (UNESCO 2013). Regarding access to ICT by education level, regional data shows that secondary schools have the largest proportion of ICT equipment (74%); Uruguay is the exception, as the Plan Ceibal has prioritized equipping all primary schools (Hinostroza and Labbe 2011; UNESCO 2013).

In addition to this, since the end of the twentieth century, the region has seen the implementation of 15 types of projects and modalities for the integration of ICT into schools, out of which five have had greater development: (i) the computer laboratory model, (ii) the computers in the classroom model, (iii) the mobile lab or laptop model, (iv) the school networks model, and (v) the one-to-one model; this latter model has had the largest development in recent years (Lugo and Kelly 2010; Sunkel et al. 2013; Sunkel and Trucco 2011; UNESCO, IIPE & OEI 2014).

In brief, since the middle of the first decade of the twenty-first century, the countries in the region have made substantial progress in terms of access to technological infrastructure and equipment in the home; however, this situation is heterogeneous with great variations among countries, with Uruguay taking the lead, thanks to its policy for universal access in primary schools including the provision of access to computers to about 50% of homes with school-age children in 2009. As regards connectivity to the Internet, the progress has been slower due to high costs in services that persist in the region; however, Internet connectivity is higher in homes with school-age children and mainly seen in countries such as Brazil, Uruguay, Chile, and Argentina (city of Buenos Aires); in the latter, access to the Internet in 13-year-old students' home reaches 98% (Fraillon et al. 2014). As of 2009, most of the school population in Bolivia and Honduras still did not take a leap forward in terms of home access to the Internet, while Caribbean countries (particularly English-speaking countries) have significantly higher levels of ICT access and use than most South American and Central American ones.

The Use of ICT by Teachers and Students

Information about the use of ICT by teachers and students in the region is scarce; however, it is possible to indicate that levels of ICT use by teachers tend to be low and uneven between and within countries. According to Sunkel and Trucco (2014), countries with a critical mass of teachers who already use computers have a basis for advancing in the incorporation of ICT in lessons; such is the case of Cuba, Chile, and Uruguay. Thus, teachers would be in an "adaptation" phase according to models of ICT adoption and integration, adapting traditional teaching strategies, incorporating new technologies, and organizing students to work independently in small groups.

With regard to ICT practices by students, the results of the PISA 2009 test with 15-year-old students from Chile, Panama, Trinidad and Tobago, and Uruguay do not reveal large differences in their patterns of ICT use compared to 2006's results; that is, students use technology at least once a week for different types of activities but commonly associated to recreation and communication uses, such as browsing the web for entertainment purposes, chatting, downloading music/movies, and sending e-mails. A higher percentage of students who declared to perform these activities with high frequency were from Uruguay and Chile. However, the activity most frequently mentioned by the students in these countries was to use ICT in lessons for school work which set them quite above from the average OECD student (Claro et al. 2011).

Teacher Training in and About ICT

The ICT policy for education in the region has included teacher training which focuses on four main issues: (i) ICT literacy for the development of digital skills, (ii) pedagogical use of ICT, (iii) the creation of virtual communities for professional development, and (iv) school management. In recent years, students in initial teacher education and students from the school system have been included into this policy. Some countries, such as Panama or Paraguay, have defined guidelines to encourage an integral training system which blends professional development for graduated teachers with student teachers; other countries have proposed training actions aimed at teachers with the possibility of including student teachers, which is the case of Uruguay as part of the Plan Ceibal or Argentina as part of the National Teacher Training Plan. In other countries, differentiated actions for teachers and student teachers have been designed, as in the case of Chile with the definition of ICT standards and competencies led by the Red Enlaces, or Mexico with the Sectorial Education Program, or Brazil with its policy for continuous teacher training (Vaillant 2013).

In most countries, teacher training programs usually take the form of workshops, short courses, or postgraduate diplomas for the curricular integration of software applications or specific digital tools (e.g., digital whiteboards), for the appropriation of pedagogical methodologies based on ICT (e.g., project-based learning), or for developing specific skills required in the design of ICT-mediated learning environments (e.g., ICT and inclusion). One recent development in the region has been the promotion of teacher training in both blended and e-learning modalities, either in a collaborative, individual, or self-instructional mode.

Results and Quality Assurance on the Use of ICT

The education policy in the region focuses on quality, therefore assessing the impact and contribution of ICT to learning processes has been an ongoing concern over time. A first development on the subject has been the creation or use of conceptual frameworks for the definition of competencies or standards on what the use of ICT in the classrooms should be expected. In this regard, not only international frameworks elaborated outside the region have been used for this purpose but also conceptual models created within the region itself (Hinostroza and Labbé 2011; OREALC 2014b).

Among the main international models used, we find the ICT Competency Standards for Teachers Framework developed by UNESCO in 2008, the Standards for Teachers developed by the International Society for Technology in Education (ISTE), the framework for the integration of ICT in education based on the

Technological Pedagogical Content Knowledge (TPACK or TPCK) model proposed by the American Association of Colleges for Teacher Education (AACTE) and the Partnership for 21st Century Skills, and the Skills and Competency framework developed by the OECD and used in the PISA Program (Vaillant 2013). Among the models created in the region, we can find the following: the Competency Standards framework developed in 2008 by the National Council for Standardization and Certification of Labor Competencies in Mexico (http://conocer.gob.mx/) which seeks to enable teachers to manage information on the web, design learning materials, and facilitate school activities with the support of ICT; the updated Competencies and ICT Standards in the Teaching Profession framework, designed by the Red Enlaces in Chile (MINEDUC 2010); and the Adaptation of Teaching Guides in Costa Rica proposed by the National Program for Educational Informatics and the Omar Dengo Foundation in 2010 (Vaillant 2013).

A second development has been the implementation of assessment procedures to obtain data about educational impacts. In this regard, regional assessment initiatives have been carried out by the UNESCO Institute for Statistics (UIS), which, in the context of the Partnership on Measuring ICT for Development, seeks to gather information about the use of ICT in education. In 2009, the UIS constructed a set of indicators for the elaboration of databases and reports that are used as a benchmark for the fulfillment of the Millennium Development Goals and the goals of the Education for All movement. At the country level, the Chilean Education Quality Measurement System (SIMCE) elaborated a test which seeks to measure the development of digital skills in lower secondary school students. The results have allowed us to appreciate the impact of the use of ICT in schools for the development of higher-order thinking skills (MINEDUC, CEPPE & PAÍS DIGITAL 2013).

Recent Developments on Policies on ICT in Latin America and the Caribbean

Due to recent ICT policies that favor the incorporation of mobile devices into schools, the region has embarked on developing initiatives based on the one-to-one model and innovative educational practices that take advantage of open educational resources which are available on national education portals.

ICT Initiatives with One-to-One Models

In order to improve equal access to digital resources, economic productivity, and quality of learning, since 2006 ICT policies based on the one-to-one model have been implemented in the region. Digital devices such as laptops, usually with Internet access, are provided to individual students to facilitate their learning. By 2010, initiatives of this type had been implemented in 17 countries; Uruguay's Plan Ceibal is the most notable experience in the region; so far the program has covered all primary schools in the public school system.

The successful implementation of Plan Ceibal has been mainly due to a strong institutional support from the state as well as an efficient logistical implementation which has provided free Internet connectivity to all participating schools and homes (Severin and Capota 2011). However, one limitation of the project has been the high costs involved in the purchase of a laptop computer for each student, which has made other countries in the region decide to adopt different modalities such as the mobile lab model which consists of one or more trolleys carrying 20 or 30 netbooks into classrooms. Argentina and Chile have implemented experiences of this type (Lugo et al. 2012; UNESCO, IIPE & OEI 2014).

A variant of the one-to-one model is the pedagogical use of varied mobile devices (e.g., tablets, cell phones, netbooks, pocket PCs) to carry out mobile learning experiences (m-learning). Projects of educational initiatives in this modality include marginalized populations and indigenous communities living in rural areas. However, regional and local national education policies that recognize this type of learning are still scarce due, mainly, to restrictions on the use of cellular phones in the classroom. Ecuador is the exception; the use of the cell phone in this country is allowed under the teacher's responsibility and for the implementation of pedagogical activities only (Chiappe 2016).

A few studies on mobile learning initiatives using cell phones in Latin American countries (no such initiatives were identified in the Caribbean) carried out by UNESCO show that more experiences of this type are implemented in secondary and postsecondary institutions than in primary schools. A few examples can be seen in Chile (e.g., PSU Mobile Program) where mobile phones are used to prepare students for university selection tests and also in Colombia and Chile (e.g., Global Bridge IT) where teachers use mobile phones to project videos or other digital content in the classroom. In Colombia, in rural areas, cell phones are used to improve illiteracy rates; in Argentina, school supervisors use cell phones to improve the management of the school system (Severin and Capota 2011; Lugo et al. 2012).

Despite the success achieved by mobile learning experiences in the region, there are criticisms regarding some shortcomings found in a few impact evaluations, as well as barriers that could restrict the expansion and sustainability of mobile learning initiatives in the region, such as the high costs of Internet connectivity, the limited access to terrestrial and mobile broadband, and the high costs of purchasing a smartphone or the lack of policies regarding the development of content for these devices (Lugo and Schurmann 2012; Lugo et al. 2012). All these factors have cast doubt on whether the choice of this model is the most appropriate for all countries in the region (Severin and Capota 2011).

Digital Educational Content and Open Educational Practices (OEP)

In the first decade of the twenty-first century, the countries in the region started to distribute digital educational resources through national education portals hosted on the web in Internet. The first countries to develop these resources were Argentina, Brazil, Chile, Mexico, and Peru. At present, 20 countries in the region have set up a network of national portals called the Latin American Network of Educational Portals – RELPE (http://www.relpe.org) – whose main objectives have been to improve the quality and equity of education through the free exchange and use of digital educational resources located in member portals and to set up actions for the exchange of policies, experiences, and collaboration in the use of ICT in education (Ferreyra 2015).

The content published in the Network is organized according to the level of education (primary, secondary, and tertiary) and has a curricular classification by learning domains. At present, some countries in the region, such as Chile, Peru, and Argentina, are restructuring their national portals and reorganizing the contents in terms of new forms of knowledge construction and how users interact with it (Ferreyra 2015). Currently, there is a shortage of open educational resources (OER) policies in the region, as recommended by the Paris Declaration on OER in 2012; only 9 countries out of 38 have adopted a national policy in this regard (UNESCO 2013); in several countries, free-access licenses (e.g., Creative Commons) are used in order to protect a work's intellectual property rights (Chiappe 2016).

Among the barriers that could limit the generation and expansion of OERs in the region, we can find the lack of support to keep the "sustainability" of the projects due to difficulties in Internet connectivity in some countries, the lack of knowledge about this topic, or the lack of incentives on the part of educational institutions to favor the use of OERs (Hoosen 2012).

There is a great variety of experiences regarding the generation of learning objects and open educational resources in the region (see examples in Chiappe and Martínez 2016); however, the impact of their use has been low and not always the use of OER has evolved toward innovative pedagogical practices that could be promoted through ICT policies in education (Chiappe 2016; Andrade et al. 2011).

In recent years, there have emerged innovative educational initiatives known as open educational practices (OEP) that incorporate the use of open educational resources. These initiatives are practices of an educational nature (teaching, evaluation, didactic planning, or curricular design) to which some attributes of "open" are applied, such as free access, adaptation, collaboration, sharing, and remixing (Chiappe and Martínez 2016). Experiences of this type in the region are still scarce, with more initiatives at higher education levels than at school levels. One example is Uruguay, in the context of the Plan Ceibal, where teachers and teacher training students participate in a network of centers (Red REA) with the purpose of creating open educational digital resources and produce digital content in a distributed and open manner through micro-virtual workshops (Rivero and Rabajoli 2016).

Relevance of Cross-National and Worldwide Strategies and Plans for Latin America and the Caribbean

Policies and strategies for the incorporation of ICT in education in Latin America and the Caribbean have been influenced by the overall process of transition to the information society (Sunkel and Trucco 2014). From the political point of view, this influence has been exerted on three different levels: global, regional, and national.

At the *global* level, international agreements have been signed among the countries of the world within the context of forums and global summits. For instance, at the World Summit on the Information Society (WSIS) in Geneva 2003, governments from 175 countries committed themselves to "building an inclusive Information Society and putting the potential of knowledge and ICT at the service of development," which meant eliminating the digital divide of access to ICT. Two goals relating to ICT in education were set up in the action plan: (i) "to use ICT to connect universities, colleges, secondary schools and primary schools" and (ii) "to adapt all curricula in primary and secondary education to fulfill the objectives of the Information Society, taking into account national circumstances" (UIT 2005, p. 28).

In this way, the Geneva summit calls on governments to "define national policies to ensure the full integration of ICT at all levels of education and training, including curriculum development, teacher training, institutional management, and support for the concept of lifelong learning" (UIT 2005, p. 36). In addition, the declaration recognizes the important role of universal primary education as a key factor in creating a fully integrated information society, thus highlighting the centrality of education in this global instance (Sunkel and Trucco 2014).

Lastly, another instance of global influence has been the World Forum on Education of 2015, which took place in the Republic of Korea, where 160 countries adopted the Incheon Education Declaration 2030 and made a commitment to "harness the technologies of (ICT) to strengthen education systems, dissemination of knowledge, access to information, effective and quality learning," as a way to meet the goals of the Sustainable Development Objective 4, which seeks to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (Incheon Declaration, World Education Forum, UNESCO 2015).

At the *regional* level, a number of events have taken place, notably the Regional Ministerial Conference of Latin America and the Caribbean and the different versions of the Regional Action Plan on the Information Society in Latin America and the Caribbean (eLAC), all of them with the purpose of creating a regional approach to information society development and how to address its challenges. The Plan has given rise to four versions: eLAC2007, eLAC 2010, eLAC 2015, and eLAC 2018.

The eLAC 2007 Plan focused on developing three lines of action: (i) deepening knowledge and understanding of critical areas, (ii) formulating and strengthening concrete initiatives and projects at the regional level, and (iii) supporting the development and implementation of national initiatives through intra-regional exchange. In the education area, the goals of the Plan were twofold: increase the connectivity to the Internet in schools, particularly in educational centers located in rural areas, and improve the student-computer ratio in the region (CEPAL 2013a).

The eLAC 2010 Plan fostered the use of ICT for development and the achievement of economic growth with equity, reflecting thus a change in orientation, moving away from a technocentric tendency, to a more integral human and social development. The educational goals of this Plan were structured along four central themes: the environment (which refers to curriculum development), access (referring to connectivity), capacities (students' ICT use and teacher training), and content (portals, applications, and services) (CEPAL 2013a).

On the other hand, the eLAC2015 Plan proposed the use of ICT as tools for development and social inclusion, aligning its goals with the Millennium Development Goals and the World Summit on the Information Society (WSIS). It recognized that education is one of eight priority themes among its educational goals and that ICT policy should be a state concern in the educational field. The goals of the Plan were (i) to connect all educational institutions to broadband Internet and promote public policies for the establishment of academic networks, (ii) to ensure ICT training for teachers and managers, (iii) to promote the production of multimedia content freely available on the Internet, and (iv) to promote support for the Latin American Network of Educational Portals (RELPE) (CEPAL 2013a).

Finally, in Mexico City, in 2015, the region set up the Digital Agenda for Latin America and the Caribbean eLAC2018, which was structured around five themes: access and infrastructure, digital economy, e-government, social inclusion and sustainable development, and governance. In the area of social inclusion and sustainable development, the agenda formulated an educational objective that seeks to "incorporate or strengthen the use of ICT in education and promote the development of programmes that include teacher training, new pedagogical models, the generation, adaptation and exchange of open educational resources, management of educational institutions and educational evaluations" (CEPAL 2013a), which implies a greater challenge for national ICT policy agendas in the education field.

One important factor for the region has been the uneven performance of countries in achieving the goals of the Education for All (EFA) movement (Dakar 2000, Geneva 2003) and the Millennium Development Goals (ONU 2000). In 2002, five strategic areas for the universalization of primary education were defined and the Regional Education Project for Latin America and the Caribbean (EPT/PRELAC) was created, which acted as a regional coordinating body for the global project (EFA). Although PRELAC gave little attention to technology issues, in 2008 a second version of the project, Educational Goals 2021, was presented which incorporated within the overall goal – to improve the quality of education and the school curriculum – two specific goals with regard to ICT: "to improve the computer-student ratio" and "to foster the regular use of ICT in the teaching and learning process" (OEI 2010, p. 118). This reinforces the sense of priority and dynamism of the present policies for the integration of ICT in education in the region which are formulated within a framework of new challenges for the education area in terms of coverage, continuity, quality, and equity (Severin 2014).

At the *national* level, the countries in Latin America and the Caribbean have developed national digital agendas which contain objectives and policies that each country must carry out in its transition to the Information Society. The first digital agenda emerged in Brazil in 2001; by 2012, most countries in the region have formulated national digital agendas. A recent study which included six countries shows that the most frequent objectives of the national digital agendas center around the following themes: infrastructure deployment, access to broadband Internet and connectivity, ICT industry including capacity building, content development, e-government, and e-education; the study also identified some challenges that the countries in the region need to address, such as coordination among the actors involved in policy implementation, capacity building in local governments, support for the implementation of programs defined in the agendas, and evaluation and monitoring of policies (CEPAL 2013b).

In brief, although the plans and frameworks established at the global level have highlighted the importance of generating ICT policies in education, this influence has not been exerted in a direct fashion in the region due, mainly, to a lack of coordination between information society policies, designed at global or regional level and ICT policies for education set up at national level. According to Sunkel and Trucco (2014), the process of adoption of ICT policies in the region has not followed a "top-down" approach by which the guidelines established at the level of the World Summit would have a direct translation at the regional level and then at the national level. They illustrate this point by stating that the emergence of ICT projects and policies in education in the region dates back to the early 1990s (e.g., Educational Informatics Program in Costa Rica, Red Enlaces in Chile, ProInfo in Brazil, Red Escolar in Mexico), a while before the international agreements had been set out. In this regard, OREALC (2016) points out that this situation could be an important factor as to why the introduction of ICT in the education system in the region has not produced the desired impact, which could in turn affect the educational outcomes and goals that the policies seek to achieve.

The lack of coordination and alignment in the application of ICT strategies and policies in education, in addition to the complexity involved in the process of innovation and change, would appear to affect negatively the progress the region is making at closing the first digital divide, while securing that the second divide can be addressed effectively, in spite of new and challenging educational goals. Hence, the Economic Commission for Latin America and the Caribbean (CEPAL) and UNESCO/OREALC have proposed guiding frameworks for the integration, implementation, and monitoring of ICT policies for the education sector in the region, which jointly address issues of access, capacity building, applications, and policies (Sunkel et al. 2013; Sunkel and Trucco 2014) in accordance to national and international objectives and by taking a quality in education perspective (OREALC 2016).

Challenges and Relevance of Research for Policies on ICT in Education in Latin America and the Caribbean

In general, public ICT policies have been supported by a favorable climate of opinion about their contribution (promise) based on an aura of a priori success and effectiveness, rather than on evidence and results of empirical and contextual research (Sancho 2009). Thus, the synergy effect between research-decision and application-evaluation is not evident or long lasting. However, valuable studies have been carried out on aspects such as the implementation of the Internet in primary school systems in Argentina (Steinberg 2013) or the development of digital skills in

K-10 students after the application of the SIMCE-TIC Test in Chile (MINEDUC-CEPPE-PAÍS DIGITAL 2013).

Regional institutions regularly draw up reports and studies on the development of ICT policies. Among the most active, the following stand out: the Economic Commission for Latin America and the Caribbean (CEPAL), which has developed studies and frameworks for the analysis and evaluation of ICT policies in education (Sunkel et al. 2013); the UNESCO-OREALC Office in Santiago, Chile, which has developed analytical studies and proposals for the integration and evaluation of ICT strategies based on quality and inclusive education criteria (OREALC 2016; UNESCO 2013); the UNESCO Office in Quito, with contributions on the use of ICT in education on people with disabilities (Samaniego et al. 2012); and the International Institute for Educational Planning (IIPE) in Buenos Aires, which has focused the attention on the use of emerging digital environments, such as mobile learning (Lugo and Schurmann 2012), and the pedagogical introduction of ICT in schools. In addition, the United Nations Children's Fund – UNICEF – has contributed to a set of studies and research analyses on policies for incorporating ICT into the primary education level in Argentina, Chile, Uruguay, Peru, Colombia, and Mexico (Balarin 2013; Diaz-Barriga 2014; Galvis 2014; Jara 2013; Vacchieri 2013; Vaillant 2013). Finally, the Latin American Network of Educational Portals (RELPE) has also produced research reports on exemplary classrooms practices in one-to-one modalities (Marés 2012).

Extra regional institutions also provide very valuable comparative information; however, their analysis often includes a few countries in the region. One example is the report prepared by the OECD in 2015 to compare the development of digital skills for the learning of 15-year-old students, in which only Mexico, Chile, and Costa Rica participated, or the report prepared by the International Association for the Evaluation of Educational Achievement (IEA) (Fraillon et al. 2014), which evaluated the skills of eighth-grade students (13 years old) for collecting, managing, producing, and exchanging information; only Chile and the city of Buenos Aires (Argentina) were included in the analysis.

It is worth noting the design of instruments to support research on ICT in education that have been produced by some institutions in the region, such as the digital skills assessment matrix for the school population (e.g., HTPA Matrix), or the monitoring of the implementation of ICT in educational institutions (e.g., National Census of Educational Informatics) designed by the Red Enlaces in Chile. Also, the education portal created by Colombia Aprende which includes a section for researchers or the research studies on twenty-first-century skills and the effects of ICT use in the development of language and mathematics skills carried out by the Omar Dengo Foundation in Costa Rica.

As for future research developments, the latest Horizon Report (Adams Becker et al. 2016) identifies six challenges that the region needs to address: (i) narrow the achievement gap, (ii) foster personalized learning, (iii) promote digital equality, (iv) generalize innovations in teaching, (v) provide opportunities for authentic learning, and (vi) rethink teacher's role in the students' learning process. It also proposes the projection of short-, medium-, and long-term trends that should be

Table 1 Trends, challenges, and technologies for schools (K-12)

Trends		Technological innovations
Near-term	Coding as a literacy	Makerspaces
	Students as creators	Online learning
Mid-term	Collaborative learning	Robotics
	Deeper learning approaches	Virtual reality
Far-term	Redesigning learning spaces	Artificial intelligence
	Rethinking how schools work	Wearable technology

Source: Prepared by the authors based on Adams Becker et al. (2016, p. 2)

considered by educational systems, as well as the presence of particular innovations that are beginning to make their way into education (see Table 1).

Perspectives for Developments in Latin America and the Caribbean

The main challenges in the education sector in the region are contained in the regional Educational Goals 2021 project, which are very clear as to the need to improve the quality and equity in education so as to tackle poverty and inequality and thus foster social inclusion. In this context, the different countries seek to integrate ICT in educational projects as a way to address unresolved challenges such as illiteracy, early school dropout, child labor, students' poor performance, and poor quality of the public education offer (OEI 2010).

Despite the fact that the region has developed ICT policies for education in the last 20 years, the information presented in previous sections demonstrate the uneven progress made in this area. To this end, countries must continue to make sustained efforts for closing the digital divide relating to access, as well as tackle the challenges of the "second" digital divide so that young people are offered new opportunities for learning which can prepare them to deal with the challenges of the information society. In this sense, ICT policies in education should continue to focus their attention on outstanding issues but also on more current ones such as the following presented below.

Infrastructure, Technological Equipment, and Content

Although there has been a significant progress in the region in terms of access to technological equipment and infrastructure, yet half of households with 15-year-old students still do not have access to computers and Internet connection. Likewise, Internet connectivity has not had equal coverage in all countries, which is due to the high costs of its services. Therefore, it is necessary to continue with the improvement and expansion of the technological infrastructure, including Internet connectivity and connection to electric power networks, both in public school institutions and in low-income homes, as well as in rural areas, ensuring that the costs of services are kept within the reach of low-income groups. Also, it is necessary to strengthen and include into this expansion effort schools from the primary level as well as students from ethnic minority groups, from different cultural backgrounds, and those with special educational needs. In addition to this, it is necessary to develop ICT policies for mobile learning, particularly the production of digital educational content and for the different types of devices that are being integrated in schools.

Pedagogical Practices and Conditions for Change

Teachers in the region are still in a stage of "adaptation" with regard to the adoption of ICT in education, which means that different barriers need to be solved in order for them to move to higher levels of ICT integration and use. As was seen in previous sections, there are different models of ICT integration in the schools in the region, meaning that teachers need to incorporate new pedagogical practices into their teaching repertoire and participate in permanent training to address the challenges posed by the new technological developments. According to Lugo and Brito (2015), change in educational practices is one of the most sensitive issues for the policies on ICT integration in the education system; therefore, it is necessary to constantly review both the pedagogical conditions in which the teachers work as well as teachers' personal dispositions and skills toward change so that they can better deal with the barriers of the second digital divide.

Quality of Learning and Skills Development

Students in the region use ICT more frequently at home than in the school and for recreational and communication purposes. Although ICT use at school is less frequent, this is commonly oriented toward the development of skills and learning activities, meaning that ICT policies should continue their efforts in fostering the pedagogical use of ICT to improve the quality of learning, including the development of new information processing skills, problem-solving skills, and collaborative learning skills, among others, required for the full participation in the information society and digital age (Fraillon et al. 2014; Cobo 2010).

Evaluation of ICT Policies

At the national level, there has been a lack of coordination among the different actors involved in the design and implementation of ICT policies as well as in the alignment of goals of the ICT strategies or policies with those of the information society and the education in general, which can affect the expecting results or impacts. Therefore, an integral perspective to ICT policy design, implementation, and monitoring is needed, one which can consider the integration of digital technologies in education within a more complex system of pedagogical innovations (Sunkel et al. 2013; OREALC 2016).

Educational Research on ICT

The great challenge of research in the region lies in the need to highlight the real contribution of ICT to solving the problems of inequality and inequity in education systems. Therefore, research on ICT in education should expand the focus of attention, which so far has been directed toward finding better means and better prescriptions to be included in the classroom (Sancho 2009), incorporating with determination, among other topics, the following:

(I) Processes of resignification and naturalistic adaptation made by teachers and students based on their beliefs, dispositions, and experiences lived inside and outside the classroom
(II) New ways of interacting with information and knowledge construction experienced by students
(III) Relocation of the learning process and the conception of classroom
(IV) The construction of diverse digital cultures that coexist within the educational system itself

It is necessary to promote research that analyses the contribution of ICT as part of a complex, non-predictable system, for which new research methods are required to allow for a more comprehensive, systemic, and longitudinal understanding and explanation. In an unequal and diverse region, research on ICT in education must contribute to equity and cognitive justice (González 2014).

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Index

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