M. J. Bishop · Elizabeth Boling
Jan Elen · Vanessa Svihla *Editors*

Handbook of Research in Educational Communications and Technology

Learning Design

Fifth Edition

ASSOCIATION FOR EDUCATIONAL COMMUNICATIONS & TECHNOLOGY

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AECT
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Editors
M. J. Bishop
Kirwan Center for Academic Innovation
University System of Maryland
Adelphi, MD, USA

Elizabeth Boling
Instructional Systems Technology
Indiana University
Bloomington, IN, USA

Jan Elen
Education and Training
KU Leuven
Leuven, Belgium

Vanessa Svihla
Organization, Information & Learning Sciences
University of New Mexico
Albuquerque, NM, USA

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Foreword

What compels people to take on a task as complex and time-consuming as editing a *Handbook of Research on Educational Communications and Technology*? This is the fifth edition of these handbooks, a series that was initially conceived at the 1993 conference of the Association for Educational Communications and Technology (AECT) in New Orleans and later refined at the Professors of Instructional Design and Technology (PIDT) retreat that same year at the Shawnee Bluffs alumni camp on the shore of Monroe Lake in Indiana (Jonassen, 1996a). Although he had the assistance of such notable scholars as John C. Belland, Marcy P. Driscoll, Francis (Frank) M. Dwyer, Donald (Don) P. Ely, Robert (Bob) B. Kozma, Rhonda S. Robinson, and Robert (Bob) D. Tennyson, Dave Jonassen did by far the lion's share of the editing on the first two editions (Jonassen, 1996b, 2004). Anyone who experienced Dave's editorial feedback during work on the first two editions of the Handbook can attest to the painstaking rigor he applied to the task.

The editors of subsequent volumes have been equally rigorous, but at least they shared "the burden" (and the honor) with others. Along with Dave Jonassen, these editors would be appropriate inclusions on anyone's list of outstanding scholars in our field. J. Michael (Mike) Spector, M. David (Dave) Merrill, Jeroen van Merriënboer, and Marcy P. Driscoll edited the third edition, and Mike Spector, Dave Merrill, Jan Elen, and M. J. (MJ) Bishop edited the fourth edition. The fifth edition in which this Foreword appears has been edited by MJ Bishop, Elizabeth Boling, Jan Elen, and Vanessa Svihla, yet another impressive team of superb editors. Without speaking for them, our conviction is that these editors took on the complex and time-consuming task for a love of their field, the wish to make cutting-edge scholarship widely accessible to both emerging and established scholars alike, and the commitment to supporting exchange among members of our community. As have the others, we find that this volume succeeds on all three points.

A New Direction

The editors of this fifth edition decided to take a bold new direction with the Handbook. Past Handbooks contained many chapters focused on specific technologies or things. For example, the first edition had five chapters focused on "hard technologies" such as television and ten more chapters about "soft technologies" such as "educational games and simulations." This emphasis on specific technologies continued through the fourth edition, which includes 12 chapters on "emerging technologies" such as e-books and open educational resources. By contrast, most chapters in this new edition focus on difficult problems and how they can be addressed through innovative designs and appropriate technology. In this new Handbook, the editors have curated an excellent set of contributions that target serious educational problems such as the challenge of motivating and engaging students and the need to make learning environments more accessible for all. In addition, the new Handbook contains 13 design cases that are uniquely indexed with the research chapters focused on specific problems.

Was this shift to a problem focus necessary? We certainly think so. Those living in every modern age since the development of journalism have probably concluded that they were experiencing the most calamitous times in history, but our own times certainly seem especially fraught with serious peril. Extreme nationalism is on the rise around the globe, racial and religious conflicts persist, global tensions among superpower nations are increasing, the economic gap between haves and have-nots is expanding, and climate change threatens our very existence on the planet (Harari, 2014).

Arguably, the best hope for addressing these and other global problems is improving educational opportunities (Desai, Kato, Kharas, & McArthur, 2018). However, learning opportunities and the effectiveness of educational programs still lag far behind needs and expectations (Brock & Alexiadou, 2013; Malone, 2013). Research in the field of educational communications and technology illustrates the persistence of educational problems. For example, the *Technological Horizons in Education Journal* featured this headline in late 2017: "Most Teachers Say Classroom Tech Helps Students, but Teachers Need More Training." In fact, the study described in the article found that "Nearly four in five – 78 percent – of teachers say they haven't received the training they need to effectively use the technology they're asked to in the classroom" (Bolkan, 2017, para 1). Similarly, in a Spring 2018 survey of more than 2000 K–12 teachers, PwC (2018) found that "Only 10% of US teachers surveyed feel confident teaching higher-level technology skills" (p. 2), a finding that was consistent across grade level, school affluence, and teacher experience level. Who cannot be discouraged by the fact that after decades of providing preservice and in-service technology training, most teachers still say they are ill-prepared to integrate technology into their teaching (Stallard & Cocker, 2014)?

Professional development for technology integration is just one area where so much relevant research and development remain to be done. The editors of this Handbook originally defined seven major challenges as the foci for various research reviews, e.g., "understanding how instructional design/technology can help all learners to be successful" and "understanding how instructional design/technology contributes to learning outcomes within specific subject-matter domains." The last of the major challenges in their organizational scheme was "understanding the role instructional design/technology plays in achieving larger educational goals." Sadly, not a single review was completed for this challenge.

For us, it is disappointing, but not surprising, that educational technology and communications researchers were unable to submit even a single review related to how our field responds to larger educational goals. After all, the bulk of the scholarship in educational technology and communications has been focused on "things" rather than on "problems." In an attempt to summarize the history of the last two decades of educational technology, Weller (2018) identified the 20 most significant "different educational technology, theory, or concept" from 1998 to 2018. Seventeen of these referred to specific things (e.g., learning objects for 2000 and MOOCs for 2012), and none of the selections focused on a specific problem. Indeed, Weller wrote in reference to his 2017 selection, blockchain, that "its adoption [can be seen] as an end goal in itself, rather than as an appropriate solution to a specific problem." The same can be said for virtually every educational technology introduced into schools, universities, training centers, and other locations where learning is supposed to occur over the past 60 years (Reeves, 1995; Reeves & Reeves, 2015). Online and blended learning contexts are also susceptible to having new technology tossed over their virtual walls, often with no or even detrimental effects, a factor likely contributing to the underperformance of these approaches (Bettinger & Loeb, 2017).

Despite the gaps that were not able to be filled in the proposed Handbook structure, there are signs of hope throughout this volume that our field is beginning to focus less on technology per se and more to the solution of specific challenges. For example, excellent reviews are reported with respect to "enhancing self-regulated learning in online learning environments," "developing expertise and expert performance," "improving knowledge transfer," and "promoting critical thinking," among others.

The focus on challenges in this edition of the Handbook is also supported by the inclusion of design cases. The editors have solicited and reviewed more than a dozen design cases to offer a range of rigorous and detailed descriptions of instructional designs being carried out in the field. These unique design cases are focused on important challenges in education and training and encompass topics as diverse as criminology, foster parent training, and military science. These original works of scholarship enable readers to walk in the shoes of real-world designers as they experience the highs and low of meeting design, development, and evaluation challenges. The integration of these original design cases with the research synthesis chapters yields an innovative Handbook replete with invaluable insights that can and should be applied to the advancement of research *and* practice in our field and beyond.

Scholarship to Address Contemporary Challenges

We fully appreciate scholarship that builds scientific understanding of the world around us. At the same time, we feel a sense of urgency to ensure that such understanding is put to *use*, with the ultimate goal of contributing to the quality and benefits of education. Given this goal, we see multiple opportunities to leverage the expertise manifested in the current Handbook. While additional possibilities abound, we describe three potential perspectives from which the Handbook might be used.

First, we recommend adopting an external framework of major goals or significant problems for organizing the research literature in our field and viewing the Handbook as a toolkit for addressing them. One such candidate could be the 17 Sustainable Development Goals specified by the United Nations General Assembly in 2015 to be achieved by 2030 (Dodds, Donoghue, & Roesch, 2017). Only one of these goals is directly related to education, specifically Goal 4: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." But all 17 of the goals have obvious links to education, e.g., Goal 1 "End poverty in all its forms everywhere," Goal 2 "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture," Goal 3 "Ensure healthy lives and promote well-being for all at all ages," and Goal 5 "Achieve gender equality and empower all women and girls." Poverty will not be reduced, much less eradicated, unless the populace of the world is provided with excellent educational opportunities. Indeed, effective education is the key to ending hunger, improving health, empowering women and girls, and accomplishing all other Sustainable Development Goals. And if there is one lesson that the research and development efforts described in this Handbook highlights above all others, it is that learning and design must always proceed technology if effective educational programs are to be developed and sustained (Kolb, 2017).

A second recommended approach involves building research agendas in collaboration with practitioners in schools, universities, businesses, and other sectors and using the Handbook's focal areas to inspire and guide the initial dialogue. If undertaken in collaboration with a professional organization like the Association for Educational Communications and Technology (AECT), such an endeavor could establish the field of educational technology as preeminent in meeting global problems related to education. Imagine how such a collaboration could foster robust, multi-year research agendas focused on important problems and innovative solutions, the outputs of which yield direct added-value for practice. Such an approach might not only support teaching and learning in the field. It could also help develop the shared understanding, language, and eventually infrastructure so urgently needed to change the academic promotion and tenure system, which remains one of the largest obstacles to conducting research that matters. Tenure and promotion decisions must rely on evidence of impact, but current indicators to quantify impact – journal citations, impact factors, or the amount of funding researchers have attracted – focus on scholarly merit only.

Third, we suggest viewing the focal areas of the Handbook as reminders of key issues to attend to when designing solutions to educational challenges that involve technology. This can be useful in the case of research-informed design, as well as when it comes to design-based research. This kind of work is “a genre of research in which the iterative development of solutions to practical and complex educational problems also provides the context for empirical investigation, which yields theoretical understanding that can inform the work of others” (McKenney & Reeves, 2019, p. 6). Many of the contributions within this volume can help designers of solutions to educational problems by offering analytical lenses, design considerations, or evaluation constructs.

The AECT’s mission is to “provide international leadership by promoting scholarship and best practices in the creation, use, and management of technologies for effective teaching and learning” (www.aect.org). As such, it seems entirely fitting that this volume of the Handbook is focused on contemporary challenges and how innovative designs and appropriate technologies can address them. Our hope is that the readers will be able to use the outstanding contributions in the Handbook for researching and developing solutions that offer added value to practice while at the same time contributing to the enrichment of theoretical knowledge. More than anything, we hope that this trend toward sharing usable knowledge evident in both the research chapters and the design cases will be continued in the future.

Thomas C. Reeves
The University of Georgia
Athens, GA, USA

Susan McKenney
University of Twente
Enschede, The Netherlands

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PART 1
Research Chapters

Introduction to Research Chapters

Jan Elen and M. J. Bishop

Our world is complex. While some aspects remain stable over time, others gradually evolve, and still others drastically change. Various authors have attempted to capture those evolutions and to point out the implications for educational research in general and educational *technology* research in particular. In 2015, Tom Reeves and Patricia Reeves published a thought-provoking reflection in *Educational Technology* titled "Educational Technology in a VUCA World." Arguing that we are living in V(olatile) U(ncertain) C(omplex and) A(mbiguous) times, the authors claimed that educational technology research requires a dramatic shift away from its current focus on *things* to a focus on *problems* instead.

From the start, our conception of this edition of the *Handbook* was inspired by the ideas of Reeves and Reeves. We agreed that the *Handbook* should better represent how the scholarship of our field is relevant for society. And, while problems in education and in society have, of course, been discussed in previous editions of the *Handbook*, our hope was to reorganize this edition around those problems, instead of technology being the main focus. We decided, therefore, that this edition of the *Handbook* should be organized in a way that can meaningfully inform design practice by focusing first on the tasks, issues, challenges, and problems we are trying to solve through the use of technology/technological approaches rather than to make the main focus of our research on technology with a related, subordinate discussion on how research findings/technological developments might be relevant for particular tasks, challenges, or problems.

J. Elen (✉)
Education and Training, KU Leuven, Leuven, Belgium
e-mail: jan.elen@kuleuven.be

M. J. Bishop
Kirwan Center for Academic Innovation, University System of Maryland, Adelphi, MD, USA

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The decision to reorient the research chapters in the *Handbook* from a focus on *things* to a focus on *problems* was not one that was made solely by the editors. Ample support was received from an International Advisory Board. The board met at AERA and during several AECT conventions (2015, 2016, 2017) and, whenever needed, members were consulted through conference calls. The editors are grateful for the support of the board and want to explicitly acknowledge their contributions here: Ana-Paula Correia, Erica DeVries, Camille Dickson-Deane, Manu Kapur, Thomas C. Reeves, Gordon Rowland, Frederick Sarfo, Jeroen van Merriënboer, Andrew Walker, David Wiley, Alyssa Wise, Patricia Young.

Given that our ambition was to make challenges, issues, or problems the focus of the *Handbook*, we needed a framework to categorize and identify relevant topics. Developed in close collaboration with the International Advisory Board, that framework outlined seven areas of educational need for which relevant educational technology research might be done. Starting at the most general, in "Section 1: Understanding How Instructional Design/Technology Can Help All Learners Be Successful," our intent was to bring together research that would offer a deep understanding of fundamental processes to be considered when addressing educational issues by using educational technology/applying instructional design principles. Taking the opposite perspective, "Section 2: Understanding How to Accommodate Differences Among Learners Through Instructional Design/Technology" covers research that reveals the relevance of individual differences and offers insights on how instructional design and technologies have accommodated physical and cognitive, gender, age, equity, cultural, and language differences among learners.

In education, goals play a major role and are continuously discussed. The current debate about twenty-first-century skills only illustrates the point. In "Section 3: Understanding the Role Instructional Design/Technology Plays in Achieving Broader Learning Outcomes," we attempted to consolidate research on how instructional design/technology supports the realization of learning outcomes that are extremely important, but also often difficult to attain –such as critical thinking or "soft skills" like empathy. While Section 3 adopts a general, domain-transcending view, "Section 4: Understanding How Instructional Design/Technology Contributes to Learning Outcomes Within Specific Subject-Matter Domains" specifically focuses on disciplinary differences. There we explore how issues particular to specific disciplines can be addressed by educational technology.

Education does not happen in a vacuum, it is contextualized. Over the years, our awareness of the role and the impact of that context has continued to evolve. These learning contexts are at the core of "Section 5: Understanding the Role Instructional Design/Technology Plays in Different Learning Contexts" where issues regarding the interrelationship between context and instructional design and technology are addressed.

Last, but far from least, another important area of challenge for educational practice is the evaluation of learning (both formative and summative). That perspective is the focus of "Section 6: Understanding the Role Instructional Design/Technology Plays in Measuring and Communicating Learning Outcomes."

We called for researchers to propose chapters that discuss how instructional design/technology can help us understand and even resolve key issues in education. The authors of these research chapters have curated, analyzed, synthesized, and critically discussed the research of the last 5 years. The chapters offer ways in which motivation and self-regulation can be strengthened, how the probability of transfer can be enhanced, how issues of accessibility can be addressed, how second language development can be promoted, and how the ability to solve ill-structured problems can be strengthened. The role of technology in various domains stemming from arts and humanities to mathematics and STEM is scrutinized, and contexts as diverse as workplace learning and informal learning are presented. The different chapters show the great potential for the shift in focus for this edition of the *Handbook*, but also reveal remaining issues and challenges.

While we believe the framework is potentially powerful, we did face some challenges as editors. For some extremely important topics, we have not been able to identify (within a reasonable period of time) researchers who wanted to review and synthesize the relevant literature. While some were eager to discuss their particular research and to reflect on its practical applications, they were not interested in starting from problems and looking for relevant research. Hence a few major elements are missing. Most notably, we had to eliminate Section 7 we had planned on, "Understanding the Role Instructional Design/Technology Plays in Achieving Larger Educational Goals", and we had hoped to include chapters on supporting the development of sensory and cognitive processes and the promotion of information literacy, among others. And, in some cases where we do have chapters, the reader may find that while the review may start from a problem-based focus, it nevertheless discusses those problems from a particular technology-centric lens rather than to provide a more technology-agnostic view. So, while the *Handbook*'s reorientation is not entirely complete from our perspective, at least the turn has been initiated. It will be up to the editors of the next edition to complete the maneuver.

We hope the present edition induces a discussion about what our field is all about and how we will address major problems and challenges. The framework that guided our work can be a starting point for that discussion, helping us establish a research agenda in which technological artifacts, particular instructional approaches, or research perspectives are functional rather than essential. Such work may help build consensus on how to describe problems –and solutions to those problems. Developing shared terminology could eliminate confusion and help us develop more cumulative findings. The field of instructional design and technology might then evolve by putting actual issues and real problems at the core, using explicit and transparent terminology, and building on previous research. We envision a field that continuously but cumulatively readdresses the problems and challenges, enriched by new perspectives, methodologies, and insights – a field that is truly scholarly and relevant.

Section I
Understanding How Instructional Design/ Technology Can Help All Learners Be Successful

Motivating and Engaging Students Using Educational Technologies

Brett D. Jones

Introduction

What motivates individuals to engage in learning activities? Educators, administrators, researchers, and instructional designers have sought answers to this question, often because motivation is believed to affect learners' participation in learning activities and, consequently, their learning and achievement. The purpose of this chapter is to (a) provide a definition of motivation and the closely related concept of engagement, (b) discuss some of the antecedents and consequences of motivation, (c) list some motivation theories, (d) explain how motivation and engagement have been assessed, (e) discuss how instructors and instructional designers can design instruction to motivate students, (f) consider the motivating effects of current technologies, and (g) discuss some issues in the study of motivation and engagement. This chapter is aimed at a variety of audiences, including educators, administrators, and instructional designers who are interested in applying motivation concepts in instructional settings. For brevity, I use the term "instructors" throughout this chapter in reference to anyone who designs instruction, including teachers and instructional designers. This chapter is also intended to help researchers and students who are interested in understanding how motivation has been conceptualized and studied.

B. D. Jones (✉)
Virginia Tech, School of Education, Blacksburg, VA, USA
e-mail: brettjones@vt.edu; http://www.themusicmodel.com/

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Defining Motivation and Engagement

The words "motivation" and "engagement" are common to anyone who works with or studies learners in an educational setting. Yet, defining these terms precisely can be quite difficult, in part, because motivation and engagement have multiple definitions and meanings to different people in different contexts. I have found the definitions presented in this chapter to be (a) consistent with much of the research in the disciplines of education and psychology and (b) practical and useful to instructors and researchers. Readers who want to delve into the nuances of these constructs should read the *Handbook of Research on Student Engagement* (Christenson, Reschly, & Wylie, 2012a) because it presents a wider variety of perspectives related to motivation and engagement.

Motivation can be defined succinctly as "the extent to which one intends to engage in an activity" (Jones, 2018, p. 5). Note that this definition includes "the extent" of the motivation (which is the magnitude or energizing part of motivation) and "an activity" (which indicates the direction of the motivation). Therefore, motivation involves an amount of energy and the direction of that energy. Also note that motivation is an *intention* to do something, which provides an indication as to what the person intends to do in the future. For example, students might say, "I'm really motivated to learn Spanish." In this case, the magnitude is fairly high (they're "really" motivated), and the direction is toward the activity of learning Spanish. Although these students intend to learn Spanish, it is unknown whether they will actually engage in the activities required to learn Spanish. Once individuals participate in an activity, they are "engaging" in the activity, and they can either (a) stay motivated and intend to remain engaged or (b) lose their motivation and decide to stop engaging. Therefore, motivation precedes engagement (Christenson, Reschly, & Wylie, 2012b). For individuals to remain engaged over time, they must stay motivated and intend to continue engaging.

So what exactly is engagement? Engagement can be defined most simply as a learner's active participation in an activity. This simple definition becomes more complex when we try to define an "activity." A useful way of categorizing activities is to place them into a one of four levels ranging from general to specific (Skinner & Pitzer, 2012), as shown in Fig. 1. Engagement in prosocial institutions (e.g., engagement in school, church, 4-H, YMCA) is at the most general level and includes institutions that promote youth development and protect students from risks. Engagement in school activities (e.g., engagement in academics, sports, band, clubs) is at the next most general level, followed by engagement in classrooms within the school (e.g., engagement in the curriculum activities and engagement with a teacher and other students). Engagement with a particular learning activity is at the most specific level. For example, Zhou and Yadav (2017) examined the effects of media and questioning on students' reading engagement by comparing the engagement of students who heard a story read by a person, to that of students who used multimedia to read and interact with the story. Given these levels of activities,

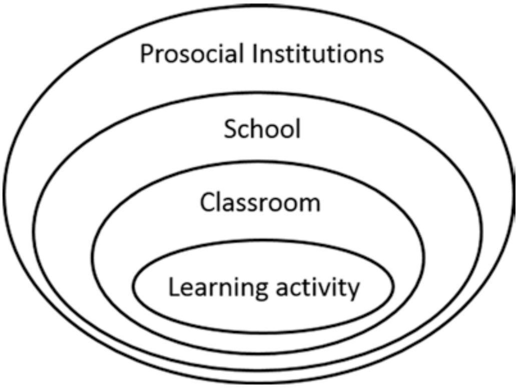

Fig. 1 Four levels of activities in which learners can engage

when discussing a learner's engagement, instructors and researchers need to carefully consider and specify the level at which they are focusing.

The simple definition of engagement provided in the prior paragraph becomes more complex when we try to define "active participation." Scholars have identified a few different dimensions of active participation. Most commonly, researchers have studied behavioral, cognitive, and emotional engagement (Fredricks, Blumenfeld, & Paris, 2004; Sinatra, Heddy, & Lombardi, 2015), and recently, some researchers have studied agentic engagement (Reeve, 2013). Behavioral engagement includes a variety of observable behaviors necessary to succeed, such as putting forth effort, persisting at activities in the face of difficulties, attending class, following class rules, and completing homework. Cognitive engagement has been conceptualized in at least two different ways (Fredricks et al., 2004): (a) as learners' psychological investment in learning, such as having a preference for challenges and hard work, and (b) as learners' use of strategic, self-regulated learning, such as paying attention, concentrating, using effective learning strategies, and using metacognitive strategies (i.e., planning, monitoring, and evaluating their cognition during tasks). Emotional engagement includes energized affective reactions in the classroom such as enthusiasm, enjoyment, and interest. Lastly, students who exhibit agentic engagement ask questions, tell their teacher what they like and do not like, and express their preferences and opinions (Reeve, 2013).

A construct related to engagement is *disengagement*, which can be defined as the absence of engagement. Learners who are disengaged put forth little effort, are passive, lack initiative, and/or give up working on a task (Skinner, Kindermann, & Furrer, 2009). Although some researchers have noted that engagement and disengagement are somewhat negatively correlated (i.e., as engagement increases, disengagement decreases, and vice versa), differences can exist in how they relate to other variables. For example, in one study, disengagement was more strongly related to students' exam grades than engagement (Robinson et al., 2017). Martin, Anderson, Bobis, Way, and Vellar (2012) have noted that both engagement and disengagement are needed to capture students' persistence at school.

Another construct closely related to disengagement is *disaffection* (Skinner et al., 2009), which includes the behaviors of disengagement, but also includes withdrawing mentally (not paying attention) and ritualistic participation (going through the motions). Readers interested in this construct should read Skinner et al. (2009) for a more complete description and to examine the items they administered to elementary school students, which include those related to behavioral disaffection (e.g., "I don't try very hard at school") and emotional disaffection (e.g., "When I'm doing work in class, I feel bored.").

Antecedents and Consequences of Motivation and Engagement

Many scholars consider motivation to precede engagement, such that motivation is one's intent, and engagement is one's actions (Christenson et al., 2012b). This leads to the practical and important question: What factors influence one's motivation? Often, many factors are involved in affecting learners' motivation, including those external to the learner (e.g., the instructional design, the curriculum, the learner's peers, the school and community culture) and those internal to the learner (e.g., beliefs, values, affect, needs, personality characteristics). Figure 2 shows how these concepts are related at the level of the class or learning activity. In the remainder of this chapter, I focus on mostly these two levels and less on the school and prosocial institution levels shown in Fig. 1.

Figure 2 shows that the internal and external variables interact (as depicted by the vertical double-headed arrow) to affect learners' perceptions in a learning environment, which then affect students' motivation and engagement in the learning environment. Ultimately, these factors affect outcomes, such as learning and

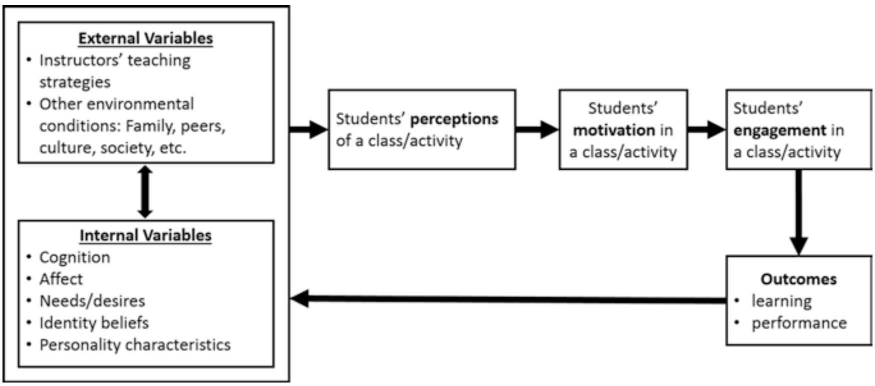

Fig. 2 Simplified representation of the MUSIC® Model of Motivation. (From *Motivating Students by Design: Practical Strategies for Professors* by B. D. Jones, 2018. Copyright 2018 by Brett D. Jones. Adapted with permission)

performance (Hughes, Luo, Kwok, & Loyd, 2008; Ladd & Dinella, 2009). The outcomes then cycle back to affect the internal and external variables. Let's consider an example of this process.

> Mia is a ninth-grade student who values learning to speak Spanish because she believes that it will help her achieve her career goals (an internal variable). Mia enrolls in her high school Spanish language class, and after the first week, she perceives it to be useful to helping her become a better Spanish speaker. Therefore, she is motivated to do well in her Spanish class, and she engages in the class assignments. Unfortunately, Mia did not do well on the first test in the class (an outcome). Her low grade decreased her self-efficacy for speaking Spanish (an internal variable) and caused her teacher (an external variable) to consider whether there was something he could do to help Mia improve. Mia's teacher shows her a new app that she can use on her iPad that will help her learn Spanish, and consequently, her Spanish self-efficacy increases a little because she believes that she can succeed in the class if she uses the app. She also believes that the extra effort it will take to succeed will be worthwhile because she still finds the class useful (a perception of the class) and is motivated to engage in the class assignments.

This example provides a demonstration as to how external and internal variables can interact to affect learners' perceptions of the learning environment, motivation, engagement, and outcomes.

Some researchers study only certain parts of this model. For example, researchers have investigated how internal variables (e.g., goals) affect students' motivation to engage in massive open online courses (MOOCs) and have documented that students enroll to gain knowledge or skills in a particular topic, to earn a certificate, to meet other people interested in the topic, and to advance in school or in a career (Hew & Cheung, 2014; Williams, Stafford, Corliss, & Reilly, 2018). Once they are then enrolled in the course, students' perceptions of the course will also affect their motivation to engage in the course activities. Certain course perceptions are especially critical to predicting students' motivation, as I will describe in a following section. As an example, students' perceptions of the usefulness of a MOOC platform (icourse.com) were found to be related to their motivation (intentions) to continue using the platform (Yang, Shao, Liu, & Liu, 2017).

Motivation Theories

Motivation would probably be easier to understand if there was one grand theory of motivation that could explain all of human motivation. However, researchers have been unable to identify such a theory or construct, and as a result, motivation researchers now study motivation using a variety of constructs and "mini-theories" (Reeve, 2005). A construct is defined as "an individual characteristic that we assume exists in order to explain some aspect of behavior" (Miller, Linn, & Gronlund, 2013, p. 81). For example, *interest* is a construct because it is an individual characteristic and it can't be seen (i.e., it must be assumed to exist). As an example, an instructor might say "Juan is very interested in robotics." This instructor can't see Juan's interest in robotics, but she can infer it from Juan's behaviors (e.g., Juan stays afterschool to work in the robotics lab) and verbal statements (e.g., Juan says "I like trying to figure out how to use the different sensors on the robot.").

One problem with the mini-theories' approach to motivation is that it has led to a lot of theories, which can make it difficult for instructors and researchers to know which ones are most useful in different situations. I provide an alphabetical list of several theories related to motivation and engagement in Table 1. It is beyond the scope of this chapter to provide an explanation of each of these theories. Even trying to provide a one- or two-sentence description is difficult because it can lead to confusion and misunderstandings for readers unfamiliar with nuances of the theories. Readers interested in these theories should consult the explanations provided by the primary developers of the theories (see the references in Table 1).

Some researchers have developed theories and models that go beyond motivation in an attempt to integrate motivation, volition, and learning. In the context of

Table 1 Examples of theories related to motivation and engagement

Theories
Arousal theories (Berlyne, 1960; Duffy, 1957)
Attachment theory (Ainsworth, 1979; Bowlby, 1969)
Attribution theory (Weiner, 2000)
Behaviorist theories (Skinner & Epstein, 1982)
Belonging theories (Baumeister & Leary, 1995; Goodenow, 1993)
Caring theories (Johnson, Johnson, & Anderson, 1983; Noddings, 1992; Wentzel, 1999)
Competence theories (Elliot & Dweck, 2005; Harter, 1978; White, 1959)
Domain identification theory (Osborne & Jones, 2011)
Emotion theories (Pekrun, 2009)
Expectancy-value theory (Wigfield & Eccles, 2000)
Flow theory (Csikszentmihalyi, 1990)
Future time perspective theory (Lewin, 1942; Nuttin & Lens, 1985)
Goal orientation theories (Ames, 1992; Maehr & Midgley, 1991; Nicholls, 1984)
Goal setting theories (Locke & Latham, 2002)
Goal theories (Ford, 1992; Locke & Latham, 2002)
Identity and identification theories (Finn, 1989; James, 1890/1981; Voelkl, 1997)
Interest theories (Hidi & Renninger, 2006; Krapp, 2005; Schraw & Lehman, 2001)
Locus of control (deCharms, 1968)
Rewards and intrinsic/extrinsic motivation theories (Cameron & Pierce, 1994; Deci, 1975; Deci & Ryan, 1985)
Self-concept theories (Marsh, 1990; Shavelson & Bolus, 1982)
Self-determination theory (Deci & Ryan, 1985, 2000)
Self-efficacy theory (Bandura, 1986, 1997; Pajares, 1996)
Self-esteem theories (Rosenberg, 1979)
Self-regulation theories (Bandura, 1986; Pintrich & de Groot, 1990; Zimmerman, 2000)
Self-theories of intelligence (Dweck, 1999, 2006)
Self-worth theories (Covington, 1992)
Social cognitive theory (Bandura, 1986, 1997)
Stereotype theories (Aronson & Steele, 2005)

educational technologies, Astleitner and Wiesner (2004) presented an integrated model of multimedia learning and motivation, and Keller (2008) explained an integrative theory of motivation, volition, and performance. I encourage readers to review these references if they are interested in more comprehensive models that include detailed relationships between motivation, learning, and performance.

Assessing Motivation and Engagement

Because motivation is defined as an individual's intent, it is difficult to measure. How do you measure someone's intent to do something that they haven't done yet? Because of this difficulty, researchers do not usually assess motivation directly; instead, they measure motivation-related constructs (such as those that are part of the mini-theories listed in Table 1) and then infer someone's motivation based on these constructs. For example, researchers have used "self-efficacy" as one measure of students' motivation. Self-efficacy is a person's judgment of his/her capabilities to complete a certain task (Bandura, 1986). Someone who says "I'm confident that I can solve 10 double-digit addition problems" (e.g., 12 + 45) has a high self-efficacy for completing double-digit addition problems. Self-efficacy is not motivation, but students who have higher levels of self-efficacy for an activity are more likely to choose to engage in the activity, put forth more effort in the activity, and persist at the activity when faced with challenges (Bandura, 1997). All of these outcomes (i.e., choice, effort, and persistence) can be considered indicators of one's motivation to engage in an activity and possibly similar activities. Consequently, researchers may assess students' self-efficacy as a measure of their motivation to engage or reengage in a particular activity (e.g., van der Meij, van der Meij, Voerman, & Duipmans, 2018).

Because motivation-related constructs and engagement constructs are often measured similarly, the explanations in this section are relevant to both constructs. I find that instructors often determine students' motivation and engagement by observing students' behavior and/or assessing the quality of their work. For example, an instructor may infer that students are motivated and engaged if they pay attention or ask questions during class and/or score highly on tests and assignments. These types of observations and assessments are often very useful and practical for instructors. Researchers generally use a wider variety of measures than instructors, including (a) self-reports (e.g., questionnaires, interviews, stimulated recalls, think-alouds, and dialogues), (b) behavioral measures, (c) ratings by others, and (d) physiological data (e.g., neuroscientific data). In a review of measures used to assess academic engagement in technology-mediated learning experiences, Henrie et al. (2015) found that 61.1% of the studies used quantitative self-report measures (e.g., questionnaires), 39.8% of studies used qualitative measures (e.g., interviews, open-ended questionnaire items, discourse analysis, observation), 34.5% of studies used quantitative observational measures (e.g., frequency of behaviors observed or monitored), and 11.5% of studies used other measures (e.g., performance, biophysiological sensors).

Self-Reports

The most common method used by researchers to study learners' motivation has been to assess learners' self-reports on questionnaires because they directly assess students' perceptions or beliefs, they can produce reliable scores, they are easy to score, they can be standardized across contexts, they can be administered quickly, and they can be administered online (and therefore, they can be used when learners are at a distance or unavailable in person) or with paper and pencil. Questionnaires can include one or more "instruments," "inventories," or "scales" that are usually comprised of three or more items that students rate on Likert-type scales (e.g., 1 = *strongly disagree*, 2 = *disagree*, 3 = *somewhat disagree*, 4 = *somewhat agree*, 5 = *agree*, 6 = *strongly agree*). For example, the college student version of the MUSIC® Model of Academic Motivation Inventory (Jones, 2012) includes a "usefulness" scale with five items that assess learners' perceptions of the extent to which an activity or class is useful to their future. Two of the items are "In general, the coursework was useful to me" and "The knowledge I gained in this course is important for my future." Students respond to these items by providing a rating from 1 (*strongly disagree*) to 6 (*strongly agree*). The scores from these two items and the three other items in the scale are averaged to produce a score that indicates the extent to which students believe that the course is useful to their future. This usefulness scale is considered to be an indirect measure of students' motivation because students are more likely to be motivated to engage in a course when they find it useful to their future (Wigfield & Eccles, 2000). As an example, Streiner and Bodnar (2019) used this usefulness scale (along with other scales) to assess students' perceptions of a gamified learning environment. Then, they made changes to the game platform and reassessed students' perceptions using the scale again to examine how students' perceptions were affected by their changes to the platform.

Researchers often check the reliability of a scale by showing that the scale items are highly correlated (e.g., calculating Cronbach's alpha) and may correlate the scale scores with other scale scores or outcomes (e.g., grades) to provide evidence for the validity of the scale (e.g., we would expect the usefulness scale to correlate with behavioral engagement). Questionnaires can also include open-ended items that allow students to provide text responses.

Besides questionnaires, other types of self-reported data include interviews (verbal responses to questions), stimulated recalls (recall of thoughts about prior performances on tasks, sometimes while they are watching a video of their prior performance), think-alouds (verbalizations of thoughts, behaviors, and feelings during a task), and dialogues or discourse analysis (conversations between two or more individuals) (Schunk, Meece, & Pintrich, 2014).

Despite the variety of self-report measures available and their frequent use, these measures have several limitations, including (a) the possibility that learners provide responses that are socially acceptable instead of their true beliefs, (b) that individuals' self-reported responses do not match their actual behavior, (c) that young children may not be able to provide accurate responses, and (d) that self-report measures must be completed at a time separate from engaging in the activity, which can interfere with the learner's engagement (Bowman, 2010; Fulmer & Frijters, 2009). In addition, it can be difficult to assess learners' levels of engagement over time with questionnaires, especially during shorter durations (e.g., a 20-minute activity). To capture learners' motivation or engagement over time, researchers have used the experience sampling method (Hektner, Schmidt, & Csíkszentmihalyi, 2007) in which individuals are contacted at various points during an activity or a day and asked to stop what they're doing to answer questions related to their motivation and engagement (e.g., Xie, Heddy, & Greene, 2019).

Readers interested in using a self-report questionnaire might consider one of the 14 surveys that Henrie et al. (2015) identified to assess students' behavioral, cognitive, or emotional engagement in technology-mediated learning environments. When selecting a measure of engagement, it is important to select one that assesses engagement at the activity level intended (see Fig. 1 for some possible activity levels). Similarly, it is important to recognize that some self-report measures assess students' perceptions of a class or activity (e.g., "This class is useful to my everyday life."), whereas other measures assess students' perceptions of a domain, such as mathematics (e.g., "Mathematics is useful to my everyday life."). For example, to determine how an online educational game would affect students' attitudes toward mathematics after playing the game for 14 weeks, Mavridis, Katmada, and Tsiatsos (2017) assessed students' perceptions of mathematics (as a domain), as opposed to examining how students perceived the usefulness of the game itself.

Behavioral Measures

Behavioral measures can be used to assess learners' motivation and engagement by documenting their actions. Behavioral measures include watching learners' behaviors in real time (or on video) and counting the frequency of behaviors (e.g., number of times students ask questions) or keeping track of the amount of time learners spend on an activity (more time spent is assumed to indicate that learners are more motivated or engaged). As noted by Henrie et al. (2015): "In technology-mediated learning settings, behavioral engagement can potentially be measured by computer-recorded indicators such as assignments completed; frequency of logins to website; number and frequency of postings, responses, and views; number of podcasts, screencasts, or other website resources accessed; time spent creating a post; and time spent online" (p. 43). A limitation of behavioral measures is that they do not capture learners' thoughts and feelings. Therefore, although these measures allow researchers to document the extent to which learners' exhibit certain behaviors, these measures don't allow them to determine *why* they engaged in it, which could be important to understanding learners' motivations in some situations.

Ratings by Others

As opposed to measuring learners' behaviors directly, observers (e.g., teachers, peers, parents, trained researchers) can *rate* characteristics that indicate learners' motivation or engagement. For example, in one study, students' engagement was measured by rating their attention, effort, persistence, verbal participation, and positive emotion using a 7-point scale ranging from 1 (*not at all*) to 7 (*extremely*) (Reeve & Jang, 2006). Ratings by others may provide a more objective measure than learners' self-reports. However, ratings may require more inference about learners' motivation or engagement than measuring behavior directly.

Physiological Data

Recent technological advances have allowed researchers to study students' motivation and engagement using physiological data. Physiological data, such as neuroscientific data, may allow researchers to identify the neural mechanisms that underlie learners' motivation and engagement and explain the processes involved in motivation-related behaviors. As an example, neuroscientists have examined the effects of rewards on individuals' motivation-related behaviors (Hidi, 2016).

Brain activity can be measured using functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG) event-related potentials (Kim, Reeve, & Bong, 2017). An fMRI produces brain scans that show changes in brain activity in different regions of the brain while the individual lies in a machine and participates in mental tasks. EEGs produce waveforms based on the individual's brain signals. The EEG waveforms indicate the rise and fall of brain signals from different parts of the brain. Lin and Parsons (2018) noted that EEGs and other new brain imaging techniques may be especially useful in studying media multitasking. For example, virtual reality-based neuropsychological assessments allow researchers to situate participants in virtual environments while completing multiple tasks (e.g., Parsons & Barnett, 2017). This type of assessment can allow researchers to track more closely how participants are engaging in multiple tasks and how they switch from one task to another.

Kim et al. (2017) cite several advantages of using neuroscientific data to study motivation. First, it may be possible to identify distinct patterns of neural activity, which could help researchers to distinguish more clearly among motivation constructs. Second, it may be possible to define "motivation" more precisely and identify the diverse and dynamic subprocesses involved in motivation and engagement. Third, it may be possible to use neuroscience methods along with other methods (e.g., self-reports, behavioral measures, ratings by others) to overcome the limitations of those methods. Some of the limitations of using physiological data to study learners' motivation and engagement include that these data require learners to enter into a machine (fMRI) or wear a cap with sensors (EEG), which restrict the types of activities in which learners can participate. Other limitations are the cost of the technologies and the skills required to use the technologies and interpret the data produced.

Designing Instruction to Motivate and Engage Students

Identifying motivating and engaging strategies that are consistent with theories and research can be overwhelming for instructors because of the plethora of mini-theories and constructs available (see Table 1). To help instructors make sense of this information, I developed the MUSIC® Model of Motivation (Jones, 2009, 2018), which is based on motivation research and theories, including, but not limited to, the theories listed in Table 1. The five key principles of the MUSIC model are that instructors need to ensure that students: "(1) feel *empowered* by having the ability to make decisions about some aspects of their learning, (2) understand why what they are learning is *useful* for their short- or long-term goals, (3) believe that they can *succeed* if they put for the effort required, (4) are *interested* in the content and instructional activities, and (5) believe that others in the learning environment, such as the instructor and other students, *care* about their learning and about them as a person" (Jones, 2018, p. 9). The first sound in each keyword of these five principles (i.e., eMpowerment, Usefulness, Success, Interest, and Caring) forms the acronym MUSIC.

Figure 2 shows that learners' *perceptions* of the class or learning activity are central to their motivation and engagement. The MUSIC model focuses on five specific perceptions (i.e., empowerment, usefulness, success, interest, and caring) that researchers have found to be critical to students' motivation in educational settings. Therefore, instructors need to consider how learners' internal variables (e.g., cognition, affect, needs/desires, identity, personality characteristics) and external variables (e.g., family, peers, culture, society) will interact with the instructional design to affect how learners perceive the instructional environment. These design considerations occur within the broader design of the class or activity.

Figure 3 shows the five basic elements of the MUSIC model design cycle: (1) select the course objectives, (2) select the instructional and MUSIC model strategies, (3) implement the strategies, (4) assess students' MUSIC perceptions and progress toward the course objectives, and (5) evaluate the assessment results to identify whether there are problems (Jones, 2018). The MUSIC model design cycle can be integrated with or complement other more complete instructional design models (e.g., Dick, Carey, & Carey, 2015). In the remainder of this section, I provide some example strategies that are consistent with the components of the MUSIC model (see Jones, 2018, for more strategies).

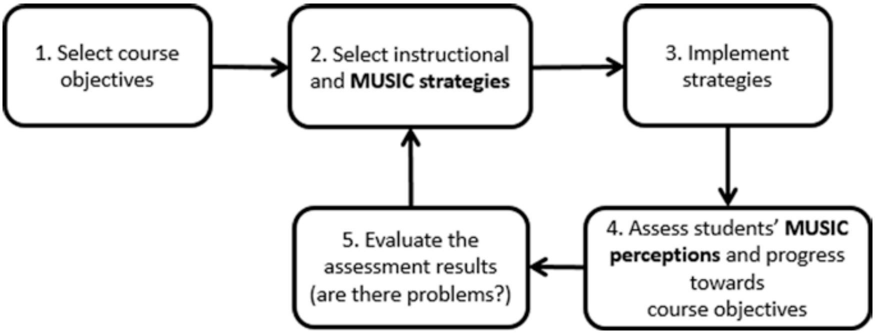

Fig. 3 The MUSIC® Model of Motivation design cycle. (From *Motivating Students by Design: Practical Strategies for Professors* by B. D. Jones, 2018. Copyright 2018 by Brett D. Jones. Adapted with permission)

Empowerment Strategies

Learners tend to be more motivated and engaged when they are *empowered* (Deci & Ryan, 2000). In the MUSIC model, empowerment is defined narrowly to indicate that students have the autonomy to make decisions within their learning environment. The importance of learner autonomy in educational technology settings is evidenced by the publication of several research articles presented in a special issue of the journal *Educational Technology Research and Development* (ETR&D) titled "Technology-Enhanced Ownership and Autonomy" (Lan, 2018). Yet, *learner autonomy* is not always synonymous with the concept of *empowerment* in the MUSIC model. Instead, empowerment is most consistent with the "right of learners to determine the direction of their own learning" (Benson & Voller, 1997, p. 2), as opposed to simply allowing learners to be autonomous by working on their own. For learners to feel empowered, they must believe that they have choices and have some freedom within their learning environment. Students enrolled in an online course that requires students to work independently to read a textbook chapter and complete an online quiz may be learning autonomously, but may not feel any empowerment if they don't believe they have any choices in these activities.

Instructors can empower students by giving them choices. Jones (2018) provides examples such as allowing choices within assignments, allowing students to choose which assignments they want to complete, allowing choice of assignment topics, and allowing choice of assignment format (e.g., traditional paper, video, project, product, model). In a design to increase student tutors' perceptions of empowerment, Park and Kim (2016) designed a virtual tutoring system that gave students choices over (a) their tutoring goals for the lesson, (b) the lesson delivery format, and (c) the tutee they want to teach. In another study of peer feedback using a web-based tool (Yuan & Kim, 2018), college students reported that they experienced autonomy when they were given choices about the criteria they could use to assess their peers' work. As Yuan and Kim explain, "They were asked to choose two of the following three criteria: (a) accuracy of the content, (b) language of the essays (i.e., grammar, spelling, wording, syntax), and (c) avoiding plagiarism (i.e., A minimum of two sources should be used; paraphrasing needs to follow the three-word rule)" (p. 30).

By definition, learner-directed approaches to teaching give students some control over their learning and can promote feelings of empowerment. Common learner-directed approaches include problem-based learning, project-based learning, inquiry approaches, case studies, and constructivist approaches. Other strategies to empower students include avoiding controlling rules and language and allowing students to talk more during classes (Jones, 2018).

Usefulness Strategies

Learners are motivated to learn about a topic and engage in activities related to that topic when they believe that what they are learning is useful to their goals in life (Brophy, 1999; Eccles & Wigfield, 2000). For example, when college students perceive that mobile learning content is useful, they are more motivated to adopt mobile learning (Hao, Dennen, & Mei, 2017). Similarly, Korean university students who reported that their MOOC course was useful were more likely to report higher levels of learning engagement (Jung & Lee, 2018).

Instructors can help learners understand the usefulness of topics and activities by explicitly explaining the usefulness of the content. Other strategies to convey usefulness include having students explain to one another the usefulness of the content (McGinley & Jones, 2014) or having others (e.g., professionals, experts, former students) explain the usefulness (Jones, 2018). Online virtual worlds (e.g., *Second Life*, http://secondlife.com) are another way that instructors can provide educational experiences that are otherwise more difficult or expensive to engage in; examples include touring a replica city from the past, designing clothing, setting up a store, practicing language skills in foreign cities, and examining 3D molecules (EDUCAUSE, 2008; Harrison, 2009).

Success Strategies

For learners to be motivated to engage in activities, they need to believe that they can succeed at the activities (Bandura, 1986). When learners do not believe that they can succeed, they will not engage, or if they do engage, they will not willingly engage for long unless they begin to experience success. Therefore, success beliefs are critical to learner engagement. Individuals' success beliefs for an activity are influenced by their prior experiences with that activity, by what others tell them (i.e., verbal persuasion such as "you can do it!"), by watching others engage in the activity, and by their physiological reactions to that activity (e.g., heart rate, perspiration)

(Bandura, 1986). In a study designed to increase secondary students' perceptions of success in an inquiry physics activity, researchers used verbal persuasion by having an animated pedagogical agent give learners motivational messages during the activity (e.g., "Oh, this one looks difficult, let's take some time to look at it"; van der Meij, van der Meij, & Harmsen, 2015, p. 389). Using an experimental design, the researchers were able to document interaction effects between the experimental conditions (which received the motivational messages) and the control condition (which did not receive the motivational messages). As is typical in these types of studies, increases in students' perceptions of success (i.e., self-efficacy) were used as an indicator of students' motivation, and they were assumed to be important because other studies have linked higher self-efficacy to higher achievement.

Instructors can also help students believe that they can succeed by attributing students' struggles and failures to their lack of effort and/or use of inadequate strategies (Weiner, 2000). Students are more likely to persist in the face of failure when they believe that they can succeed by exerting more effort or by trying different learning strategies (Dweck, 1999, 2006). Instructors can also ensure that their expectations for students are high, but reasonable; otherwise, students may experience debilitating anxiety, which can reduce their motivation. Instructors can help students succeed and reduce anxiety by matching the difficulty levels of the learning activities and assignments with the abilities of the students (i.e., the activities are not too easy or too difficult).

Some studies of online learning have measured "teaching presence" as a way to assess the extent to which students believe that instructors support their success through their design and organization of the course content (Jung & Lee, 2018; Shea, Pickett, & Pelz, 2003). Teacher presence includes instructional strategies that help students believe that they can succeed in the course, such as providing feedback, helping to solve problems, and resolving technical issues (Gregori, Zhang, Galván-Fernández, & Fernández-Navarro, 2018). Providing honest, frequent feedback is a critical means to let students know whether or not they are being successful.

Interest Strategies

Researchers generally agree that the "interest" construct can be divided into *situational* interest and longer-term, *individual* interest. Situational interest refers to the interest and enjoyment students experience at any one moment as they engage in an activity (Schraw & Lehman, 2001). Individual interest refers to the interests students have developed over time, and as a result, they value the topic or activity, have more knowledge about it, and tend to like it (Hidi & Renninger, 2006). Consequently, interest strategies in the MUSIC model include both those that interest learners in particular activities (e.g., playing a video game, solving mathematics problems) and those that take into consideration learners' individual interests (e.g., an interest in learning about history, an interest in tennis). Students who are more situationally interested in an activity tend to be more motivated and engaged in that activity (Hidi

& Renninger, 2006). For example, when students find that using the social web tools in a course is enjoyable and interesting, they are more likely to rate their active learning higher in the course (Molinillo, Aguilar-Illescas, Anaya-Sánchez, & Vallespín-Arán, 2018).

Instructors can increase students' situational interest by using strategies that catch and hold students' attention, such as using novelty and limiting distractions (Jones, 2018). Other strategies include piquing students' curiosity about the content or stimulating emotional arousal by providing surprising information, showing enthusiasm, and pacing instruction appropriately (i.e., not too quickly or slowly). Some instructors have used massively multiplayer online games (MMOGs) in higher education courses, and students have found them to be fun and reduce boredom in classes (Bawa, Watson, & Watson, 2018). Some of the motivating characteristics of MMOGs that are most directly related to students' interest include "content elements such as user-friendly language, detailed and rich descriptions, scintillating imagery, interesting and appealing storylines and narratives," and "fantasy elements such as variety of locations including cities, forests, skylines, seas, and castles, customized alternative personas, variety of customizable characters, classes such as elevens, dwarfs, monsters, variety of occupations and skill mongering, variety of tools related to occupations, and variety of in-game trade options" (Bawa et al., 2018, p. 181). These findings also demonstrate how empowering students (e.g., providing choice of locations and customized personas) can affect students' interest, thus demonstrating how an instructional design decision (such as giving students choices) can affect their perceptions of more than one MUSIC model component (i.e., empowerment and interest).

Instructors can increase students' individual interest by relating course content to students' interests or allowing students to choose from different topics so that they can choose topics that are more interesting to them. Instructors can also create situational interest because individual interest begins originally as situational interest and then develops over time into individual interest (Hidi & Renninger, 2006). Lastly, all of the other MUSIC model components can also be used to promote individual interest (Jones, Tendhar, & Paretti, 2016; Osborne & Jones, 2011); therefore, generally creating motivating and engaging learning environments can help students develop a longer-term interest in the topic or activity.

Caring Strategies

Students tend to be more motivated in courses when they have quality relationships with the instructor and other students in the class (Wentzel, 1999). Conversely, learners are less motivated when they perceive that their instructor does not care about their learning, or others in the class make them feel unwelcome (e.g., they experience bullying). For example, students are more likely to rate their active learning higher in a course that incorporates social web-based collaborative learning when they believe that they have good interactions with their teacher (Molinillo et al., 2018).

Instructors can show students that they care by being approachable and relatable to students, by respecting students, by showing students that they care about their academic success, and by being flexible and accommodating when students experience extraordinary events, such as a death in the family (Jones, 2018). As an example, students are more likely to complete MOOCs when they perceive a stronger teacher presence (Gregori et al., 2018), which includes strategies that could promote a positive relationship between the students and the instructor such that students believe that the instructor cares about their learning (e.g., welcoming new students, encouraging participation).

Evidence for the MUSIC Model

Students and instructors find the five categories of MUSIC model strategies useful in helping them to organize a wide variety of motivational and engagement strategies (Jones, 2016). The multidimensional MUSIC model appears to provide a parsimonious model that includes the breadth of strategies identified by researchers, yet not provide too many categories that overwhelm instructors. Furthermore, quantitative research has confirmed that students find the five MUSIC model components to be distinct perceptions in samples of college students (Jones, Li, & Cruz, 2017; Jones & Skaggs, 2016; Jones & Wilkins, 2013), pharmacy students (Pace, Ham, Poole, & Wahaib, 2016), middle and high school students (Chittum & Jones, 2017; Parkes, Jones, & Wilkins, 2017; Schram & Jones, 2016), and elementary school students (Jones & Sigmon, 2016). The MUSIC model has been used to analyze learners' motivation-related perceptions in a variety of contexts, including online courses (Hall, Jones, Amelink, & Hu, 2013; Jones, 2010; Jones, Watson, Rakes, & Akalin, 2013), informal video gaming environments (Evans, Jones, & Akalin, 2017; Evans, Jones, & Biedler, 2014), STEM (science, technology, engineering, and mathematics) education programs (Chittum, Jones, Akalin, & Schram, 2017; Jones et al., 2015; Lee, Kajfez, & Matusovich, 2013; Schnittka, Brandt, Jones, & Evans, 2012), engineering courses (Jones et al., 2016; Jones, Epler, Mokri, Bryant, & Paretti, 2013; Mora, Anorbe-Diaz, Gonzalez-Marrero, Martin-Gutierrez, & Jones, 2017), K-12 classes (Chittum & Jones, 2017; Jones, Sahbaz, Schram, & Chittum, 2017; Martin & Morris, 2017; Remijan, 2017), and undergraduate face-to-face courses (McGinley & Jones, 2014; Tu & Jones, 2017).

Although the MUSIC model provides one way to conceptualize and organize motivation-related instructional strategies, the ARCS model (Keller, 1979, 1983) has also been used in the field of educational technology over many years. ARCS is an acronym for Attention, Relevance, Confidence, and Success, which align with some of the MUSIC model components: Attention aligns somewhat with the Interest component, Relevance aligns somewhat with the Usefulness component, and Confidence and Success align somewhat with the Success component of the MUSIC model. The ARCS model does not explicitly include empowerment or caring strategies, likely because it is rooted in expectancy-value theory, which does not emphasize these constructs; nonetheless, the ARCS model has been a useful tool for educators and researchers (Li & Keller, 2018).

The Motivating Effects of Current Technologies

A particular technology is not, in itself, motivating or engaging to students. Rather, technologies are motivating to the extent that they affect students' perceptions in a certain context (such as the perceptions described in the prior section). Therefore, instructors and researchers need to consider how technologies affect the motivation and engagement of particular types of students in certain contexts. A technology that motivates younger students in one country may or may not motivate older students in the same country or in a different country. For example, in a review of studies using *Facebook* as a learning tool, Manca and Ranieri (2013) found that some studies reported that the use of *Facebook* increased students' interest and behavioral engagement (e.g., participation, discussion, exchanging information). Yet, they also found other studies reporting that students in other contexts did not want to join *Facebook* for their courses and/or that they did not like using *Facebook* for their courses. These findings suggest that *Facebook* may be a useful tool to increase students' motivation and engagement in some courses for some purposes, but not others, depending on the type of students and courses.

Although it's beyond the scope and space limitations of this chapter to explain how a variety of technologies can be used to motivate students in various contexts, I provide a few examples of current technologies that show promise for affecting students' motivation and engagement (along with relevant references that may be of interest to readers). Audience response systems (a.k.a. clicker technologies) have been shown to have a somewhat positive effect on students' motivation and engagement, yet the size of the effects depend on the course content, class size, and types of questions (Hunsu, Adesope, & Bayly, 2016). Virtual and augmented reality have been used to simulate learning environments, and they appear to be effective in creating learning experiences that can increase students' interest and enjoyment (Makransky & Lilleholt, 2018; Yeh & Lan, 2018). Game-based learning also shows the potential to motivate students (Giannakas, Kambourakis, Papasalouros, & Gritzalis, 2018), although the nature and design of the game tasks can influence students' motivation and engagement (Eseryel, Law, Ifenthaler, Ge, & Miller, 2014). Mobile devices (e.g., phones, tablets) continue to be studied in both formal and informal educational settings (Krull & Duart, 2017), and apps on these devices (e.g., *GroupMe*) have been used to facilitate engagement in discussion, group work, and other course-related activities (Gronseth & Hebert, 2019). Using social networking sites such as *Twitter* (Junco, Heiberger, & Loken, 2011) and *Facebook* (Moorthy et al., 2019) has also been shown to motivate and engage students in certain contexts. Intelligent tutoring systems and adaptive instructional systems

(Sottilare, 2018) are another approach to engaging students in learning. Other possible uses of technology include helping students with disabilities to stay engaged, such as by using an app on a tablet to regulate their emotions (Fage et al., 2019). To conclude, many different technologies are being used to motivate students in many different ways. The aim of instructors and researchers should be to understand *how* these technologies can be used most effectively to motivate and engage different students in different contexts.

Issues in the Study of Motivation and Engagement

In this section, I review some of the issues faced by researchers studying motivation and engagement. A strength of the current state of the research is that investigators are studying a variety of motivation and engagement constructs in many different settings. A good knowledge base exists upon which researchers can continue to build in the future. However, my goal in this section is to discuss some of the challenges that researchers should address in future studies to ensure that they are contributing as productively as possible to the existing literature.

Construct Issues

A problem with using constructs to infer a learner's motivation is that researchers often define these constructs differently or use the same name for different constructs (Schunk, 2000). This has caused confusion because it is difficult to compare and interpret findings across studies. Therefore, it is critical that researchers define their constructs precisely and that practitioners seek to understand the constructs as they are defined by the researchers. As a case in point, researchers studying *learner autonomy* need to provide their definition of this construct because there are at least five possible ways to interpret this concept, as noted by Benson and Voller (1997). As another example, the word *motivation* tends to be used "loosely" across studies to mean different things in different studies. Researchers need to give a specific definition of motivation in their studies. In addition, researchers should not substitute the word *motivation* for other constructs. If researchers are measuring self-efficacy, then they should refer to the construct as *self-efficacy* and not *motivation* because the two constructs are not synonymous.

Similarly, it is important for researchers to define *engagement* precisely because the engagement construct can be measured at different levels (see Fig. 1) and defined in different ways. Unfortunately, most researchers who have studied digital technologies in learning environments have not provided clear definitions of student engagement, as documented in a study by Henrie et al. (2015). Even when clear definitions of engagement are provided, there can be overlap in some definitions. For example, a student asking questions during a class could be considered an instance of behavioral engagement (the student is behaviorally participating in class appropriately) or cognitive engagement (the student is curious or recognizes his confusion and is seeking clarity). Researchers need to decide how to handle these situations and explain their procedures clearly to their readers.

A problem in defining motivation separately from engagement is that some constructs can be considered both motivation constructs and engagement constructs. For instance, the *interest* construct can be viewed as a motivational construct because it predicts students' choices, effort, and persistence (Hidi & Renninger, 2006). Learners who are interested in a topic are often motivated to participate in tasks related to that topic. Yet, interest is very similar conceptually to emotional engagement, which refers to learners' affective reactions in the learning environment. Affective reactions play an important role in current conceptions of interest (Hidi & Renninger, 2006; Pekrun, 2009). Researchers who study interest need to provide a clear definition of interest and how it may be different from other motivation and engagement constructs.

Researchers have also documented the importance of affect and emotional states in students' motivation more generally (Kim & Pekrun, 2014); yet, more research is needed to clarify the relationships between emotions and motivation. In some studies, positive emotions are associated with increased student engagement (Reschly, Huebner, Appleton, & Antaramian, 2008; Skinner & Belmont, 1993), and emotion regulation has been positively related to monitoring motivation in online collaborative environments (Xu, Du, & Fan, 2014). However, in other studies, emotions have not significantly impacted students' behaviors (Zhou, 2013). Other studies have examined emotions as mediators. For example, the emotional construct "anxiety" mediated the relationship between students' success perceptions and their interest in a competitive gameplay activity (Hong, Hwang, Tai, & Lin, 2015). Further studies are needed to explicate the relationships between students' emotions, motivation, and behavior.

Methodological Issues

Given the confusion that can arise in defining constructs, researchers need to not only define their constructs precisely but also explain their construct measures thoroughly. Importantly, researchers need to ensure that their construct definitions are consistent with what their measures assess. At a minimum, descriptions of self-report measures (such as quantitative scales) need to include the name of the scale, an explanation of what the scale measures, the number of items in the scale, the number of response options and option labels (e.g., *strongly agree*), any modifications the researchers made to the original scale, sample items, and reliability and validity evidence related to the use of the scale previously and in the present study. Sample items can be especially useful in helping readers to understand what the measure assesses.

Because learners' motivation can vary over time (van Roy & Zaman, 2018), researchers need to consider *when* they are measuring learners' motivation and what conclusions they can draw based on their findings. It may be necessary to measure learners' motivation over several time points to assess learners' range of motivations. For example, one study examined the effects of an animated pedagogical agent on secondary students' perceptions of success and usefulness before, during, and after an inquiry physics activity (van der Meij et al., 2015). The researchers were able to document changes in students' perceptions over time and identify interaction effects between the experimental and control groups over time. This type of study can provide useful information about when learners' motivation-related perceptions change, which can help identify possible design elements that affected these perceptions.

Interpretation Issues

Researchers need to ensure that they interpret their findings accurately. Some researchers have assumed that if a motivation-related construct (e.g., self-efficacy) increases, that "motivation" increases, which may not be true. The fact that a student's self-efficacy for a task increases does not necessarily indicate that the student's motivation for the task increases because learners may believe they can complete a task (i.e., they have a high self-efficacy for a task), yet still not be motivated to engage in the task.

Conclusions

Because motivation, engagement, and related constructs are often defined and used differently, consumers of research (e.g., instructors, researchers, college students) must strive to understand the construct definitions, assessment measures, and procedures used by the researchers to interpret research findings appropriately. For example, consumers cannot assume that they know what "motivation" or a particular motivation construct means in a particular study; instead, they need to determine how the researchers defined it in their study. Researchers must also do their part by explaining their work precisely (e.g., defining all constructs) and discussing the strengths and limitations of their work. Although researchers may never agree completely on how motivation- and engagement-related constructs should be defined and used, clear explanations of constructs, assessment measures, and procedures will help others to interpret research findings.

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Technologies to Enhance Self-Regulated Learning in Online and Computer-Mediated Learning Environments

Jaclyn Broadbent, Ernesto Panadero, Jason M. Lodge, and Paula de Barba

To be described as a self-regulated learner, the learner must activate "self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals" (Zimmerman, 2000 p. 14). Self-regulated learners plan, set goals and engage in strategies to achieve those goals. Through evaluation and reflection, these strategies are monitored and modified to enhance one's progression towards goal achievement. The beneficial effects of self-regulated learning (SRL) have been found in academic achievement across all educational levels (e.g. Dignath & Büttner, 2008; Panadero, 2017) and different learning settings (e.g. Broadbent & Poon, 2015; Richardson, Abraham, & Bond, 2012).

In the digital age, more learning is occurring online and is increasingly mediated by educational communications and technologies, even in schools and on campus. Online learning is an educational instruction that occurs using technology, which

J. Broadbent (✉)
School of Psychology, Deakin University, Geelong, VIC, Australia

Centre for Research in Assessment and Digital Learning (CRADLE), Deakin University, Geelong, VIC, Australia
e-mail: jaclyn.broadbent@deakin.edu.au

E. Panadero
Faculty of Psychology and Education, University of Deusto, Bilbao, Spain

IKERBASQUE, Basque Foundation for Science, Bilbao, Spain

J. M. Lodge
School of Education and Institute for Teaching and Learning Innovation, The University of Queensland, St. Lucia, QLD, Australia

P. de Barba
Melbourne Graduate School of Education, The University of Melbourne, Parkville, VIC, Australia

Melbourne Centre for the Study of Higher Education, The University of Melbourne, Parkville, VIC, Australia

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may be engaged in entirely asynchronously or with components of synchronous learning, and with no located face-to-face class time (Broadbent, 2017). The notion of blended learning has been used to describe a mix of face-to-face instruction with mediating technologies; although technology is now so widely used, the term could describe most classroom instruction. In higher education, traditional face-to-face and blended education has several advantages in supporting self-regulated learning over online delivery. For example, the structured nature of study through timetabled classes, practicals, seminars and tutorials helps supports time management and organisational skills. Availability of interactions with teachers and peers supports peer-learning and help-seeking strategies and even effort regulation. And the opportunity for immediate external feedback (from peers and teachers) in real time promotes metacognitive reflection and can be used to guide students to modify strategies during learning.

Online learning, on the other hand, provides learners with flexibility and accessibility to study anywhere, at any time, without requiring one's physical presence at a campus location (Means, Toyama, Murphy, Bakia, & Jones, 2009). This flexibility affords online learners the ability to live great distances from a campus location and juggle their studies with other priorities such as work or family. These benefits are often obtained at a cost, as the online mode may also result in reduced opportunities for student-to-teacher and student-to-student interactions and communication. Further, as time is not typically structured around fixed instruction, online learners may need to provide their own structure around learning, determine for themselves when and how to engage with course content, manage their time efficiently and persist in study despite competing life demands (Kizilcec, Pérez-Sanagustín, & Maldonado, 2017). Online learning environments demand an increased level of self-regulated learning, but often with less support from teachers and peers than more traditional and blended learning classrooms. Unsurprisingly, completion rates for online learners are nearly half that of students in more traditional environments (Edwards & McMillan, 2015). Limited ability to self-regulate, a lack of self-regulatory skills and limited opportunities to develop either are possible reasons why the attrition rates are so high (You & Kang, 2014). Thus, finding ways for online students to develop SRL is critical when learning in online environments.

However, in many instances, educators move their instructional practices in and out of digital learning environments, without consideration of how the digital learning environments impact student's ability to self-regulate. It is likely that educators do not consider whether (1) students know how to self-regulate online, (2) students know how to adapt their self-regulation needs in online and face-to-face learning environments, (3) strategies applied in face-to-face learning contexts work equally as well in online environments, and (4) transferring traditional teaching design and material to the online learning environment will result in the same learning outcomes for students. Because of the importance of self-regulated learning to academic success and lifelong learning, educators need to be proactive in ensuring that digital learning environments, educational communications and educational technologies foster and enhance SRL (Azevedo, Taub, & Mudrick, 2018; Poitras & Lajoie, 2018).

This chapter explores how technologies may enhance SRL in online learning environments. The chapter first gives an overview of self-regulated learning theory and discusses how SRL may differ in online and face-to-face contexts. It then explores how educational and communication technologies can be used to help students develop SRL, either prior to or outside of course instruction or as technology embedded within online learning environments and used during learning. Ready-made online tools such as blogs, podcasts, social media (Twitter, Instagram, Facebook, etc.) and wikis are considered, as is the potential of learning analytics to enhance SRL. Lastly, the chapter examines some of the challenges of the field of SRL and the use of educational technologies.

What Is Self-Regulated Learning?

The field of SRL is currently one of the most prominent areas of research in educational psychology, as it provides a powerful theoretical and practical framing for the cognitive, motivational, emotional and behavioural aspects of learning (Panadero, 2017). As already defined, students that are self-regulated activate a diverse range of learning strategies to achieve the goals they have established. While there are a number of different models and perspectives used to explain this process, and we will be taking a socio-cognitive perspective in this chapter, all contain four common assumptions regarding how students can self-regulate their learning.

Firstly, all models assume that self-regulated students can monitor and regulate their cognition, behaviour, motivation and emotion (Panadero, 2017). While the different SRL models may place a stronger emphasis on different areas (e.g. Winne and Hadwin (1998) on cognition, Boekaerts (2011) on emotion and motivation), all assume that the four areas can be regulated by the students and, therefore, used strategically for increasing learning. Secondly, student behaviour is goal directed, and the process of self-regulation includes modifying behaviour to achieve those goals. Importantly, students construct their goals and meaning from both the learning context and prior experiences. Thus, it is crucial to create a positive learning classroom climate to enhance learning goals (e.g. Alonso-Tapia & Fernandez, 2008). Thirdly, SRL is cyclical and composed of different phases and sub-processes, with five of the six leading models of SRL analysed including three phases: preparatory, performance and appraisal (Panadero, 2017). And lastly, self-regulatory behaviour mediates the relationship between a student's performance, contextual factors and individual characteristics. In other words, SRL is constructed from experience in the social environment, and students need to consider the context to self-regulate successfully (Zimmerman, 2013).

The most cited SRL model, and for that reason the one we present in this chapter, is the cyclical phases model developed by Barry Zimmerman (2000, 2013). This model includes three phases. The first one is called the forethought phase in which the student analyses the task, sets goals and plans accordingly. This phase is energised by several motivational variables such as motivation, interest and self-efficacy.

The second is called the performance phase when the student executes the task using a number of self-control and self-observation strategies to monitor his/her progress towards the established goals. The final one is the self-reflection phase in which the student judges his/her work and, depending on his/her attribution style, reacts to the result. This experience will affect the student subsequent task performance. For the remainder of this chapter, we use Zimmerman's theory of SRL to frame our discussions. Like most other SRL models, Zimmerman's model has been applied most often in more traditional face-to-face learning environments. Thus, it is important to explore whether SRL deployment works the same in digital environments as it does for traditional learning contexts. For that reason, in the next section, we will explore what the similarities are in both contexts in relation to SRL.

Self-Regulated Learning in Traditional Versus Digitally Mediated Environments

The transition from secondary to tertiary education is typically characterised by a reduction in structured class time per week, less direct contact with one's teachers and greater reliance upon SRL. It is therefore in the higher education environments that the need for SRL is perhaps most apparent (Sitzmann & Ely, 2011). Further, within the higher education context, it is well established that the strategies students employ to self-regulate their learning impact their academic performance (Broadbent, 2017; Broadbent & Poon, 2015; Richardson et al., 2012). For example, in their meta-analysis, Sitzmann and Ely (2011) found that SRL strategies accounted for 17% variance in learning in their sample with a large proportion of university students. However, it is also clear that students differ in the strategies they employ to self-regulate their learning, as well as the frequency with which they utilise these strategies (Broadbent & Fuller-Tyszkiewicz, 2018; Dörrenbächer & Perels, 2016). While these individual differences likely reflect the strategies learners have been taught previously and/or found to be helpful, strategy utilisation preferences may also reflect the constraints of one's learning environment. Either way, better understanding of how, when and where strategies are utilised may help us personalise SRL interventions, particularly in an online context.

A large meta-analysis by Richardson et al. (2012) compared the findings of 126 studies of SRL motivations and strategies used by students in higher education settings. They found that the strategies of effort regulation, time management, metacognition, elaboration, critical thinking, help-seeking and concentration significantly predicted student's grades; weighted mean correlations (*r*) ranged from 0.15 to 0.32, with the highest predictor observed being a motivational one: performance self-efficacy. If we just focus on the explored strategies, the highest predictors were effort regulation, time management, elaboration and metacognition. However, Richardson et al. meta-analysis included studies performed in face-to-face contexts, and a growing number of students are now undertaking higher education wholly, or at least partially, online. Educators could easily assume that students self-regulate the same in both the online and face-to-face learning environments and that strategies students apply in face-to-face learning contexts work equally as well in online environments. Few studies ($n = 12$) have been conducted focusing on the SRL strategy use of online-only learners and their relationship with academic success in the last decade (Broadbent & Poon, 2015).

The meta-analytic review by Broadbent and Poon (2015) looking at the relationship between online learners, SRL and academic achievement found that only four learning strategies were significantly associated with online learner's grades – metacognition, time management, effort regulation and critical thinking – and that these relationships were weaker than those found for learners in traditional environments (Richardson et al., 2012). While it is important to keep in mind that the number of selected publications of this online meta-analysis is discrete in comparison to the ones in Richardson et al. (2012), some conclusions can still be extracted. Broadbent and Poon (2015) concluded that although SRL strategy use in more traditional settings appear to generalise to online learning environments, the effects of SRL strategies may be "dampened in the online learning environment" and "we should not assume that online learning in itself fosters SRL strategies use or development" (p. 12). Further to this point, educators should also not assume that learners know how to transfer their SRL skill to an online environment or that transferring traditional teaching design and material to the online learning environment will result in the same learning outcomes for students. In fact, the higher attrition rate of online learners in comparison to those students who attend face-to-face classes suggests this not to be the case (Clay, Rowland, & Packard, 2009) and that any lack of ability to self-regulate is a significant contributor to the dropout rate in higher education (Cho & Shen, 2013). It should be acknowledged that both meta-analyses focused on self-reported student data, which means these findings do not address students' real-time needs when using learning technologies across setting, domains and contexts. While previous online learning research is limited in this manner, online learning environments do present the promising potential to foster students' abilities to regulate their learning, using digital technologies that could be used for direct instruction of SRL skills (Azevedo et al., 2018).

Technologies to Support and Foster SRL in Online Environments

Digital technology-based interventions used to support and foster SRL in online environments usually take two approaches. First, some educational technologies (e.g. online training or mobile-based apps) provide direct instruction on how to acquire and develop SRL. This direct instruction is usually prior or parallel to (and outside of) course instruction. Here the technology is used for the primary purpose of helping the students learn how to regulate their learning. Second, other digital technologies and communications (e.g. nStudy, MetaTutor) are embedded within online learning environments to support and promote SRL while students are completing learning tasks (e.g. learning about the blood system). Embedded technologies use scaffolds, prompts and feedback to improve SRL and occur alongside (and within) course-specific content (Azevedo et al., 2018). Despite the complexity of SRL, both types aim to develop and enhance SRL strategies such as goal setting, planning, metacognition and self-reflection. Importantly, both types of technologies have been situated within what has been termed “the third wave of SRL measurement” (Panadero, Klug, & Järvelä, 2016). According to these authors, the latest SRL advancement is to employ tools that measure and scaffold SRL at the same time. Next, we will present some examples of both types of SRL interventions.

Regarding SRL direct instruction technology, one example would be online SRL training sessions prior to the course itself (e.g. Bellhäuser, Lösch, Winter, & Schmitz, 2016; Dörrenbächer & Perels, 2016). This particular intervention focusses on improving aspects of SRL within all three of Zimmerman’s phases (discussed earlier). Training sessions are usually weekly, over several weeks, and may be accompanied by learning diaries. While originally conducted in face-to-face settings (Schmitz & Weise, 2006), SRL training has been successfully transferred to online web-based platforms, resulting in improvements in both student’s SRL declarative knowledge and subsequent SRL behaviour (e.g. Bellhäuser et al., 2016; Dörrenbächer & Perels, 2016). Methodologically, daily learning diaries show promising intervention results as they expose daily fluctuations of SRL strategy use and also track changes in SRL use after training sessions (Panadero et al., 2016). The effect of the diaries on learning happens via self-monitoring (Panadero et al., 2016; Schmitz & Weise, 2006) and can target all three phases of Zimmerman’s process model. However, the use of online and app-based SRL diaries, like the web-based training, is only in their infancy. Bellhäuser et al. (2016) have conducted one of the few studies that used online versions of daily diaries for SRL. They found that SRL training was more effective than daily diary use alone. This finding suggests that while daily diaries can enhance SRL, gains are minimal if students are not taught how to implement SRL strategies effectively.

A potent challenge for the SRL direct instruction technologies is that they require students to dedicate extra time in addition to their course instruction. Besides completing course-related activities, students are required to either complete a separate module on SRL or complete extra tasks throughout the semester to make entries into their diaries. As mentioned previously, time management is one of the main SRL skills related to online achievement (Broadbent, 2017; Broadbent & Poon, 2015). Therefore, such additional study load should be considered in the course design when implementing these technologies as an additional workload for students.

Regarding the second type of interventions, digital technologies can be embedded within online learning environments to support and promote SRL while students are completing learning tasks. Examples with large empirical support are gStudy, now defunct, that was later developed into nStudy (Winne et al., 2006; Winne & Hadwin, 2013). Winne and Hadwin’s (2013) nStudy provides a combination of cognitive tools within an online learning environment where students learn about a certain topic using a wide range of multimedia resources. The web-based application assists students to apply "well-established principles to assist learning" (p. 809) while at the same time collects trace data about the students' learning experiences (e.g. personal comments, summaries, underlined passages). It also allows input from peers and teachers to direct their future learning experiences. This collected trace data are then feedback to the learner, who can then learn and adapt their future behaviour. Importantly, conclusions extracted from trace data should be used with caution, as the data only represents a behavioural measure of a process that is largely cognitive. In the case of nStudy, for example, it does not adaptively scaffold the students' learning, and all assessments to determine metacognitive behaviour are post hoc (Azevedo et al., 2018). This means that the data obtained are largely dependent on researcher interpretations (Bernacki, 2018). Further, embedded technologies such the former gStudy and the current nStudy are perhaps currently only suited to well-defined tasks/problems, where there are defined steps to follow during problem-solving. On the other hand, ill-defined problems, those that must synthesise a range of inputs and where problem-solving does not progress in the same manner each time, are more difficult to capture. This is not to say that nStudy is not effective, only that it should be noted that true metacognition during learning is more difficult to detect than it might appear at first.

A second example of embedded SRL interventions is intelligent tutoring systems (ITS) . Intelligent tutoring systems combine (1) tutoring functions, such as providing prompts and assigning tasks, with (2) a multidimensional student model, which is continuously updated based on students' current psychological states, such as their learning strategies used, current level of knowledge and emotions, while (3) at the same time fostering SRL development for future learning situations (Goldberg & Spain, 2014; Ma, Adesope, Nesbit, & Liu, 2014). For example, MetaTutor (Azevedo, Johnson, Chauncey, & Burkett, 2010) aims to scaffold the self-regulatory process to enhance academic achievement within a science context. Notably, MetaTutor contains both training aspects before learning and adaptive scaffolding during learning by providing feedback on performance. Importantly, this feedback can be used to correct ineffective learning strategies and replace them with new, more effective ones. However, like all scaffolding systems, proper scaffolding remains a challenge for MetaTutor. For example, SRL should be faded and even removed once independence has been reached. However, knowing when and how to fade is difficult and not achieved yet with MetaTutor. Until ITS can fade scaffolding intelligently, one research question would be if learners are better off using simpler tools over which they must exercise some control.

Further, the content-dependent nature of many of these ITS do rely on proper learning design to be employed, which can result in costly and time-consuming efforts to apply them in real-life courses (see section "Current Challenges to Enhance Students' Self-Regulation in Online and Computer-Mediated Environments" for an expansion of this argument). Further, as discussed by Self (1998), perhaps the best ITS are those that will work collaboratively with the student, where the computer would also learn from the joint activities with the student and without a student model. While out of the scope of this chapter to pursue further, it leads us to some important questions. Are student models needed to be able to appropriately fade scaffolding for students? Is this different for content-dependent/non-dependent and for well-/ill-defined tasks? In our opinion, both answers are yes.

Thus, while ITS like MetaTutor have potential, they struggle to have a direct, broad impact on SRL as they are designed at the moment in natural learning situations and are accompanied by high implementation costs. For these reasons, there is still a lot more work to be done in this area before the positive learning results found in these specific learning environments can be translated easily to other online or, even more, face-to-face situations.

The Use of Non-SRL Tools for SRL Purposes

All direct instruction (e.g. nStudy) and embedded digital technologies (e.g. MetaTutor) mentioned so far have been purposely built to support SRL. These are usually costly endeavours, mainly for research purposes in educational psychology. An alternative approach is to use digital technologies and communications that are already available, either to the general public or to the education sector, to support and develop SRL (or build up on top of these tools). Examples of ready tools include blogs, podcasts, social media (Twitter, Instagram, Facebook, etc.) and wikis. When purposefully incorporated in course design, these tools are particularly adept at encouraging collaboration, help seeking and peer learning, as well as goal setting, task strategies and self-monitoring, but less able to support the process of self-evaluation and time management (Dabbagh & Kitsantas, 2012). It is also unclear which elements of multimedia instruction might influence – negatively or positively – students' capacity for SRL or how these and similar types of resources (such as interactive modules, images, videos, etc.) influence students' capacity for SRL. More research is needed to understand how these tools and resources can be designed within these environments in subtle (i.e. design features) or in less subtle (i.e. metacognitive prompts, overt feedback for SRL) ways to scaffold and/or support SRL.

A New and Promising Area for SRL Research: Learning Analytics

The rapidly developing field of learning analytics has the potential to contribute to the progress of technologies to support and foster SRL. Learning analytics is the "measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs" (Long, Siemens, Conole, & Gašević, 2011). That is, students' digital traces across different platforms can contribute to a better understanding of their learning process. The use of traces allows SRL to be conceptualised as an event, which means that students' real-time actions are taken into consideration, rather than the interpretation of their actions (Winne & Perry, 2000). Through learning analytics, a large amount of data can be collected and understood via innovative ways of interpreting and evaluating these data (Lodge & Corrin, 2017). Interpreting what digital traces might indicate about self-regulation has been one of the challenges in SRL research (Roll, Baker, Aleven, & Koedinger, 2014). Moreover, at present, the data being collected are often not interpreted in a timely manner sufficient for use by the student or teacher to have direct and positive impacts on the students' SRL. In order for this to occur, there are three points researchers need to prioritise (Roll & Winne, 2015).

First, learning analytics should capture student data related to all phases of SRL (this challenge is discussed further in the section "Current Challenges to Enhance Students' Self-Regulation in Online and Computer-Mediated Environments"). The embedded SRL tools previously presented have been designed to include features that record data already connected to specific SRL phases. In nStudy (Winne & Hadwin, 2013), students add tags to parts of the text they highlighted while studying (e.g. can do, can't do). These tags contextualise the behaviours with the cognitions of the student, allowing researchers to identify how students are regulating their learning. However, the vast majority of naturalistic online learning environments do not include specific features that connect data to SRL. One way researchers have been dealing with this challenge is using features of the context, such as the course learning design, to provide meaning to the data (Lockyer, Heathcote, & Dawson, 2013). That is, the way a course is designed informs the quality of students' actions and strategies used to regulate their learning. In a recent study, Corrin, Barba, and Bakharia (2017) investigated students' help-seeking behaviour across four massive open online courses (MOOCs). Firstly, the authors identified student actions that could represent help-seeking behaviour according to features commonly present in MOOCs learning design, such as search queries in discussion forums and seeking for specific content within a video. They then examined the prevalence of these actions across the courses. Findings indicated that courses with specific learning designs, such as providing integration between discussion forums within content areas, had more students engaging in help-seeking behaviours than other courses. Initiatives like these are a first step towards creating alternatives to capture meaningful learning analytics related to SRL in open online environments.

Second, methods of data analysis need to have a capacity for identifying particular patterns related to SRL. Advances in learning analytics over the last years have focused on using data mining and machine learning techniques to unveil students' complex patterns on the use of learning strategies. One example is the use of sequential data mining (e.g. Zhou, Xu, Nesbit, & Winne, 2010). This technique focusses on analysing students' actions that provide evidence of their cognition operations, taking into consideration the states preceding such actions (Winne & Perry, 2000). Recently, Siadaty et al. (2016) developed and implemented a protocol on how to analyse students' SRL sequential data in online environments. They detailed the important steps of defining the traces that would represent SRL processes in the sequential analysis and how they conducted that analysis. These included instructions on what types of events could be identified as SRL in a particular context, such as goal planning and implementing strategy changes, and how to parse the dataset taking into account the sequence of these events. This study highlights one of the crucial aspects of developing methods to identify SRL patterns: the creation of SRL data representations that can be adapted and applied to different online contexts and technologies to identify SRL patterns. However, this is still a work in progress. Even though these methods provide guidelines on how to identify SRL, application in real-world educational settings is currently considered to be costly and time-consuming.

Third, effective interventions to foster and support SRL using learning analytics need to be created based on the SRL data collected and analysed. One example of a learning analytics intervention that has gained traction from both researchers and the industry is the use of dashboards. Dashboards provide learning analytics back to students through visualisations as a form of feedback. Dashboard developers expect that students will interpret these data in a meaningful way, helping them to regulate their learning. This, however, is not always the end result, as dashboards rely on students' ability to interpret and act upon the data (Corrin & de Barba, 2014). Further, it appears that unless any tutorial or guiding tool occasionally compels the learner to engage in SRL phases, the impact may be negligible. For the learning analytics field to explore interventions that go beyond providing students visualisation of their data, the field needs to advance in the previous two priorities – collect meaningful SRL data and use adequate methods to identify SRL processes – to then investigate the effectiveness of SRL interventions (see also Lodge, Panadero, Broadbent, & Barba, 2019). This way, timely and personalised interventions to support and foster SRL can be successfully developed and implemented using learning analytics.

Current Challenges to Enhance Students' Self-Regulation in Online and Computer-Mediated Environments

There are a number of challenges we face in developing students' self-regulated learning in online learning environments (see Table 1). These challenges should be seriously taken by future researchers to ensure we find answers. Next, we will discuss six challenges to developing self-regulation in online and computer-mediated environments. First, a challenge we have discussed throughout the chapter is our reliance on inferring SRL processes through behavioural data. We will not discuss it further here.

Second, inherent in the definition of SRL is learning, and claims about an SRL process or processes being advantageous in different learning environments or for different types of learners must include evidence of a relationship with learning

Table 1 Challenges we face in developing students' self-regulated learning in online learning environments

1	Inferring SRL (meta)cognitive processes through behavioural data
2	Unexplored effects of the SRL interventions on learning and performance
3	Capturing the whole SRL process with all its phases rather than segments
4	Domain-specific or non-specific interventions
5	Change agent decision
6	Capacity of the technology-based SRL interventions to enhance the students' independent development of SRL

outcomes. Surprisingly, some studies on online SRL do not include academic achievement (e.g. grade, GPA), with only ten studies meeting this requirement in 2005–2015 (Broadbent & Poon, 2015). For SRL research to move forward, we must ensure that we target learning outcomes, so we can better understand how the different phases and strategies improve learning.

The third challenge is how research could capture the whole SRL process. Most theories and models define SRL as a recursive process between different phases (Panadero, 2017). If our research pulls apart individual pieces for scrutiny, it may not provide an accurate picture of the role that the pieces play in the larger construct of SRL. Work by Taub et al. (2017) is promising, which highlights the importance of using multimodal multichannel SRL data to capture different aspects of SRL at the same time. In their study, they used eye tracking combined with log files and examined how these data interacted to predict performance. However, multimodal researchers have not yet found a sufficient way to capture all aspects of the SRL process, for example, student motivation (Azevedo et al., 2018). At present, many studies provide support for different aspects of SRL, either through various tools, through access to tutors or feedback, through prompts and through peers. However, it is still unclear which aspects/tools are essential to promote SRL, what can be adapted and which can be changed to suit specific contexts. Exploring ways to investigate SRL that encapsulates the complexity is an ongoing challenge for SRL researchers (Bardach, Peeters, Panadero, Klug, & Lombaerts, under review). As suggested by Panadero (2017), future research needs to combine conclusions from previous meta-analyses with SRL model validation studies. Panadero further argues that this would allow researchers to test even more specific SRL models' differential effects. Lastly, it is worth considering if perhaps fidelity to "principles" that can be readily converted to design parameters rather than strict methodology and prescriptive approaches is the key (see also Horvath & Lodge, 2017). This is one example of the broader issues related to the translation of laboratory-based, controlled research to real-life educational settings (see Horvath & Lodge, 2017).

Fourth, another challenge is whether SRL interventions should be domain specific or general. Content-specific SRL training fosters SRL in students through implementing training alongside or within coursework (e.g. training on SRL strategies for mathematics within a mathematics course). A number of studies have shown that effective SRL strategies do vary across academic subjects (Green et al., 2015), suggesting that content-specific approaches may be more appropriate in scaffolding SRL development. On the other hand, content non-specific SRL training involves providing a program targeting SRL skills not specifically tied to any other content. Content non-specific training programs have also been shown to be effective in encouraging SRL knowledge and skills in students in a number of higher education courses (Dörrenbächer & Perels, 2016; Schmitz & Weise, 2006). We find an empirical answer to this challenge by looking at Hattie and Timperley (2007) meta-analysis: "simple strategies (such as mnemonics, memory systems) could be taught outside the content, but that most strategies have to be taught within the content domain" (Hattie, 2012 p. 115 referring to his 2007 publication). What are the implications of this tension for the type of SRL interventions we have been discussing (e.g. nStudy)? Given that many of the technologies have been purpose built within very specific content interventions, they might have a more limited transferability capacity, as we will further elaborate in our sixth challenge. However, technology-based SRL interventions can also be designed with a non-content-specific approach, with the intent of teaching SRL skills in a general manner (e.g. Bardach et al., under review). The main thing here is that the authors of the particular intervention, whatever the approach might be, need to be aware of the limitations and potentials of their approach based on the content specificity matter.

Fifth, another challenge is who should be the change agent. Dignath and Büttner (2008) found that SRL treatments were more effective when researcher led rather than teacher led in primary and secondary schools; however, this may be a result of inadequate teacher training as suggested by the meta-analysis authors. Still, this is problematic for scalability and transferability of interventions, if a researcher needs to be leading the interventions. It is possible these barriers may be overcome through the use of online web-based platforms, although a meta-analysis by Benz (2010) shows that computers have been less successful at improving SRL development than humans. Feasibly, this finding is confounded by the differences in the type of SRL development targeted via each of these mediums. Human support usually occurs before learning and targets strategy instruction, whereas computer-mediated support is often given as process support during the learning experience. Computer-mediated support may be less successful because it focusses on the employment of learning strategies without accounting for the learners' prior knowledge and understanding of the skill. Further, computer-mediated technology, at present, cannot provide the same quality of adaptive learning as provided by a human tutor. That is not to say that we give up on this path of SRL development as the flexibility, reach and cost-effectiveness of technology-enhanced SRL development put these types of SRL development programs in a promising position in the future. Further, as learning analytics continue to develop, they will eventually provide scalability of training by leveraging big data to target students' own online behaviours, e.g. intelligent tutoring systems and systems with automated feedback and flexible pathways. At present, however, some human guidance is needed to achieve higher learning outcomes for students.

Lastly, sixth, this brings us to the biggest and often overlooked challenge in the use of technology for the development of students' self-regulated learning, that is, does interaction with the technology build independent SRL skills in learners? Or does the technology support SRL on the assumption that the technological scaffold will always be there during learning? If we assume the latter, the technology aids the learner with "distributed metacognition" that prompts and supports SRL during the student's interaction with the technology. Distributed metacognition is a process whereby metacognition is shared between the learner and the computer to expand the metacognitive resources of the learner to beyond what they would have achieved alone (Kirsh, 2005). While this may improve learning outcomes, there is little empirical research that has addressed whether it also enhances metacognitive knowledge and independent self-regulation outside the interaction with the technology. Much of the technology we have discussed, nStudy, MetaTutor, learning analytics, etc., attempt to support students' self-regulation with the aim of achieving positive learning outcomes and increased content knowledge. However, most overlook the importance of student agency in their own self-regulation, and few consider the development of metacognitive skilfulness outside of interaction with the technology. We believe for technology to truly progress in this area; the onus for self-regulation ultimately still needs to lie with the student.

Conclusion

As described in this chapter, there are many avenues that are being explored to enhance the development of SRL when learning online and with a computer. These technologies can be used by students to plan their own learning activities, monitor themselves, collaborate with peers and self-evaluate their own learning outcomes. Importantly, when learning technologies are deliberately used to support self-regulation, motivation and engagement in online learning contexts, students' academic performance will significantly improve (Kitsantas, Dabbagh, Hiller, & Mandell, 2015). The technologies discussed in this chapter aim to support learning and ultimately foster students to learn how to learn. They aim to support and help students to develop their skills to set goals, plan their strategies, improve self-assessment skills and promote help-seeking behaviour. While an amiable pursuit, we are still a long way from achieving this aim, with a number of challenges and mixed findings from a range of technologies used to enhance SRL.

With this in mind, educators should not assume that learning online occurs in the same way it does in traditional settings, and they need to choose the technologies that both suit their pedagogical purpose and are appropriate for the medium. For example, if the purpose is to foster student-to-student interaction to enhance metacognitive monitoring, this will be facilitated in a very different way in an online environment than it would be in a live classroom. It should also be noted that these technologies are limited at the moment because a significant portion of the information provided back to the educator in the online environment is behavioural data, though this is changing due to the higher potential and accuracy of multimodal data as mentioned above (Azevedo et al., 2018). These crude data are problematic given the high-level nature of SRL as a complex set of cognitive/metacognitive processes. Currently, this is the reality of SRL research; it is a complex phenomenon of the mind impossible to observe for the teachers, an issue that is compounded when the pedagogical purpose and mode of delivery are not explicitly factored in. Thus, researchers and educators alike need to be mindful of the inferences we can make about SRL and how to intervene on the basis of behavioural data alone.

To conclude, the biggest agent in learning regulation is the student themselves. So, while educators should take advantage of the opportunities that technology afford to improve student's SRL, it is important to remember that the onus for self-regulation ultimately needs to be on the student. Technologies can only ever open the door for students; they cannot do the self-regulation for them, even if we assume a strong distributed cognition position on the role of machines in all this.

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Developing Expertise and Expert Performance

Peter J. Fadde and Patricia Sullivan

Introduction

One of the great joys in life is seeing experts at work in their realms. They routinely do what seems impossible to others. They seem to know what's going to happen before it happens. They save lives in operating rooms and influence lives in classrooms. Some of their domains of performance[1] are as ancient as the medieval guilds; some are emerging so rapidly that formal training and education can't keep up. While the world needs more experts, it also needs them more quickly than the years typically required to "make" an expert. Indeed, as first hypothesized in early 1970s chess research (Simon & Chase, 1973) and later evidenced in research on high-level music students (Ericsson, Krampe, & Tesch-Römer, 1993), attaining the highest levels of expert performance requires around 10 years or 10,000 hours of *deliberate practice* that is directed by a coach, targets specific skills to improve performance, provides timely feedback and repetition to refine target skills, and is effortful rather than inherently enjoyable.

Perhaps because it proclaims the primacy of hard work over talent, the 10,000-Hour Rule has been widely promulgated in popular literature such as *Talent is Overrated: What Really Separates World-Class Performers from Everybody Else* (Colvin, 2008); *The Talent Code: Greatness Isn't Born. It's Grown. Here's How*

[1] The term "domain" can have different meanings. In education and instructional design, it often means domains of learning, e.g., cognitive, psychomotor, and affective. We use the term as it is used in expertise studies, to refer to distinct areas of work or performance.

P. J. Fadde (✉)
Department of Curriculum and Instruction, Southern Illinois University, Carbondale, IL, USA
e-mail: fadde@siu.edu

P. Sullivan
Department of English, Purdue University, West Lafayette, IN, USA

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(Coyle, 2009); *Outliers: The Story of Success* (Gladwell, 2008); *Bounce: Mozart, Federer, Picasso, Beckham, and the Science of Success* (Syed, 2010); and *Peak: Secrets from the New Science of Expertise* (Ericsson & Pool, 2016). Despite the popular as well as theoretical appeal of expertise studies, however, there is a gap between describing expertise and developing it. For instance, the deliberate practice framework that fits so neatly with images of aspiring musicians and athletes fits less well with professionals who may not start their 10,000-hour clock until they reach college age and are unlikely to reach levels of expertise until their third or fourth decade (Ericsson, 2008). There is a role, then, for instructional design researchers and practitioners in bridging from expertise studies to expertise training, especially in professions such as law, medicine, nursing, education, business, architecture, social work, counseling, physical therapy, law enforcement, pharmacy, accountancy, information technology, dietetics, public health, engineering, finance, and even instructional design.

As with efforts to find shared ground between the fields of instructional design (ID) and Human Performance Technology (Foshay, Villachia, & Stepich, 2013) as well as between ID and Learning Sciences (Lin & Spector, 2017), our challenge is to find insights that add to our ID knowledge base (Richey, Klein, & Tracey, 2011) without oversimplifying or cherry picking from another discipline. Of course, constructivist learning approaches such as cognitive apprenticeship (Collins, Brown, & Holum, 1991), problem-based learning (Hmelo-Silver, 2004), four-component instructional design (van Merriënboer, 1997), and first principles of instruction (Merrill, 2002) imbue educational environments with elements of professional work. However, constructivist learning approaches have not been as widely adopted in professional training contexts where ID practitioners value more systematic approaches (van Merriënboer & Boot, 2009). In addition, cognitive task analysis (CTA) methods that reveal expert knowledge and have improved professional education curricula (Clark, Feldon, van Merrienboër, Yates, & Early, 2008; Yates & Clark, 2012), are largely ignored by many ID practitioners because of the high level of skill and effort required to conduct CTA (Schraagen, 2009).

What we seek in this chapter, therefore, are ways to bridge from expertise research to ID practice in highly applicable ways. We first clarify these goals by unpacking the chapter's focal question. We then consider who can benefit from expertise training and what expert skills are appropriate to train. We conclude by describing four models that apply principles of expertise studies to designing expertise training.

Focal Question: How do we facilitate the development of expertise and expert performance through instructional design and technology?

How alludes to our focus on practical application of expertise theories, research, and methods. Historically, with roots in World War II-era military training, ID has been highly successful in training to levels of certifiable competence (Molenda, 2010), but expertise is assumed to come with experience, mentorship, and non-instructional professional development activities such as reading journals and attending conferences (Richey et al., 2011). We contend that systematic ID approaches can expand to include expertise training.

We includes current and future ID professionals along with academic faculty in instructional design, learning design and technology, workforce education, cognitive psychology, and human factors engineering. Instructors and curriculum designers in college-based professional education programs also have particular interest in accelerating expertise and expert performance.

Facilitate suggests that we are assisting mature and motivated performers to accelerate the natural development of expertise and expert performance over a career spent in a domain. Facilitation of expertise may operate in a preparation stage, such as professional education, or during professional work. Ultimately, the goal is for performers to become self-regulated learners guiding their own development.

Development alludes to the focus of modern expertise studies on *individual development* in contrast with traditional interests in *individual differences* (Ericsson, 2017). Rather than talent or inherited attributes, expertise is primarily attributed to thousands of hours of *deliberate practice* under the direction of an instructor that is designed to improve performance by targeting specific deficiencies with activities that are at the edge of performers' abilities, offer timely feedback, and can be repeated to refine performance (Ericsson et al., 1993).

Expertise and *expert performance*, as individual terms, are associated with knowledge and skills, respectively. The combined phrase, though, emphasizes knowledge in the service of performance. While traditional expertise studies attempted to codify expert knowledge, the *expert-performance approach* aims to capture exceptional performance in naturally occurring events that can be recreated in controlled conditions in order to investigate the cognitive mechanisms of expert performance (Ericsson, 2008).

Instructional design and technology (IDT) refers to distinct, and often mediated, learning activities more than course-level curricula. Although training for expert performance is often associated with simulator-based training, the deliberate practice framework aligns well with long-established instructional methods such as drill-and-practice and technologies such as computer-based training (CBT) that can deliver measureable and repeatable learning activities.

Issues and Considerations in the Design of Expertise Training

Asking how we can facilitate expertise and expert performance leads to asking who can benefit from expertise training and what specific aspects of expertise to train.

Who Can Benefit from Expertise Training?

The most obvious beneficiaries of expertise training are performers in *Type 1* domains (Hoffman et al., 2014) that engage in direct competition (such as sports and performing arts) and have a culture of practice. *Type 2* domains that don't meet the criteria for *Type 1*, including most professions, are less familiar with deliberate practice. Figure 1 depicts a *culture of expertise* continuum that represents beliefs of various domains regarding how expertise is attained.

Chess, music, and sports represent classic *Type 1* domains that have direct competition, objective feedback on performance, and an established culture of practice. *Type 2* domains include academic domains, such as history and literature, which emphasize knowledge more than performance skills and can be characterized as having a *culture of study*. Although "performance" can include academic skills such as locating and synthesizing sources, these don't align with conceptions of drill-like deliberate practice associated with *Type 1* domains. Other *Type 2* domains have *cultures of experience* that place high value on holistic experience-based learning, such as student teaching and medical residencies. These domains can also be an unnatural fit for deliberate practice. Even when teacher education theorists (e.g., Berliner, 2000, 2001; Darling-Hammond, 2005; Dunn & Shriner, 1999) directly reference deliberate practice to develop teacher expertise, a typical sentiment is that:

> For most of us, the word "practice" elicits images of repeated performances aimed at refining and perfecting some skill, usually a motor skill. Teachers do not practice, they "teach." (Dunn & Shriner, 1999, p. 647)

Strong correlations have been shown between the amount of deliberate practice and the level of performance for the classic *Type 1* domains of chess, music, and sports (Baker & Young, 2014; Macnamara, Hambrick, & Oswald, 2014; Ward, Hodges, Starkes, & Williams, 2007), but only tenuous correlations between deliberate practice and level of performance have been shown for *Type 2* domains such as education and other professions (Hambrick et al., 2014). Indeed, the lack of competitions or rankings that clearly designate level of performance makes it difficult to apply the expert-performance approach in *Type 2* domains (Ericsson, 2015), for both research and training purposes. Translating to *Type 2* domains the expertise theories, research, and methods developed in *Type 1* domains requires teachers, trainers, and ID professionals to expand conceptions of deliberate practice. For example, analysis of expert performance in many domains shows that experts are

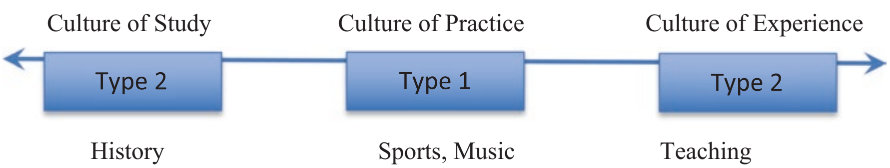


Fig. 1 Continuum depicting cultures of expertise in professional domains

better able to plan, execute, and monitor their own performance (Ericsson, 2015), suggesting that expertise training should address these metacognitive skills with deliberate practice activities that are focused and measureable, offer timely feedback, and can be repeated to refine performance.

What aspects of expertise and expert performance should be targeted for training?

The problem with training expertise and expert performance is that they seem to represent massive amounts of accumulated knowledge and skills. Fortunately, our focus is on what *differentiates* expert from near-expert performers rather than the totality of experts' knowledge and skills. This difference is the target of studies that adopt the expert-novice research paradigm introduced in pioneering chess studies (e.g., Simon & Chase, 1973). In their classic experiment, Simon and Chase (1973) compared an internationally ranked chess player with a skilled but unranked player on the representative task of reconstructing the arrangement of pieces on a chessboard after a brief look at the board. As would be expected, the expert performed much better, but only when the arrangement of pieces came from an actual chess match. When the arrangement of pieces was arbitrary, the expert's advantage largely disappeared. Simon and Chase concluded that the expert possessed chess-specific schema that permitted him to chunk meaningful information, thereby circumventing limits of working memory.

The assumption underlying expertise training is that acquiring skills that differentiate expert from near-expert performers will enable a near-expert performer to become an expert performer. While this assumption is not fully proven, it provides a starting point for expertise training. In the expert-performance approach, the first step of an expertise researcher, or an instructional designer who seeks to facilitate performers' advancement to expertise, is to identify specific knowledge or skills that demonstrate repeatable superior performance in natural settings (e.g., Ericsson, 2008). This goal is facilitated by models that represent stages of development, starting with novice and progressing to expert but with special attention to the transition points between near-expert and expert performance. The Dreyfus and Dreyfus (1980) five-stage model is particularly useful because it highlights specific mental functions associated with the transitions to expert level, which can potentially serve as appropriate targets for expertise training.

Table 1 shows that advancement from competent to proficient is associated with a change in the *recognition* function from decomposed to holistic, which is consistent with research showing that experts typically transition from decontextualized

Table 1 Mental functions at skill levels in Dreyfus and Dreyfus (1980) model

Skill level/mental function	Novice	Competent	Proficient	Expert	Master
Recollection	Non-situational	Situational	Situational	Situational	Situational
Recognition	Decomposed	Decomposed	Holistic	Holistic	Holistic
Decision	Analytical	Analytical	Analytical	Intuitive	Intuitive
Awareness	Monitoring	Monitoring	Monitoring	Monitoring	Absorbed

rule-based reasoning to context-rich instance-based reasoning (Gonzalez, Lerch, & Lebiere, 2003). Advancement from proficient to expert is associated with a change in the *decision* function from analytical to intuitive, which is consistent with research in the area of naturalistic decision-making (Klein & Wright, 2016).

While the model is theoretical rather than empirical, it provides potential starting points in narrowing the range of knowledge and skills that might be targeted for expertise research or training. In the next section, we look more closely at recognition and intuitive decision-making as targets for expertise training.

Mental Functions for Expertise Training

While covering all research addressing expertise is beyond the scope of this chapter, we find it important to the crafting of instruction to address mental functions that are important to training that aims to develop expertise, namely, pattern recognition and intuitive decision-making.

> The situation has provided a cue: This cue has given the expert access to information stored in memory, and the information provides the answer. Intuition is nothing more and nothing less than recognition. (Simon, 1992, as cited in Kahneman & Klein, 2009, p. 520)

The connection between recognition and intuitive decision-making is central to the *Recognition-Primed Decision-Making* (RPD) model, which proposes that experts apprehend a situation and, without conscious effort, a potential solution presents itself. The expert then mentally simulates the solution and, if the simulated outcome is acceptable, executes the solution (Klein, 1998). David Jonassen adapted RPD in his ontology of problem solving as *strategic performance problem solving* (Jonassen, 2011) and described it as a very high form of human cognition that requires extensive experience and training (Jonassen, 2012). However, Fadde (2009b) points to evidence from sports expertise research to argue that the recognition component of RPD is less complex and can be trained in isolation from the full RPD process as a strategy to accelerate expertise.

Training Recognition Skills

Since the early 1980s, sports expertise researchers have investigated pattern recognition in the form of perceptual-cognitive skills that allow expert athletes in many fast-action sports to read cues in the movements of an opponent and thereby anticipate outcomes and make faster responses (Müller & Abernethy, 2012). Meta-analysis has confirmed that perceptual-cognitive skills differentiate expert and less-skilled cricket batsmen, baseball hitters, tennis returners, and goalies in hockey, soccer, and field hockey (Mann, Williams, Ward, & Janelle, 2007). Making the crossover from research to training, methods used to measure perceptual-cognitive skills – especially video-based temporal occlusion – have also been used to train the same skills in intermediate and near-expert performers (Larkin, Mesagno, Spittle, & Berry, 2015).

In a typical video-occlusion task used for research or training purposes, participants or trainees watch a video display of an opponent, such as a tennis server, that shows the view of an on-court contestant. Video clips of opponent serves are cut to black (occluded) at various points before, at, or shortly after racquet-to-ball contact. The participant or trainee identifies the type of serve (e.g., flat, slice, or kick) and predicts the location of the serve (e.g., backhand or forehand side). Input is typically made verbally, by ticking a paper answer sheet, or by finger press or mouse click on a computer screen. Since the video image does not change in response to input by the participant or trainee, video occlusion is not a true simulation (Hubal & Parsons, 2017). Rather, video occlusion is designed specifically to test or train early recognition of serves (or pitches or shots on goal) as an attribute of expert performers (Ward, Williams, & Hancock, 2006).

The targeting of perceptual skills (rather than vision or reaction time) and the development of video-occlusion methods in sport science laboratories demonstrate the expert-performance approach (e.g., Ericsson, 2008) that starts with identifying an aspect of expert performance in natural settings, such as expert tennis players successfully returning 130-mile-per-hour serves. The performance is then reduced to a representative task that can be repeated and measured in controlled conditions. The task is then manipulated (e.g., occluded) to reveal mechanisms of expert performance, such as expert tennis players' use of advance visual cues to circumvent limitations on human reaction time. The assumption, which has been demonstrated in the sports setting (Larkin et al., 2015), is that training the same perceptual skills that differentiate expert performers using the same occlusion methods should improve performance of the full skill and thereby help a near-expert performer reach the next level.

The success of recognition-only training skills in sports has implications for training in other domains that have feature extremely rapid and visually based reactions, such as aviation, military, and law enforcement (Eccles, Ward, Janelle, Woodman, & LeScanff, 2008; Roca & Williams, 2016; Ward et al., 2008) as well as surgical education (Causer, Barach, & Williams, 2014). In many of these domains, authentic case images and video recording may be available for use in expertise training. Indeed, expertise researchers have suggested using case video to train expert-performance skills ranging from medical diagnosis (Ericsson, 2008, 2015) to backing 54-foot semi-tractor trailers (Fadde, 2009c) to sports coaching (Ford, Coughlan, & Williams, 2009).[2]

Obviously, the direct relevance of training perceptual-cognitive skills in sports is limited to other domains that involve fast psychomotor actions. However, it also serves to demonstrate how expertise theories, research findings, and laboratory methods can inspire the design of expertise training methods.

[2] Because few studies have been published that actually implement expertise training, we rely on hypothetical training designs, such as the ones described here, to illustrate the approach.

Training Intuitive Decision-Making and Reflection

Training intuitive decision-making skills is less well established than training recognition skills. It is also more controversial. While intuitive decision-making is increasingly recognized as a valuable component of expertise and expert performance in many domains (Klein & Wright, 2016), it is not always valid or even recommended. Indeed, Kahneman and Klein (2009) debated the merits of intuitive decision-making versus the risk for biases inherent in "trusting your gut" and concluded that intuitive decision-making is real, and valuable, but that it should be trusted (and trained) only in situations that offer regularity – so that patterns can be amassed – along with timely and valid feedback.

Ericsson (2008) maintains that intuitive decision-making relies on automatic cognitive processing that he links with arrested development where further experience makes performers work faster and with minimal or no errors but does not make them advance to higher levels of expertise. Advancing to expert requires deliberate practice that is, by definition, conscious and effortful. Ericsson (2015) suggests that experts' ability to plan, execute, and monitor their own thinking – skills that are associated with reflection and self-regulated learning – are appropriate targets for expertise training. As noted earlier, *Type 2* domains that have a strong culture of experience, such as teaching, also value reflection as an attribute of expert performers. As such, deliberate practice may be better understood and more readily accepted in these domains when it targets reflection in systematic ways that meet criteria as deliberate practice. It may be that, as suggested in the Dreyfus and Dreyfus five-stage model of adult skill acquisition (see Table 1), the mental function of *awareness* continues in a mode of conscious monitoring until the highest stage of master, when awareness changes from monitoring to absorbed awareness that is automatic, but only after years of conscious reflection.

In the final section, we describe four models that can guide ID practitioners in designing expertise training. The models – which have emerged from cognitive psychology, sport science, workplace learning, and naturalistic decision-making – are appropriate for training different expertise skills, including recognition and reflection.

Instructional Design Models for Expertise Training

We describe four models below that adapt expertise research methods for expertise training purposes: (1) expertise-based training, (2) expert-performance-based training, (3) ShadowBox, and (4) integrative pedagogy. These training models highlight different aspect of expertise in various domains.

Expertise-Based Training (XBT)

As depicted in Fig. 2, XBT connects Naturalistic Decision-Making theory, particularly the Recognition-Primed Decision-Making model, with training tasks inspired by expert-novice studies in order to create CBT modules that target perceptual-cognitive skills such as situational awareness and pattern recognition. XBT uses drill-and-practice method to systematically build recognition skills implicitly through repetition with immediate feedback (Fadde, 2009a).

XBT tasks typically present research participants or trainees with still or video images and then prompt one of the interactions that are typical of representative research tasks (Chi, 2006). For example, an XBT task to train radiologists using case file images (as suggested by Ericsson, 2008, 2015) could require trainees to *recall* features from images, *detect* anomalies in images (such as mammograms), *categorize* images (e.g., the type of lesion), or *predict* the outcome (e.g., biopsy found to be malignant or benign). Since the outcome of "old" case images is known, trainees can be given immediate and reliable feedback.

XBT has primarily been applied in sports but is increasingly applied to workplace learning (Johnson & Proctor, 2017) and areas of professional education including teacher education (Sancar-Tokmak, 2016) and nursing education (Razer, 2016). An XBT-based study in nursing education involved nursing students viewing video clips of simulated hospital room patient care in which experienced nurses purposefully engaged in several non-optimal behaviors. Nursing students were tasked with viewing the videos and recognizing errors made by the nurses, filling

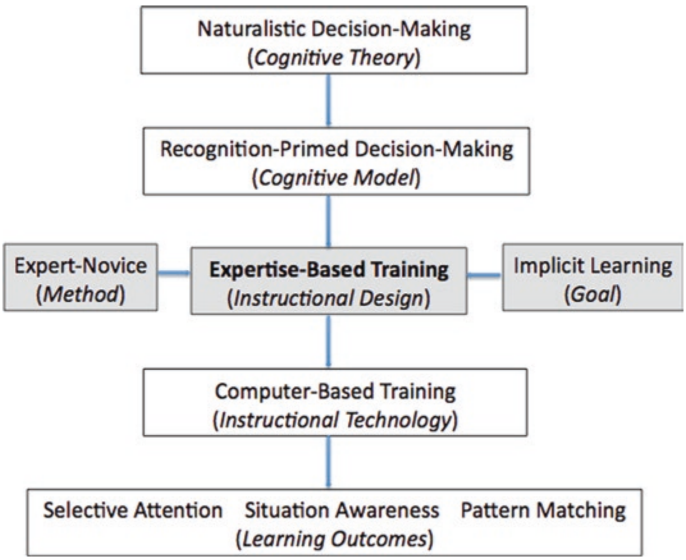


Fig. 2 Theoretical framework of expertise-based training (XBT) to train recognition skills. (Adapted with permission from Fadde, 2013)

out a computer form with their observations, and then checking their observations against the observations of three experienced nursing educators who viewed the same video clips (Razer, 2016).

Expert-Performance-Based Training (ExPerT)

The *expert-performance-based training* (ExPerT) model expands the expert-performance approach to design larger-scale expertise training activities and programs (Ward, Suss, & Basevitch, 2009). As shown in Fig. 3, ExPerT is specifically designed to apply and also extend the expert-performance approach by: (1) identifying expert performers and representative tasks that capture the essence of expert performance in natural settings, (2) devising tasks to study under controlled conditions using process methods such as eye-tracking and think-aloud protocol to identify cognitive mechanisms of expert performance, (3) tracing the developmental history of experts to ascertain when and how they acquired mechanisms of expertise, (4) developing deliberate practice activities based on the representative tasks, and (5) reiteratively assessing training effectiveness and setting new performance goals.

Blair (2016) designed a training program intended to accelerate the expertise of undergraduate peer academic counselors by having the counselors adopt client questioning and observation techniques typically associated with more experienced and professional counselors. Two versions of the expertise training program were designed, implemented in an authentic training context, and compared using quantitative and qualitative methods. One version used the ExPerT framework, and one

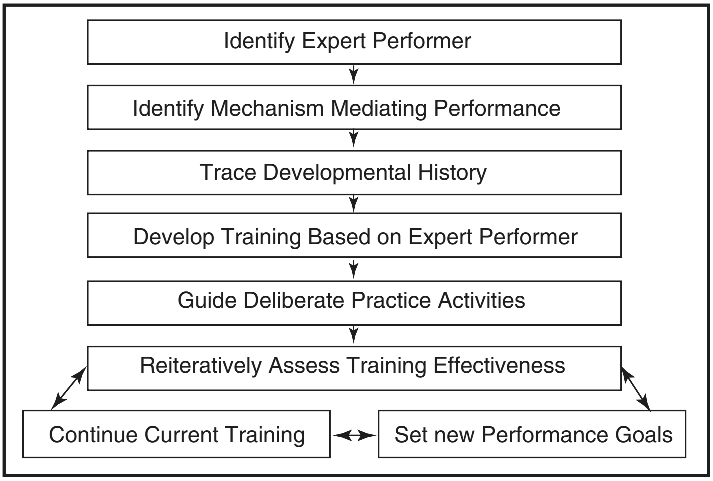


Fig. 3 Conceptual framework of the expert-performance-based training (ExPerT) model. (Adapted with permission from Harris, Eccles, Ward, & Whyte, 2013)

used XBT activities. The ExPerT version involved "live" simulation with experienced peer tutors role-playing student clients, while the XBT version tasked trainees with identifying suboptimal behaviors in videotaped role-plays between experienced peer counselors, one acting as a student client. Both versions were more effective than a control condition consisting of the established direct instruction peer tutoring curriculum. The ExPerT version produced the largest learning effects, albeit with higher instructional investment in the form of "live" role-playing that involved subject matter experts. The recognition-only XBT activities were less effective but, if delivered in CBT form, could be completed as web-based self-instruction. The researcher concluded that both methods have a place in an instructional designer's expertise training toolkit.

ShadowBox

Another approach to capturing and transmitting expert situational thinking is offered by the *ShadowBox* method developed by MacroCognition LLC and based on Klein's RPD model (Klein, 1998). As shown in Fig. 4, the ShadowBox process (MacroCognition, n.d.) starts with identifying training goals and conducting cognitive interviews with experts, similar to a cognitive task analysis process. Rather than generating curricular content, however, input from experts is used to create realistic scenarios. In ShadowBox training, trainees read a scenario, such as a public event security threat, that is presented on paper or computer. The scenario is stopped at various decision points. Trainees are presented with a list of decision options and tasked with prioritizing the options. After making their selections, trainees are shown the priorities made by a panel of experts completing the same scenario. Trainees are prompted to reflect on differences between themselves and the experts. Trainees also can read the experts' rationale for prioritization (Borders, Polander,

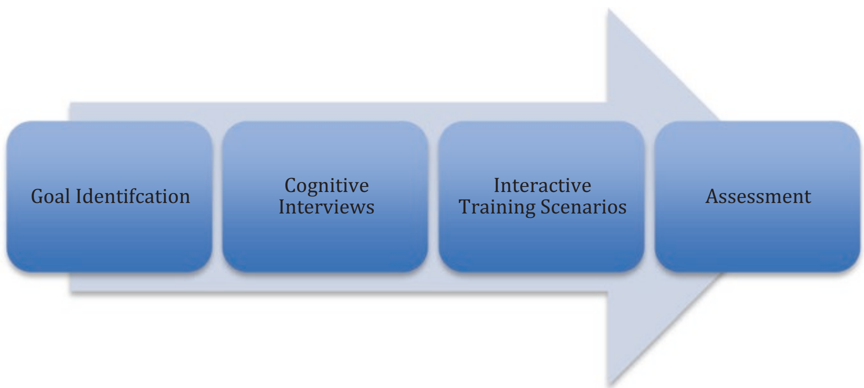


Fig. 4 ShadowBox process. (Adapted from MacroCognition LLC)

Klein, & Wright, 2015). ShadowBox has been employed in military, law enforcement, health care, and social services domains. A ShadowBox program to train Marines in "Good Strangers" interactions with civilians in conflict areas resulted in trainees aligning with experts 28% more than a comparison group (Borders et al., 2015). However, Klein (2015) points out that learning value comes less from matching the experts than from carefully considering the experts' responses. ShadowBox targets recognition, reflection, and intuitive decision-making as cognitive skills associated with higher levels of expertise.

XBT, ExPerT, and ShadowBox provide frameworks for designing expertise training that is engaged in during formal training periods, be they pre-service professional education or in-service professional development. However, in many professional domains, performers' progression from competence toward expertise will occur less through formal training and more through informal learning of tacit knowledge and skills embedded in everyday work (Klein & Hoffman, 1993). While implicit learning is assumed to come with extensive domain-specific experience, however, "mere experience" proves to be a poor predictor of expertise (Ericsson, 2008), suggesting that experiential learning needs to be scaffolded. The last model we describe aims to bridge from formal education to informal workplace learning, in large part through reflection.

Integrative Pedagogy

Reflection on action is widely done as after-action review by teams in military, medical, and business settings. In addition, many teacher education programs promote the *reflective practitioner* (Schön, 1983) as an aspirational disposition. As shown in Fig. 5, reflection is an integral part of the *integrative pedagogy* model

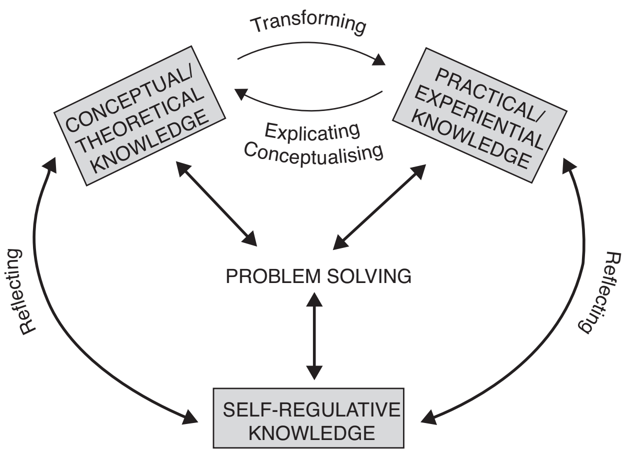


Fig. 5 Integrative pedagogy model. (Adapted with permission from Tynjälä, 2008)

(Tynjälä, 2008) of learning in the workplace that connects formal learning of theoretical knowledge gained in education with experiential knowledge gained at work.

Although the *integrative pedagogy* model is more descriptive than it is proscriptive, it does point out several cognitive activities that cultivate expertise: transforming, explicating, and conceptualizing between theoretical and experiential knowledge in the course of solving problems, along with reflection as a self-regulated learning strategy (Zimmerman, 2006) that can be consciously practiced by in-service professionals. The model provides a framework for overcoming the “arrested development” that can lead to performers remaining at a level of competent performance even after years of domain experience (Ericsson, 2008). Integrative pedagogy is especially appropriate for connecting professional education to professional work.

Professional education typically includes mastering an established body of declarative knowledge and requisite skills through college-based professional education that often leads to certification (Boshuizen, 2004) and an initial stage of professional competence. Whether self-directed by the performer or guided by a coach, progressing to stages beyond competence can be facilitated with a plan that includes reflection on action (Jung, Kim, & Reigeluth, 2015). With experience, some performers master *reflection-in-action* (Schön, 1983) that involves consciously experimenting with new approaches, monitoring situations even while performing, and anticipating outcomes of potential actions. Reflection-in-action shares much with intuitive decision-making and represents a very high level of expertise.

The expert training models described above are not comprehensive or definitive but rather demonstrate that specific elements of expert performance, such as recognition and reflection, can systematically be trained in ways that are inspired and guided by the deliberate practice framework and the expert-performance approach from modern expertise studies. Below we provide an example that uses the models to design expertise training in the context of classroom teaching (Fadde & Sullivan, 2013).

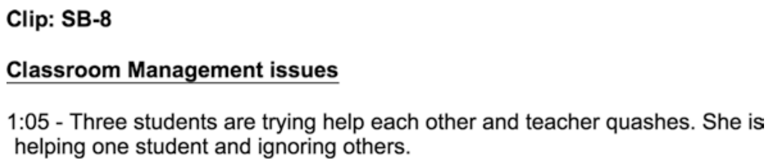
Example: Training Classroom Noticing Via Video

The participants in the study were preservice teachers who were near the end of the introductory course to a two-year Teacher Education Program (TEP). The course had covered several aspects of teacher-student interaction, including *classroom management* and *student questioning* to ascertain students’ cognitive processes. Both topics included instruction on strategies for teachers to apply in various classroom management and student questioning situations. Teacher expertise research shows that experienced teachers are able to observe student behaviors and consider if, when, and how to apply strategies *while* delivering a lesson (Feldon, 2007). Novice teachers, however, are not able to observe, consider strategies, and deliver a lesson at the same time. Satisfying the first step of the ExPerT model, the ability to observe and consider while teaching represented a reliably reproducible superior performance of experienced teachers in the natural classroom setting. It is a combination of recognition and reflection-in-action skills.

Once identified, the target expert skill was theorized as *classroom noticing* (Rosaen, Lundeberg, Cooper, Fritzen, & Terpstra, 2008; Sherin & van Es, 2005). A representative task was devised using "old" case video of student teachers delivering lessons. The videos contained instances of classroom management and student questioning. A representative task then was structured so that it could be repeated in a controlled setting (step 2 of ExPerT). The videos were edited into 1–2-minute segments to facilitate timely feedback and repeated trials – both elements of deliberate practice. The video segments were not chosen to demonstrate particular behaviors but rather to depict routine classroom activity.

The students in the TEP class were tasked with watching for examples of either classroom management or student questioning behaviors by the classroom teacher. Since not all videos contained target behaviors, students needed to *detect* (an XBT task) target behaviors. They then needed to *categorize* (a second XBT task) behaviors as classroom management or student questioning. Students watched the video clips on a computer monitor in a computer lab. They typed their observations into an on-screen form (see Fig. 6). Once the form was submitted, the student was shown a similar form that contained the observations made by two experienced teacher educators when they viewed the same video clip (a repurposing of the expert-novice research paradigm). Students were instructed to compare their observations with those of the experts and to reflect on differences between what they noticed and what the experts noticed. Students, who had been instructed to try to match the experts, then selected the next video clip and repeated the observe/align/reflect process.

In this task, students were not asked to choose a classroom management or student questioning strategy, consistent with the XBT focus on recognition-only training that minimizes cognitive load (van Gog, Ericsson, Rikers, & Paas, 2005). Applying the ExPerT model, with iterative rounds of assessment and recalibration, would entail showing more challenging classroom videos or adding strategy selection tasks. A ShadowBox approach might show students a number of strategy options and ask them to rate or rank the options before showing them the experts' ratings or rankings. When these pre-service teachers reach student teaching, then they can apply the integrative pedagogy model to tie theoretical knowledge gained in the TEP to practical knowledge gained in the classroom. If a substantial amount of deliberate practice, such as the noticing activity, were completed during their time in the TEP, the preservice teachers would be positioned to take self-regulated



Clip: SB-8

Classroom Management issues

1:05 - Three students are trying help each other and teacher quashes. She is helping one student and ignoring others.

Fig. 6 Student observation entered in classroom noticing activity learning strategies and reflection as a habit of mind into their professional careers, thereby amplifying their critical early-career experience.

Conclusions

As with Learning Sciences (Lin & Spector, 2017) and Human Performance Improvement (Foshay et al., 2013), instructional design gains from exploring shared ground between ID and expertise studies (Lajoie, 2003). Teachers, trainers, and ID professionals, along with faculty in professional education programs, are able to facilitate the development of expertise and expert performance through instructional design and technology. To further bridge expertise studies to expertise training, expertise training research needs to move beyond short-form projects that demonstrate feasibility and onto transactional theory-to-practice research (Ericsson & Williams, 2007) that embeds longer-form training programs in authentic contexts and analyzes process and outcome results using mixed quantitative and qualitative measures (e.g., Fadde, 2016).

As shown in Fig. 7, typical and accelerated trajectories to expertise may end up at a similar level of achievement. However, individual performers, along with their

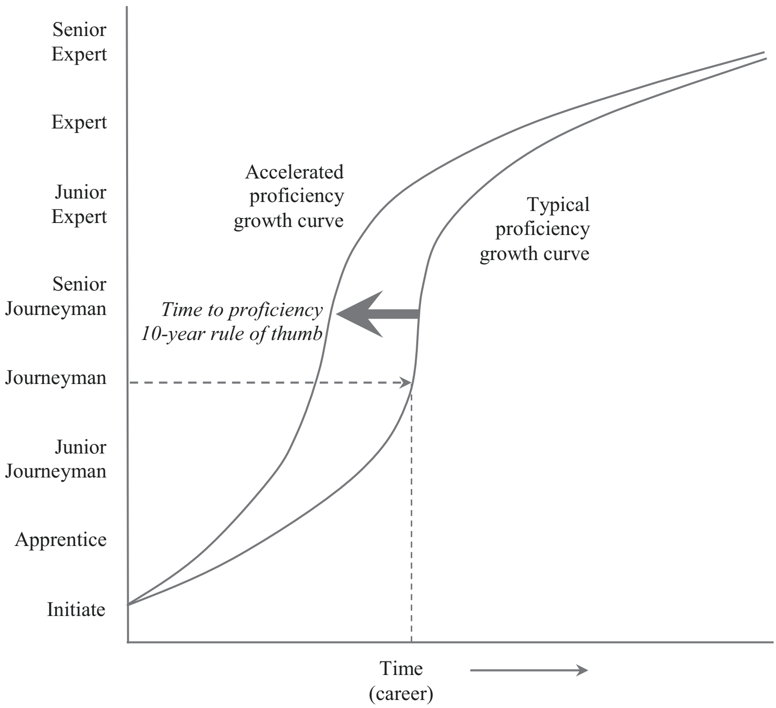


Fig. 7 "S" curve of expertise. (Adapted with permission from Hoffman et al., 2014)

customers, students, and patients, all benefit from performers reaching expert stages earlier in their careers and thereby amplifying their productive output. Although expertise and expert performance are considered to be highly domain specific (Ericsson, 2006), it may be that expert learning (Williams, Fawver, & Hodges, 2017) is the shared road to excellence and the role of ID researchers and practitioners is to provide the "expertise to make expertise" (Bransford & Schwartz, 2009, p. 432).

In line with this volume's applied focus, we conclude by offering several suggestions for designing expertise training:

- Start working on pieces of expertise early: Performers don't need to be proficient, or even competent, to start working on a "piece of expertise" such as classroom noticing.
- Devise deliberate practice activities that are guided by a coach (including a self-coach), target specific subskills to improve performance, require concentrated effort, and provide timely feedback with opportunities to repeat and refine skills.
- Resist unnecessary realism in simulations: Part-task training of recognition skills can be efficient as well as effective.
- Locate academic research or conduct informal research in a domain of interest to ascertain how experts are defined and what they do differently.
- Leverage workplace events for reflection, individually and as a team – before, during, and after work events.
- Use problem-centered, problem-solving, scenario-based, and other task-based instruction methods during formal education, especially professional education.
- Design content and activities based on what experts actually think and do (e.g., cognitive task analysis) rather than what they, or others, say they should do.
- Design representative tasks to practice recall, detection, categorization, or prediction.
- Appreciate the wonder of expert performance, wherever it is encountered.

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Enhancing Knowledge Transfer

Nina Bonderup Dohn, Lina Markauskaite, and Roland Hachmann

Introduction

Fundamentally, transfer concerns a person or group putting something that has been learned in one context to use in another. This basic notion cuts across more specific conceptualizations of what the "something" is and of what is involved in its "move" between contexts. These more specific questions have been debated within educational research for over a century (Tuomi-Gröhn & Engeström, 2003, Carraher & Schliemann, 2002). They comprise further questions, e.g., how transfer is achieved and whether it is achieved differently for different types of knowledge. Over the last decades, the need to answer these questions has been accentuated by societal developments such as globalization and rapid technological progress. Diversity and frequent change of learning and work settings increasingly require people to traverse between contexts and therefore to put their knowledge to use in new ones. In response, a recent focus at both policy and practice level has become so-called transferable skills: communication, team working, problem-solving, organization skills, etc. (OECD, 2010; Princeton Career Services, n.d.; University of Cambridge, n.d.). Still, it is an open question whether such skills really exist and, if yes, which type(s) of knowledge they are constituted by or, if no, whether the problem of

N. B. Dohn (✉) · R. Hachmann
Department of Design and Communication, University of Southern Denmark, Kolding, Denmark
e-mail: nina@sdu.dk; roh@sdu.dk; http://www.sdu.dk/ansat/nina.aspx; http://designs4learning.dk/

L. Markauskaite
Sydney School of Education and Social Work, The University of Sydney, Sydney, NSW, Australia
e-mail: Lina.Markauskaite@sydney.edu.au; http://sydney.edu.au/education_social_work/about/staff/profiles/lina.markauskaite.php

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transfer has been circumvented by dubbing – that is, whether situation-specific processes have been named "transferable" without analyzing what would be required for their re-embedding in other situations and without evidence for their actual reusability.

Educational research and practice is thus challenged to investigate transfer and to design for enhancing its occurrence. Educational technology – understood broadly as information and communication technology designed to support teaching and learning – appears able to play an important role in meeting this challenge. For example, mobile educational technology is characterized by portability across contexts and by spatial and temporal flexibility of use. These characteristics may help diminish the significance of a spatiotemporal separation of contexts. Another promising characteristic is the potential for multisensory stimulation. This may enhance learners' opportunities for recalling knowledge and for identifying ways of making it relevant to new situations.

The problem statement for this chapter reads: *How can design for learning with technology facilitate knowledge transfer from educational to non-educational contexts?*

We start our chapter with a review of five major theoretical approaches to transfer. For each of them, we explicate which types of knowledge they primarily focus on. We follow Markauskaite and Goodyear (2017) and Dohn (2017) in distinguishing between three knowledge types. *Declarative knowledge* is knowledge expressible in propositional statements, often also termed propositional knowledge or know-that (e.g., "President Donald Trump was inaugurated on 20.01.2017," "Karl Marx wrote *Capital*," "Force = Mass × Acceleration"). *Procedural knowledge* is often called practical knowledge, skill, or know-how (e.g., riding a bicycle, performing surgery, carrying out a logical deduction). *Relational knowledge*, comprising experiential and contextual knowledge, sometimes just called experiential knowledge, knowledge-by-acquaintance, or know-of (e.g., knowing what kangaroo tastes like, what red looks like, and how local, cultural norms delimit what it is appropriate to say in a given context). Next, we identify four strategies for utilizing educational technologies to enhance transfer. This allows us to present examples of paradigmatic learning designs representing each of the theoretical approaches and to link them to the different strategies for technology use. We also discuss the sustainability and scalability of the learning designs.

Approaches to Transfer

The following five approaches represent different conceptualizations of what it is that transfers between situations and what is involved in the "move." Despite theoretical disagreements, the approaches are not mutually exclusive in practice. Instead, they emphasize different aspects to take into consideration when designing for transfer.

Behaviorist Approach

The behaviorist approach understands transfer as retention of knowledge across situations. It is primarily concerned with declarative and procedural knowledge and focuses on training the learner to respond with specific behavior to specific stimuli. A basic teaching strategy is therefore partitioning learning objectives into small, incremental units. Transfer between situations can happen when *identical elements* are present in the two situations (Thorndike & Woodworth, 1901). For instance, for practicing drivers to train maneuvering on icy roads, the test track should present skid conditions identical to the ones of icy roads. The drivers then learn to react in a specific way to the skid stimuli. When later stimulated by identical skid conditions of real roads, this reaction (procedural knowledge) can be recalled and transferred. However, identical elements need to be recognized by the learner. This presupposes *memory* (for retention of elements encountered) and *attention* and *judgment* (for recognition of the new elements as identical to the previously encountered ones) (Thorndike & Woodworth, 1901; Thorndike, 1913). Thus, the presence of mental phenomena and their role in successful transfer is acknowledged to some extent, but the main focus is the conditions of training and performance situations (Blume, Ford, Baldwin & Huang, 2010).

On the behaviorist view, so-called transferable skills will be mainly procedural skills. They will be transferable if identical elements are present in training and performance situations and if training is undertaken specifically with these identical elements. This may be the case for some problem-solving skills that are based on well-articulated step-by-step procedures. It is dubious whether other "transferable skills" such as communication, organization, and teamworking can be analyzed into sufficiently small stable units for them to be trained behavioristically.

Cognitive Approach

The cognitive approach can be viewed as a response to the behaviorist approach's external focus and limited attention to the mental processing: more important than external stimuli, the argument goes, are the cognitive procedures which the learner uses to deal with such stimuli. Hence, the cognitive approach focuses on *internal processing*. Transfer is seen as *generalization of principles* (Judd, 1908) into *cognitive schemas* that may be put to use in situations *differing* in their specific surface elements. Examples of cognitive schemas include the argumentation structures of Aristotelian classical logic; grammatical structures common across different languages; and classification schemes of class, order, family, genus, and species. Identity of elements between training and performance situations is not an essential precondition of transfer according to the cognitive view. Instead, transfer builds on the development of abstract cognitive schemas that generalize essential structures of a task. Such schemas are then applied to new situations through analogical mappings where tasks in the two situations are recognized as sharing structure (Thorndyke & Roth, 1979; Gick & Holyoak, 1983; Reed, 1993). Following this view, Nokes (2009) proposes that retention across contexts of abstract knowledge and of patterns of behavior is due to multiple cognitive procedures that interact with each other. The cognitive procedures involved are:

- *Analogy* (Gentner, 1983; Gentner et al., 2001), where the learner maps a current problem to a previously encountered one and draws an inference relevant to the current problem. A classic example is mapping electric current and voltage to water current and drop in a stream and drawing inferences about the relationship between current and voltage on this basis.
- *Knowledge compilation* (Anderson, 1987; Singley & Anderson, 1989), where the learner translates prior declarative knowledge into procedural knowledge and compilates the latter into rules. An example is translation of the textbook knowledge of traffic signs into procedural knowledge of driving in accordance with the traffic regulations.
- *Constraint violation* (Ohlsson & Rees, 1991) where a proposed solution to a problem is evaluated against prior knowledge of domain constraints. For example, the mathematical solution to second-order motion problems in physics (identifying a length) often provides both a positive and a negative value option. Students discard the latter, as length cannot be negative.

Overall, the cognitive approach conceptualizes transfer as retention of schemas across situations of use. It is primarily concerned with declarative knowledge (as schemas can potentially be declaratively expressed) and secondarily with the procedural knowledge of applying the cognitive schemas in a particular situation. So-called transferable skills will be actually transferable if they are learned through abstraction from the particulars of the learning situation to form generic schemas for problem-solving, communication, organization, teamworking, etc. This understanding seems implicit in much contemporary talk about learning transferable skills at both policy and practice levels (cf. references above). As discussed in the next section on the situated cognition approach, it is an open question whether these skills really consist in generalized procedural knowledge, abstracted from concrete situations.

Situated Cognition Approach

There has been widespread criticism of behaviorist and cognitive approaches to transfer for their view of knowledge as decontextualized (Lave, 1988; Brown, Collins & Duguid, 1989; Greeno, 1997, Carraher & Schliemann 2002; Lobato, Ellis & Munoz, 2003). The basic argument is that they overlook the significance of *relational knowledge*, i.e., the contribution of both subjective experience and contextual factors at a given time in a given situation. Knowledge is *situated* and gets specific content from the situation. For example, what constitutes the best buy in a supermarket is not necessarily the largest quantity of the best quality for the least money (though, notably, this would be the situated solution of a school assignment). It will depend on personal taste, keeping qualities, storage capacity at home, car space for transport, etc. Making use of knowledge requires one to take this *situativity* into account. For this reason, situated cognition tends to focus on *acts of knowing*, rather than on knowledge (Greeno, 1997), i.e., on the *process* of letting knowledge be specified in accordance with situational demands and possibilities. Radical situative views question the meaningfulness of the concept of transfer itself, claiming that knowledge is distributed between the mind, activity, and environment in such “acts of knowing” (Lave, 1988). Less radical views acknowledge the existence of transfer and take the situated nature of knowledge into account. For example, Lobato, Rhodehamel, and Hohensee (2012) present an *actor-oriented* view concerned with the way individuals make sense of their learning experiences. The focus is on how learners in practice generalize their learning experiences and transfer these generalizations to new tasks. The generalizations are sometimes highly idiosyncratic and would be characterized as wrong on the cognitive approach.

A similar conceptualization of transfer is found in the notion of “epistemic games” (Collins & Ferguson, 1993; Morrison & Collins, 1996; Perkins, 1997). Proponents suggest that certain kinds of higher-order or generic knowledge, if suitably linked with content and context of knowing, can play an important role in thinking beyond specific situations. When people engage in various knowledge-generating activities, they use particular strategies to guide their thinking: scientists conduct scientific experiments to test their hypothesis; lawyers construct legal arguments to present a case in court; politicians engage in particular kinds of a political debate to convince their voters. In all these examples, people’s thinking strategies follow particular sets of rules and moves that are recognizable within the respective cultures of scientists, lawyers, and politicians and transfer between situations. Learning the thinking strategies is inseparable from situated experiences of playing the epistemic game within the particular epistemic community.

Transfer, on these moderate views, is not the mere move of knowledge from one situation to another, but a fine-tuned situated specification. Further, it is not understood primarily as retention of knowledge. Instead, it is viewed as the transformation of procedures and experiences from earlier situations, in accordance with the situational demands and possibilities of the present one. The situated cognition approach focuses on procedural and relational knowledge, while declarative knowledge often is conceptualized through these other knowledge types. For instance, it is argued that the concepts involved in declarative knowledge are “filled out” with subjective experiences and contextual meanings. From this perspective, so-called transferable skills are therefore not transferable per se, but only to the extent that procedural knowledge is transformed through integration with relational knowledge in response to the concrete situation.

Participationist Approach

The participationist approach springs from the situated cognition approach, and there is no sharp divide between them. Some theorists, such as Greeno (1997, 2011), belong to both approaches. However, there are variances in focus between the two approaches, and these variances bear out as differences in the recommendations they provide for designing for transfer. The situated cognition view takes the individual as outset. It focuses on that person's cognition as situated and on the transformation of knowledge across contexts in accordance with situational demands and possibilities. In contrast, the participationist approach does not take the individual as a separate unit of analysis, but the whole social practice in which the individual participates (Sfard, 1998; Lave & Wenger, 1991; Dohn, 2016). Further, knowledge is understood, not so much as cognition enabling participation, but as the participation itself in the activities valued by the social practice (Wenger, 1998). Learning math on this view is less about cognitive grasp of mathematical concepts and more about learning to participate in socially constituted math practices (Sfard, 2008).

Radical views within this approach deny the meaningfulness of transfer on the grounds that participation is confined to a given practice. It centers on concrete social negotiation of the roles and opportunities which each person can take up in that practice (Packer 2001; cf. also Sfard, 1998). Less radical views argue that patterns of participation may develop in the social practice. Some students may, for example, tend to take the lead and others to follow. Further, participation concerns given curricular domains, so the patterns of participation will concern ways of engaging with content: e.g., discussing what algorithms mean or copying others' use of them. Over time, patterns of participation may develop into dispositions for the individual to engage in learning opportunities in certain ways (e.g., as leader of arguments) (Dohn, 2016; Gresalfi, 2009). Transfer, on this view, concerns patterns of participation and how the individual's disposition to engage can be actualized in new ways in the different social conditions pertaining to new situations.

Engle, Nguyen, and Mendelson (2011) have investigated how *bonded and expansive framing of social learning contexts* (Engle, 2006) influence transfer. Framing here refers to the way a given situation is characterized as relevant by the teacher. It is effected (often implicitly) through marking out *setting* (when, where, and who), *topic* (what), intellectual *roles* (how), and the relevance of *time, place, people, and activities*. Bonded framing firmly links relevance of the learning activities to the current situation. Expansive framing extends their relevance beyond the specific learning context to future contexts of use. The research of Engle et al. shows that expansive framing has a positive effect on students' abilities to participate in related activities in new situations. That is, it helps them effect transformation of participation between contexts.

The focus within the participationist approach is on relational knowledge, because knowledge is understood as participation within given contexts, and to some extent on procedural knowledge. The existence of "transferable skills" is rejected, if understood as abstractions from concrete participation situations. Their existence is accepted, if viewed as patterns of participation and dispositions to engage, but it is stressed that actual transfer always depends on the participation possibilities in the specific performance situation.

Developmental Practices Approach

Newer research broadens the concept of transfer. The developmental practices approach, like the participationist approach, takes the social practice as unit of analysis. However, rather than look at patterns of participation within the practice, it focuses on how a social practice develops in interaction with other social practices when dealing with issues which cut across them. For example, health care of a child with a chronic disease involves the social practices of family, local medical center, and hospital wards. Appropriate care for the child will require these social practices to interact (Engeström, 2001). Three points are highlighted: (1) situations for transfer are not predetermined but arise out of need, (2) transfer concerns the finding of appropriate solutions to current, specific problems, and (3) the movement from a solution to concrete action is implemented and consolidated through the transfer process, locally to a specific practice and across time and space to other social practices.

A prominent example of this approach is *expansive learning* (Engeström, 2001, 2015) which terms social practices *activity systems*. Transfer is investigated as taking place in collective activity systems comprising more than one social practice (e.g., two organizational units or school and workplace) (Tuomi-Gröhn, 2007). Transfer is achieved through *boundary crossing* between the activity systems and in collective *object-oriented activity*, i.e., activity aimed at the issue at stake across the activity systems (e.g., the health care of chronically ill children). In such activity, new meanings and knowledge specific to the issue at hand are constructed that take their outset in the initial understandings and procedures of each activity system, but go beyond them (resulting, e.g., in new ways of conceptualizing and planning children's health care as a joint task). Transfer is thus a process of *transformation*: initial understandings and procedures of one activity system are transformed in negotiation with the initial understandings and procedures of other activity systems into new collective understandings and procedures. Construction of mediating artifacts (such as a "health plan" for chronically ill children) plays a significant role in achieving the transformation.

Expansive learning acknowledges that all collectives are constituted by individuals and that an activity system's learning is intertwined with individual learning. Nonetheless, its primary interest is learning and transfer that take place between activity systems, rather than between or within the individuals who constitute them. A more moderate position adopts a similar object-oriented view, where transfer is viewed as transformation of understandings and procedures across activity systems, but where focus is on individual learning as part of collective learning (Markauskaite & Goodyear, 2017; Moen, Mørch, & Paavola, 2012; Scardamalia & Bereiter, 2014).

From this perspective, the main goal of education is to develop students' capacities for transfer: this will support them in solving complex ill-structured problems that emerge on the boundaries of several activity systems (e.g., two organizational units). Object-oriented activity in collaboration with others, involving boundary crossing and knowledge creation, is a primary means for developing such capacities. Again, jointly creating new knowledge objects or artifacts (e.g., conceptual solutions of problems or designs of innovative products) plays an important part.

The focus within the developmental practices approach is on procedural and relational knowledge, which are viewed as characteristics of social practices, more than of individuals. So-called transferable skills are viewed as propensity to engage in object-oriented activity and boundary crossing. It is stressed, though, that the term "skills" wrongly construes this propensity as an individual matter rather than as a characteristic of social practices.

Main Strategies for Enhancing Transfer with Technology

Enhancing transfer from educational to non-educational contexts is fundamentally about facilitating learners in putting to use what they have learned within an educational context in situations outside it. From this perspective, and across the different approaches presented above, there are four main strategies for utilizing technology to enhance transfer. These four strategies correspond to four basic ways of engaging non-educational contexts from within educational ones:

(a) *Coupling educational and non-educational contexts.* This strategy focuses on creating direct links between the contexts and on coupling persons, content, and activities across them. This may be done through activities that bridge the contexts, by utilizing content from one type of context in the other, and by requiring learners to move back and forth between them. Illustrative examples are practicum periods, internships, and school projects undertaken with external partners such as libraries, firms, or local authorities. Within this strategy, *the role for technology is to enable and/or strengthen the coupling* between the contexts. Providing an online repository of curricular knowledge resources to be drawn upon during practicum is one example. Another example is asking students to develop an annotated video blog of internship episodes which can later be drawn upon in discussions within the educational setting. A third example is a blended online workspace where both students and external partners participate in their joint project.

(b) *Creating a separate educational context of training or reflection*. This strategy does not engage non-educational contexts directly. Rather, it aims to further learners' future transfer to such contexts through enhancing their development of the knowledge, skills, and understanding necessary in such contexts. This is done through providing a separate space where learners can train their skills, stimulate knowledge retention, and/or reflect on requirements of non-educational practice. *The role of technology is to supply this separate context, in the form of virtual spaces for training or reflection*. Examples of *training spaces* are interactive stand-alone computer programs for developing skills in reading, math, logical reasoning, or a foreign language. Examples of *reflection spaces* are discussion for a where students are asked to reflect on the demands which work practice will place on their skills and knowledge learned in the educational context.

(c) *Simulating a non-educational context within an educational one*. This strategy aims at “drawing in” the non-educational context within the educational one, not only training specific skills or reflecting on their use but simulating, e.g., a work practice as a whole and the learner’s participation in it. *The role of technology is to facilitate the simulation, either fully or partially*. Examples of full facilitation are computer-based simulation programs, online worlds, or virtual reality applications, where the full practice is simulated through technological tools. Partial facilitation occurs when technology is used to supplement simulation in physical space, for instance, when learners utilize the technological tools of a given work practice in their role-play of this practice.

(d) *Introducing an educational context within a non-educational one*. This strategy involves creating an educational setting within the non-educational one, typically through providing access to a course within the work setting. *Technology may facilitate the course partially or fully*. In full facilitation, the whole course takes place on or via the computer. One type is the stand-alone computer program. Another type is an online learning platform with learning resources and synchronous or asynchronous communication between teachers and other learners. Partial facilitation will draw on activities taking place between course sessions. These activities will often be authentic work tasks carried out as course assignments within the work setting and fed back to the course as examples for reflection or other course activities. Transfer is thus supported through work tasks which serve as anchor points for transferring, transforming, and integrating educational and non-educational content.

Figure 1 illustrates the four basic ways of connecting non-educational contexts with educational ones. In practical course design, these ways are often combined, e.g., at different stages of a course. Table 1 shows how these strategies are aligned to the different transfer approaches, along with the key features of each approach, the types of knowledge they focus on, and paradigmatic examples of learning designs (see section on Paradigmatic Learning Designs for Facilitating Transfer).

Paradigmatic Learning Designs for Facilitating Transfer

As the approaches to transfer are not mutually exclusive, learning designs for enhancing transfer sometimes draw on more than one approach. For example, instructional design (Briggs, Gustafson, & Tillman, 1991; Gagné, Wager, Golas, &

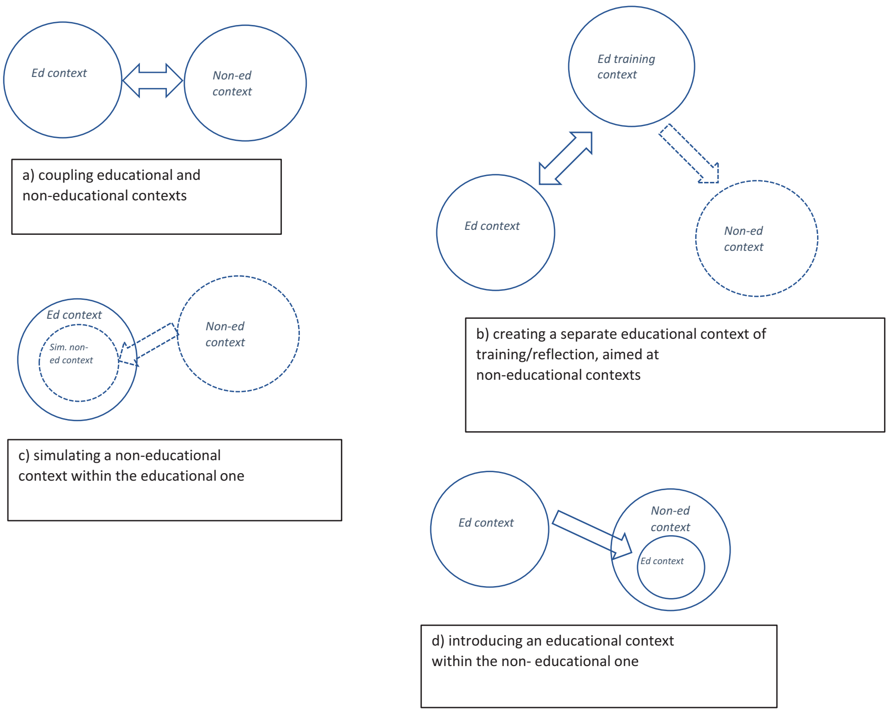

Fig. 1 Four basic ways of engaging non-educational contexts from within educational ones. The dashed arrows and contexts indicate that the context in question is not actually present, but is intended or simulated

Keller, 2005) originates in the behaviorist approach and in particular in its strategy of partitioning learning objectives into small, incremental units. In later years, it has been supplemented with cognitive explanations for why this strategy works: because incrementally checking learners' understanding of small units helps ensure that the correct mental schemas are built. Similarly, further design guidelines inspired by the cognitive approach have been added to help learners assemble the incrementally learned units into correct, larger schemas. In this section, we present five designs which, for their overall traits, are paradigmatic for each of the transfer approaches discussed in the section Approaches to Transfer, though their details may reflect other approaches. All the learning designs have been empirically investigated and corroborated in various studies.

Table 1 The key features of the different transfer approaches and their preferred strategies for enhancing transfer of specific kinds of knowledge through the use of technology

Approach	Key features	Types of knowledge	Preferred strategies for enhancing transfer	Paradigmatic example of learning design
Behaviorist approach	Transfer results from elements in tasks or environments stimulating specific recalls of knowledge and behavior through similarities between learning and performance situations	Declarative knowledge Procedural knowledge	Coupling educational and non-educational contexts (a)∗ Creating a separate context of training (b)	Transfer through computer-based skills training
Cognitive approach	Transfer results from abstraction of essential features and mapping onto new situations on the basis of shared structures	Declarative knowledge (primarily) Procedural knowledge (secondarily)	Coupling educational and non-educational contexts (a) Creating a separate context of training (b)	Model-based learning for transfer
Situated cognition	Transfer is the transformation of procedures and experiences from earlier situations, in accordance with the situational demands and possibilities	Procedural knowledge Relational knowledge	Simulating a non-educational context within the educational one (c) Introducing an educational context within the non-educational one (d)	Transfer by playing epistemic games
Participationist approach	Transfer happens through participation in social contexts where previous patterns of participation can be resituated	Relational knowledge Procedural knowledge	Coupling educational and non-educational contexts (a) Simulating a non-educational context within the educational one (c) Introducing an educational context within the non-educational one (d)	Transfer through mediational practices
Developmental practices approach	Transfer happens through boundary crossing between social practices, resulting in transformation of understandings and procedures	Procedural knowledge Relational knowledge	Introducing an educational context within the non-educational one (d)	Transfer as knowledge co-creation

Notation: ∗ – this letter refers to the transfer strategy in Fig. 1

Behaviorist Approach: Transfer Through Computer-Based Skills Training

Designing for transfer within the behaviorist approach focuses on constructing a training situation which has task conditions identical to the ones in future use situations (Grierson, 2014). The training situation can be provided using technology in various ways, ranging from specific task training over 2D and 3D computer programs to virtual reality simulations. The aim is *functional task alignment* between learning and use situation (Hamstra, Brydges, Hatala, Zendejas, & Cook, 2014). High fidelity, understood as physical faithfulness of the training situation to the use situation, is not necessarily favorable as too many irrelevant details may be present (Grierson, 2014; Hamstra et al., 2014; Norman, Dore, & Grierson, 2012). Only relevant identical elements should be reproduced in the training situation as it is important that the learner focus on precisely these elements. Psychological fidelity, understood as faithfulness of the actual specific behavior required in the training situation, appears of some significance (Norman et al., 2012). Therefore, designs for transfer build on four main principles: (1) The training task must include as many elements as possible that are necessary for task performance in the future use situation. (2) Irrelevant or unnecessary identical elements should be avoided. (3) The learner should actively engage with the relevant identical elements. (4) Psychological fidelity should be strived for.

Learning designs focused on computer-based skills training are used widely within aviation and health-care education (Cook et al., 2011; Petty & Barbosa, 2016; Rehmann, Mitman, & Reynolds, 1995; Ventre & Schwid, 2013). They are used both for initial training and for subsequent knowledge and skills retention to alleviate documented problems of "knowledge … decay[ing] quickly following formal classroom training" (Ventre & Schwid, 2013, p. 195). Relatively low-fidelity examples in the cited references include cockpit familiarization programs (e.g., a boom simulator to practice aerial refueling operations) and 2D multimodal desktop programs (video, pictures, sound, text) to practice recognition, diagnosis, and treatment of medical conditions (e.g., cardiac rhythm disturbances). An example of a high-fidelity training program is a full-motion weapon systems trainer involving an entire aircrew. From the behaviorist perspective, such training systems have three main advantages over actual practice situations as concerns preparing learners for future use situations (Grierson, 2014). Firstly, training programs are not contingent on the situations that happen to occur in practice. A range of tasks can be constructed, and the knowledge and skills involved in solving them can be practiced several times. This allows learners to become well acquainted with relevant identical task elements that they might not encounter in actual practice during the time of their training. Secondly, training programs allow the learners to experiment with different actions, including wrong ones, to identify their various outcomes. This supports the learners in discriminating between elements in the training situation. This will again enhance the probability of recognition of identical elements in future use situations and will thus support transfer. A third advantage is that computer-based training programs may be used by learners on their own, allowing them to learn at their own pace and with as many reiterations of tasks as they need for retention of knowledge and skills.

In a meta-analysis of computerized virtual patients, Cook, Erwin, and Triola (2010) found large positive effects in comparison with no intervention: a pooled effect size (95% confidence interval) of 0.94 for knowledge outcomes ($N = 11$), 0.80 for clinical reasoning ($N = 5$), and 0.90 for other skills ($N = 9$). More specifically, in a randomized, double-blinded study with 16 surgical residents learning technical operation skills, Seymour et al. (2002) found large transfer effects from virtual reality (VR) training to the operation room: VR-trained residents performed gallbladder dissection 29% faster and with five times less likelihood of injuring the gallbladder than non-VR-trained residents. However, the meta-analysis of Cook et al. (2010) also showed that, in comparison with other forms of instruction, pooled effect sizes were small: 0.06 for knowledge ($N = 5$), −0.004 for clinical reasoning ($N = 10$), and 0.10 for other skills ($N = 11$). Training programs are more effective if combined with instruction (Strandbygaard et al., 2013) and integrated in the curriculum (Issenberg, McGaghie, Petrusa, Lee, & Scalese, 2005). Thus, learning through training programs is not in general self-sustainable, though transfer based on self-study does appear possible (Petty & Barbosa, 2016). This limits the scalability of computer-based skills training, understood as the number of students who can learn effectively at the same time utilizing the learning design. Further limits come from the cost of computer programs living up to the design principles.

Learning designs utilizing computer-based training programs mainly draw on strategy (b) for engaging non-educational contexts from within educational contexts, i.e., enhancing transfer through setting up a separate educational context (the computer program) in which students may reinforce their knowledge and skills (see section on Main Strategies for Enhancing Transfer with Technology).

Cognitive Approach: Model-Based Learning for Transfer

On the cognitive approach, successful transfer relies on students' well-constructed mental schemas that represent the structural features of a given problem. Conversely, if students base their problem representation on surface features or abstract incorrectly from a single case, they will fail to transfer procedural problem-solving knowledge between structurally identical problems. *Model-based learning* is a canonical learning design aimed at helping students correctly abstract and represent the structural features of given problems (Jonassen, 2011). That is, it supports them in building correct *mental models* of problem domains and in transferring procedural problem-solving skills between problems based on these mental models (Ifenthaler & Seel, 2013; Pirnay-Dummer, Ifenthaler, & Seel, 2012).

Model-based learning is supported by computer programs providing learners with possibilities to engage with diverse representations of problems that share structural features. One example is the principle of competitive specialization in complex systems, which may be used to model both the functional specialization of visual cortex neurons and oil companies' specialization in different oil reserves. Students working with these problems might initially classify them as biological and economic phenomena, respectively. Letting them construct and explore computational models of the phenomena supports them in realizing the structural similarities beneath the diverging surface features (Goldstone & Wilensky, 2008). Goldstone and Wilensky stress that it is crucial for supporting transfer that students interact with the simulations and actively interpret them: "It is difficult for anybody to spontaneously see events as manifesting mathematical formalism…It is far more plausible for transfer to proceed by someone applying previously learned methods of interpreting events" (p. 492).

More specifically, empirical studies corroborate that computer models can support correct abstraction and development of declarative knowledge, as well as more transferable problem-solving skills (Jacobson, Markauskaite, Portolese, Kapur, Lai, & Roberts, 2017; Kelly, Jacobson, Markauskaite, & Southavilay, 2012). However, the results show that learning gains also depend on the design of instruction and teacher facilitation. For example, Jacobson et al.'s (2017) study demonstrated that ninth grade students' learning about complex systems ideas led to increased problem-solving scores, but only if the use of computer models was coupled with exploratory pedagogical strategies and not direct instruction ($F(1,106) = 4.144$, $p = 0.022$, one-tailed, effect size partial eta squared = 0.038; 56 students in exploratory learning group, 54 students in direct instruction group). Exploratory pedagogical strategies also led to significantly higher scores for problems involving transfer of complex systems knowledge beyond the domain of climate change ($F(1,106) = 3.554$, $p = 0.031$, one-tailed, effect size partial eta squared = 0.032). Further, students who were taught by more experienced teachers achieved higher results. These data imply that model-based learning is not self-sustaining, but must be integrated with effective teacher guidance. This limits the scalability of the approach. An additional restriction is that model-based learning is more appropriate for well-structured problems, which tend to be underpinned by a particular structure or principle and solvable using a particular method (e.g., applying a formula).

Table 2 presents a summary of seven main principles for designing model-based learning environments (Pirnay-Dummer et al., 2012). These principles are often combined with other instructional principles that support construction of well-founded mental models, grounded in the learners' multiple real-world experiences. Such principles include *analogical encoding* that supports construction of abstractions and decontextualization by comparing and contrasting diverse cases (Gentner, Loewenstein, & Thompson, 2003), *agent-based modeling* that facilitates learners in establishing connections to real-world experiences (Goldstone & Wilensky, 2008), and *productive failure* that aims to trigger puzzlement and attention (Jacobson et al., 2017; Kapur, 2016).

Like computer-based skills training (see the paradigmatic learning design for the behaviorist approach), model-based learning mainly draws on strategy (b) for engaging non-educational contexts from within educational contexts, i.e., it enhances transfer through setting up a separate educational context (the computer program).

Table 2 Principles for designing model-based learning environments (MLE)

Design principles	Description
1. Analytical access	Use proper sources of information for building MLE (e.g., elucidate experts' knowledge)
2. Epistemic access	Match the MML with the MLE and the students' curiosity (e.g., by considering learners' initial beliefs in relation to the subject matter)
3. Cognitive conflict and puzzlement	Induce change in beliefs by introducing cognitive conflict and providing sufficient individual feedback
4. Diversity of surfaces	Induce generalization and transfer by offering multiple similar learning experiences with phenomena differing in surface features and support their consolidation (e.g., by making comparisons)
5. Decontextualization	Stabilize and constrain generalization and transfer, by creating opportunities for learners to abstract knowledge from the learning experiences (e.g., through dialogue and reflection)
6. Multiplicity of goals and performance evaluation	Enable gradual development and tracking of understanding in ways that reveal performance in the real world
7. Diagnostic access to learning	Monitor the process of learning by implementing learning process-oriented assessment

After Pirnay-Dummer et al., 2012, p. 69
MML stands for mental model learning

Situated Cognition Approach: Transfer by Playing Epistemic Games

On the moderate situated cognition view, transfer is possible through *epistemic games* (Collins & Ferguson, 1993; Morrison & Collins, 1996). Indeed, Collins and Ferguson (1993) argue that one important purpose of education is to help students become fluent at participating in a broad range of epistemic games.

Morrison and Collins (1996) suggest several ways in which technological environments can contribute to students' learning to recognize and play different epistemic games. First, they can offer powerful *communication environments* by providing relevant textual information and tools for manipulating game-specific symbols (e.g., scientific formulas). They may also contain prompts to encourage students to perform the "moves" of the epistemic game. For example, category labels for discussion forum posts ("Explanation," "Elaboration," "Reflection," and "Application") may prompt students to engage in particular kinds of professional discourse and help them develop professional identities (Markauskaite, Sutherland, & Howard, 2008; Sutherland & Markauskaite, 2012). Second, technological environments can offer *digital toolkits for carrying out professional tasks*, e.g., software for accounting, statistics, or genome modeling. Third, technologies can provide *entire microworlds* or *virtual internship* environments (e.g., in *Second Life*) that contain multimodal prompts for engaging certain epistemic practices. One example is virtual internships for learning urban planning and developing engineering design thinking (Bagley & Shaffer, 2015; Chesler et al., 2015).

The main principles for designing for transfer concern students' opportunities to learn to engage in the epistemic practices of given epistemic communities. (1) Learning environments should make visible patterns of interaction that are typical for epistemic practices of a specific community (e.g., how to structure a technical report in engineering). (2) Learning environments should incite students to engage in such patterns of interaction, e.g., by providing templates or prompts. (3) Learning environments should provide tools used by the epistemic community in its epistemic practices (e.g., mathematical modeling tools used by engineers). (4) Learning environments should be sufficiently realistic to allow students to develop relational knowledge and other less articulated aspects that emerge from rich authentic experiences (e.g., values, identity). However, it is disputed whether high-fidelity environments are really beneficial for transfer: they may obscure important aspects and do not necessarily raise students' awareness of how professionals actually do things and why they do them in this particular way.

The rationale of the learning design of epistemic games is that the procedural and relational knowledge developed through playing them may help students deal more effectively with situations also in the real world. Transfer is seen as happening because the students encounter and learn ideas in the context of the particular way of thinking constituted by the epistemic game. This allows them to know and see the world in a different way than before. For example, Shaffer (2006) reports that middle school students' learning in a computer-based simulated design studio environment in which they worked as graphic artists resulted in students' improved understanding of transformational geometry and graphic design. Follow-up interviews and other evidence collected several months after the study showed that the students' understanding and problem-solving skills were transferred to their performance in school more generally.

Learning designs utilizing epistemic games make use of strategy (c), i.e., enhancing transfer through simulating a non-educational context within an educational one, because authentic real-world epistemic games are played within an educational setting.

Participationist Approach: Transfer Through Mediational Practices

Designing for transfer within the participationist approach centers on facilitating the development of patterns of participation relevant for future contexts. More specifically, it centers on supporting individuals in developing dispositions to engage in certain ways in anticipated future social practices and on helping them transform patterns of participation across contexts. This can be done through the introduction of *mediational practices* (Beach, 2003), i.e., practices that *mediate* and *bridge* between educational and non-educational settings. For instance, *role-play* mediates by simulating an anticipated work context within the educational context (Beach, 2003; Hansen & Dohn, 2018). Conversely, *work-based courses involving actual work tasks* provide “situated curricula” (Smith, 2012). They mediate by introducing educational structure and guidance into actual work functions (Beach, 2003; Dohn & Kjær, 2009; Svensson, Ellström, & Åberg, 2004). Mediational practices may also be instantiated through *direct coupling of settings*, e.g., in designs where learners continuously move back and forth between school and internship – practicing in internship what they learn in school and reflecting in school on their practice in internship (Dohn, 2014; Hachmann & Dohn, 2018). In mediational practices, the focus is on negotiating concrete ways of participating and on facilitating students in recognizing and reflecting on similarities and differences between settings. Learners can be supported in this through expansive framing (see the presentation of the participationist approach above) of the bridging itself and of negotiation of ways of participating.

Design principles for transfer through mediational practices are: (1) Learning activities must require learners to traverse educational and non-educational contexts (perhaps in simulated form). (2) Learning activities must require learners to engage in the socially negotiated work practices of the non-educational context (in order to develop and transform patterns of participation). (3) Within the educational setting, educators must expansively frame the traversing of contexts and the negotiation of patterns of participation. (4) Learners must be supported in reflecting on their traversing of contexts and on their different, transforming ways of participating in the educational and non-educational settings.

Technological support of mediational practices can take many forms. Expansive framing, bridging, and reflection concerning the direct coupling of contexts may be supported through, e.g., online blog posts or portfolios (Dohn, 2014). This corresponds to strategy (a) for enhancing transfer with technology. Participants’ reflection on their work-based “situated curriculum” and experienced patterns of participation can be supported through asynchronous forum discussions (Smith, 2012) or synchronous conversations on an audiovisual platform (Dohn & Kjær, 2009). Both of these options employ strategy (d) for enhancing transfer with technology. Strategy (c) for enhancing transfer with technology is exemplified by the learning design of *simulated social practices* (Hansen and Dohn, 2018): students’ future work practices are simulated within the educational setting of a course, through formulating simulated work-life tasks. The students are supported in developing patterns of participation that bridge the settings by requiring them to engage in each other’s tasks and to anchor their task work in actual existing organizations. Students engage with each other via role-play (both online and in the physical classroom) and as reflective discussion partners. The learning design is supported technologically through an online portfolio tool, accessible to all, in which work on the tasks is documented. The learning design has been empirically investigated with five consecutive cohorts of students, over 100 students in all, utilizing a mixed-method design of observation and pre- and post-intervention questionnaires. An overarching result is that the learning design strongly supports students in developing procedural and relational knowledge of workplace challenges and of how to address them in practice. This corroborates the learning design’s potential for transfer.

The design principles for transfer through mediational practices imply the need for extensive facilitation to integrate learning activities with the relevant social practices. Technological support can facilitate some temporal and geographical flexibility, e.g., allowing more students to participate in role-play than would be possible in purely physical environments. Still, mediational practices are not easily scalable to large cohorts and are quite resource demanding to sustain even with smaller cohorts.

Developmental Practices Approach: Transfer as Knowledge Co-creation

According to the developmental practices approach, transfer is the transformation of understandings and procedures, effected through collective object-oriented activity at the boundaries of several social practices. Designing for transfer therefore implies designing for such object-oriented activity, in particular, for students' collaborative engagement with real-life ill-structured problems. Some technological learning environments, e.g., Knowledge Forum (Scardamalia & Bereiter, 2014) and Knowledge Practices Environment (Moen et al., 2012), have been specifically designed to support such engagement. These learning environments build on a knowledge creation view of learning and transfer, according to which learning consists in active creation of knowledge, new to oneself and the social practice one participates in (Moen et al., 2012; Paavola, Lakkala, Muukkonen, Kosonen, & Karlgren, 2011). Transfer is the specific knowledge creation (i.e., learning) process taking place in boundary crossing. Knowledge Practices Environment contains tools and functionalities that support a range of object-oriented activities aimed at knowledge creation, such as planning, versioning of documents, commenting, annotation, etc. These activities are termed "knowledge practices." Specifically, the environment supplies tools to mediate four main aspects of object-oriented activity: the epistemic, pragmatic, social, and reflective aspects (Moen et al., 2012). Tools for *epistemic mediation* support activities directly related to developing conceptual understanding, e.g., creating, organizing, and linking ideas. Tools for *pragmatic mediation* support creation of procedural knowledge and management tasks, such as organizing, planning, and coordinating distributed work. Tools for *social mediation* support activities for building social relationships, such as maintaining contacts and updating participant information. Tools for *reflective mediation* support activities that make knowledge and practices visible and facilitate reflection and transformation of them. For example, some of these principles were applied in a course for teaching new product development where students ($N = 50$) from media engineering, industrial management, and communication learned to develop new products by working in multidisciplinary teams with customer organizations (Kosonen, Muukkonen, Lakkala, & Paavola, 2012). The study illustrates how joint work on a variety of artifacts (working documents, visual representations, prototypes, etc.) let students and industry partners effect transfer through crossing boundaries. In the process, the different participants' diverse ideas were transformed into a shared

Table 3 Design principles for supporting object-oriented activity

Design principles	Description
1. Organize activities around shared digital artifacts	Shared digital artifacts provide concrete common ground for joint knowledge work and make processes for creating and improving them visible
2. Support integration of personal and collective agency and work	Participants take responsibility for their own work and for collaborative work simultaneously. Individual expertise and learning are merged with collective knowledge creation processes
3. Foster long-term processes of knowledge transformation	Tools and practices enable links between different learning experiences and outcomes and support creative reuse of earlier activities and artifacts (transfer as transformation)
4. Emphasize development and creativity through transformation and reflection	The processes of developing shared digital artifacts emphasize interaction between practices and conceptualizations and between different types of knowledge
5. Promote cross-fertilization of knowledge practices across communities and institutions	Learning involves work on problems that have relevance outside the educational settings and create knowledge for purposes outside educational institutions
6. Provide flexible tools for developing artifacts and practices	Technological tools support shared knowledge creation by mediating different aspects of work: Epistemic, pragmatic, social, and reflective

Adapted from Moen et al., 2012, pp. 6–7, 149–155

viable solution. The study also shows that students' interaction skills and capacity to align their thoughts and actions with those of the potential users play important roles in the transformation of individual creative ideas and understandings into joint products.

The design principles for transfer as knowledge co-creation center on making the boundary-crossing activities evident, on making collaborative development of new ideas visible, on facilitating constructive interaction of the four main aspects of object-oriented activity, and on supporting the smooth integration between the different types of knowledge (Table 3).

Learning designs utilizing these design principles aim at establishing authentic knowledge building environments. In this sense, they draw on strategy (d) for enhancing transfer through introducing an educational context within a non-educational one. They require quite extensive facilitation and therefore are not easily scalable to large cohorts and may be resource demanding to sustain even with smaller cohorts.

Concluding Remarks

We conclude the chapter by highlighting the common findings on sustainability and scalability which apply across the different approaches. Overall, learning designs have greater chances of being successful if they are supported and integrated in the wider context where they are implemented (Engle et al., 2012; Illeris, Andersen, & Learning Lab, 2011; Issenberg et al., 2005; McGaghie, Issenberg, Barsuk, & Wayne, 2014; Svensson et al., 2004). Depending on the specific learning design, this "wider context" may be the educational course itself, where the support required is integration into the curriculum and instructional assistance from the teacher. The "wider context" may also be the work environment into which the knowledge is to be transferred. Here, the support required is, e.g., opportunities to engage the knowledge learned in specific work tasks and access to participate in work-place practices. Cross-institutional support between educational program and professional practice is also a relevant "wider context." It can help ensure that learners get access to and recognize professional practice situations in which they can utilize the knowledge from their educational program. In general, it is not recommended to implement unsupported learning designs, by, e.g., utilizing training programs as self-learning activities or "coupling contexts" without facilitating a transformation of patterns of participation.

These findings also imply moderate optimism about the scalability of learning designs aimed at enhancing transfer using technology. Technology does provide possibilities for more learners to engage more flexibly in a more diversified range of learning activities aiming in more varied ways at supporting them in putting to use what they have learned in other contexts. But learning designs must be supported instructionally, institutionally, and practically for transfer to be facilitated. This places financial, human, and institutional limits to the degree of scalability, both in terms of student numbers and in terms of situations of use. The vision of pure technological facilitation of learning and transfer of learning with no costs beyond the portable program itself cannot be upheld.

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Section II
Understanding How to Accommodate Differences Among Learners Through Instructional Design/Technology

Using Technology to Address Individual Differences in Learning

Pavlo D. Antonenko, Kara Dawson, Li Cheng, and Jiahui Wang

Problem Definition

Each individual possesses a unique pattern of mental abilities to process vast amounts of information, motivation levels for performing various tasks, visuospatial skills to navigate spaces and comprehend visual stimuli, and numerous other sets of aptitudes and traits that vary in their degree of stability over time. Recognizing that people think and learn differently, educators strive to design learning experiences and integrate technology to support a wide range of students with important differences in perception, attention, cognition, affect, motivation, self-regulation, and so on. Individual differences in learning are defined as skills, aptitudes, preferences, and traits that serve as a source of variability among learners and influence learning experiences and learners' ability to accomplish learning outcomes (Jonassen & Grabowski, 1993). Individual differences in learning are manifested in a variety of ways. Learners may express preferences for learning with different media (e.g., text, images) and modalities (e.g., auditory, visual, kinesthetic; Plass, Kalyuga, & Leutner, 2010). Learning is also moderated by cognitive differences such as processing speed, attention span, working memory capacity, inhibitory control (Zelazo, 2015), and a host of noncognitive variables such as interest, self-efficacy, goal orientation, and so on (Belland, Kim, & Hannafin, 2013). Motivational, cognitive, and affective variables are interconnected in many intricate ways to create each individual's subjective experience of learning (Ainley, 2006), which makes the study of individual differences, as well as design, development, and application of appropriate educational technologies, more difficult.

P. D. Antonenko (✉) · K. Dawson · L. Cheng
University of Florida, Gainesville, FL, USA
e-mail: p.antonenko@coe.ufl.edu

J. Wang
Kent State University, Kent, OH, USA

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Research on individual differences in learning has a long history (Cronbach & Snow, 1977; Eysenck, 1969). However, using technology to support learning for all students remains an elusive goal. Issues with lack of student motivation and engagement, frustration and boredom, and compromised learning in technology-supported environments continue to be pervasive and are often attributed to our inability to adapt instruction to reflect the differences among learners (Aleven, McLaughlin, Glenn, & Koedinger, 2017; Hung, 2011). A recent study exploring the technology decisions for inclusive middle-school science instruction revealed that while teachers did consider instructional technologies for inclusive science classrooms, students' learning differences were not among the factors that influenced teachers' technology selections (Rutt, Mumba, Chabalengula, & Ochs, 2017). Given these concerns, the problem addressed in this chapter is the need to conduct more research and development to capitalize on the affordances of twenty-first-century technology as well as the new and emerging assessment methods that measure dynamics of individual differences to design learning environments that account for variation among learners relative to motivation, affect, and cognition.

Historical Overview

A number of learning theories and instructional design models have emphasized the notion that learning relies on students' cognition, affect, and motivation. In 1902, John Dewey called for a reform in curriculum design that moves away from the inflexible, one-size-fits-all curricula to instructional programs that are sensitive to children's needs and interests (Dewey, 1964). Across the globe, Soviet psychologist Lev Vygotsky developed the concept of the zone of proximal development, or the difference between what learners can and cannot do without the help of a more knowledgeable other, and introduced the idea of instructional scaffolding or changing the level of support to accommodate the cognitive potential of the child (Vygotsky, 1987). The study of scaffolding, and particularly adaptive scaffolding, remains a prominent trend in educational research and practice (Belland, Walker, Kim, & Lefler, 2017).

An important development in individual differences research occurred in 1957 when Lee J. Cronbach reported on the outcomes of correlational research to relate individual differences and learning gains on different experimental treatments (Cronbach, 1957). This work helped lay the foundation for what is now known as aptitude-treatment interactions (ATI; Cronbach & Snow, 1969). A pervasive finding in ATI research has been that selection of effective instructional treatment depends on learners' knowledge in the domain (Cronbach & Snow, 1977). This finding has been incorporated in instructional design models such as Gagne's Nine Events of Instruction where one of the early design steps is "Stimulate recall of prior knowledge" (Gagne, 1985), in the student knowledge-informed use of instructional texts (McNamara, Kintsch, Songer, & Kintsch, 1996), and, more recently, in the design of learning technologies that adapt to student knowledge of the domain (e.g., Arroyo et al., 2014; VanLehn et al., 2000).

Current Perspectives

The resurgence of interest in individual differences in the 1950s and 1960s reflected an increased interest of psychologists in the study of cognition that is often referred to as the cognitive revolution in psychology (Baars, 1986). From a cognitive perspective, learning with technology requires effective processing of information presented to the learner using various media or modalities. Thus, much of the cognitivist research in educational technology has focused on the cognitive load imposed by various technology-supported learning materials. Within this line of inquiry, it is assumed that poor learning outcomes are due to the ineffective design of learning materials (e.g., when images and text are not semantically related). Cognitive load is discussed primarily as a consequence of the design of the learning materials, and differences in individual learner characteristics that may impact cognition are typically not addressed (Plass et al., 2010; Wiley, Sanchez, & Jaeger, 2014). A notable exception is research on the expertise reversal effect that discusses the design of learning materials relative to differences between expert and novice learners (Kalyuga, 2007). Specifically, students with high prior knowledge have been found to experience increased extraneous cognitive load when presented with instructional scaffolds for the material they had already internalized, whereas low prior knowledge students experienced decreased extraneous load and exhibited learning gains when presented with instructional scaffolding.

A complementary approach that puts learners and their characteristics front and center focuses on the effects of individual differences in learning with technology. Unlike scholarship exploring the properties of learning materials, an individual differences approach addresses the moderating effects of individual differences among learners that represent a spectrum of motivational, affective, and cognitive variables that we have long known exist and influence learning (Eysenck, 1969). The extent of variation among individuals across all the cognitive, motivational, and affective dimensions is incredibly vast. However, scholars do agree on a number of assumptions about differences among individuals and their learning (Jonassen & Grabowski, 1993):

- Individual differences in learning show systematic variation in the population.
- Individual differences in learning have pervasive effects on cognition, emotion, motivation, and behavior.
- Individual differences in learning affect the learner's ability to perform learning tasks and accomplish learning outcomes

The types of individual learner differences have been described in many different frameworks. For example, Jonassen and Grabowski's (1993) taxonomy of individual differences in learning distinguishes between cognitive abilities (cognitive controls, cognitive styles, and learning styles), personality styles, and prior knowledge. Some of the types of individual differences such as learning styles are still being debated (Kirschner & van Merrienboer, 2013; Pashler, McDaniel, Rohrer, & Bjork, 2009), whereas other variables such as prior knowledge, working memory capacity, motivation, and emotional arousal have been shown to be valid and relevant concepts that reflect variability among learners and serve to inform theories of learning and the practice of teaching (Akshoomoff et al., 2013).

Today, there is increased recognition that learning is influenced by affect and motivation (D'Mello & Graesser, 2011), and so a number of taxonomies have been devised to describe variations among learners relative to the motivation and emotions they experience during learning. For instance, Pekrun (2010) discusses achievement emotions, topic emotions, social emotions, and epistemic emotions that moderate learning and cognition. Ryan and Deci's (2004) self-determination theory provides a useful taxonomy of learner motivation and motivation regulation that describes learner motivation along a continuum from amotivation to extrinsic motivation (external regulation, introjected regulation, identified regulation, and integrated regulation) to intrinsic motivation with self-determined, intrinsic regulation. These taxonomies serve as logical tools that inform the study of individual differences in learning and inform the design of affective, motivational, and cognitive scaffolding.

Individual Differences as States and Processes

To facilitate the discussion of cognitive, affective, and motivational differences in learning, it may be useful to examine them along a continuum from the relatively stable and constant *states* to the highly dynamic and volatile *processes*. Prior knowledge, metacognitive awareness, reading ability, visuospatial abilities, and working memory capacity are all examples of states that remain comparatively constant over time. On the other hand, a key characteristic of processes is that they fluctuate during the learning task. For instance, boredom, frustration, cognitive load, stress, and strategy choice are dynamic processes that constantly change, reflecting situational and task dynamics such as relevance, difficulty of content, and design of instructional scaffolding. As is the case with many educational and psychological variables, however, true dichotomies (such as the above distinction between states and processes) are rare. While we believe this categorization helps with analyzing the causes and effects of individual differences in learning, it is also understood that (a) there may be great variability within both states and processes relative to their stability and volatility (e.g., an active social sciences researcher's knowledge of statistics may develop much more dynamically compared to her or his knowledge of geometry), and (b) states and processes are highly interactive (e.g., prior knowledge influences cognitive load and cognitive load impacts the development of new knowledge; Kalyuga, 2007).

An important implication of discussing individual differences as states versus processes is measurement. Due to their relative stability, states such as prior knowledge, metacognitive skills, or reading ability usually only need to be assessed once, using pre-task measures such as tests of prior knowledge or metacognitive awareness instruments (e.g., Schraw & Dennison, 1994). However, because process variables such as cognitive load or affective responses fluctuate during the learning task, continuous online assessments during the task are needed to inform individualization of learning (Sinatra, Heddy, & Lombardi, 2015).

Promising Directions

Advances in the assessment of individual differences in learning and recent technological innovations in dynamic web and mobile application development have resulted in the design of systems that adapt to individual differences at both the state level and the process level (e.g., Aleven et al., 2017; D'Mello, Dieterle, & Duckworth, 2017).

Addressing State-Level Differences

State-level individual differences in learning such as prior knowledge, visuospatial abilities, reading ability, and working memory capacity are a well-recognized phenomenon (DeBra, Kobsa, & Chin, 2010). The conventional approach to addressing state differences is to conduct a pre-task assessment and then adjust the content difficulty, presentation of information, or navigation within the task based on the results of that assessment. This approach has been successfully used to design multimedia and hypermedia applications, games and simulations, and intelligent tutoring systems (ITSs). For example, Kalyuga (2008) demonstrated that while learners with higher levels of prior knowledge showed better learning results after studying animated procedural examples in transforming graphical representations of linear and quadratic functions in mathematics, less knowledgeable learners performed significantly better after studying sets of static representations demonstrating main steps of the transformations on a single screen (Kalyuga, 2008). This expertise reversal effect has also been observed during learning with chemistry simulations (Homer & Plass, 2014), hypermedia-based concept maps in biology (Amadieu, Tricot, & Marine, 2009), and many other educational contexts. Thus, a number of learning technologies have been designed to assess student domain knowledge before instruction and then customized the content or the system to student's knowledge level (Corbett, McLaughlin, & Scarpinatto, 2000). A number of systems have also been built to adapt to changes in student understanding of the content based on student successes and errors during learning using approaches like adaptive worked examples (Booth, Lange, Koedinger, & Newton, 2013), adaptive feedback (Ohlsson, 2016), and adaptive fading of scaffolding (Salden, Aleven, Schwonke, & Renkl, 2010). For example, Salden et al. (2010) found that the adaptive fading condition in their study outperformed two nonadaptive conditions (problem solving and fixed fading) on both the immediate and the delayed posttest. Additionally, learners in the adaptive fading condition needed significantly fewer worked steps than those in the fixed fading condition, which indicates that overall the students' knowledge levels increased faster in the adaptive condition.

Working memory capacity (WMC) is another important state variable that is known to have important effects on learning. In fact, individual differences in WMC are a new principle in the cognitive theory of multimedia learning, a well-known framework for understanding and designing multimedia learning environments (Wiley et al., 2014). Many studies on multimedia and hypermedia learning have found that when learners are given more information, including additional information that should be helpful for their understanding, they may actually learn less, not more. For example, Fenesi, Kramer, and Kim (2016) examined the relationships between working memory capacity (WMC) and the principles of split attention in multimedia learning. Undergraduate students with lower WMC performed worse compared with those with higher WMC when learning from the split attention condition (audio, on-screen text, and images), but not when learning from the complementary condition (audio and images). This finding demonstrates that removing split-attention components selectively improves multimedia learning for lower WMC learners. A similar finding was reported in the context of learning from paginated versus long scrolling hypermedia pages (Sanchez & Wiley, 2009). While scrolling presentations reduced learning overall, this effect was localized to individuals lower in WMC. Adaptive learning technologies sensitive to differences in learners' WMC are still rare; however, some promising research is under way. For example, Chang et al. (2015) have proposed a system that employs six types of adaptive recommendations (e.g., suggesting note taking, summarizing, rehearsal, and other strategies) to remind and suggest additional learning activities to students based on their WMC.

Similar to WMC and prior knowledge, visuospatial abilities (VSA) represent a set of important state-level individual difference variables that allow us to search for relevant stimuli in the visual field; apprehend the forms, shapes, and positions of objects; form mental representations of those forms, shapes, and positions; and mentally manipulate them (Carroll, 1993). A recent meta-analysis demonstrated that when visualizations are present in learning materials, high VSA learners achieve significantly better learning outcomes compared to low VSA learners (effect size of $r = 0.34$). Additionally, this meta-analysis revealed that learners with low VSA can be supported using dynamic (i.e., animated) instead of static visualizations and using three-dimensional rather than two-dimensional illustrations (Höffler, 2010). Combined with the results of Kalyuga's (2008) expertise reversal study described earlier, we can see that students who tend to benefit most from instructional animations are those who have a high level of prior knowledge even when their spatial ability is relatively low. These findings produce important implications for designing instructional adaptations based on pre-task assessment of learners' prior knowledge and spatial ability states.

Pretraining Approaches

In addition to preassessing learners on state individual differences and designing variants of instructional systems or tools to accommodate the abilities, traits, and prior knowledge of individual students, a promising approach is to conduct pretraining on these respective variables prior to learning (Mayer, Mathias, & Wetzell, 2002). Despite being fairly stable over long periods of time, many of the state variables are in fact malleable and can be improved using carefully designed training interventions. For instance, promising findings have been reported regarding working memory training interventions (Schwaighofer, Fischer, & Bühner, 2015). This particular meta-analysis examined 47 studies with 65 group comparisons and revealed positive near-transfer effects to short-term and working memory skills that were sustained at follow-up for immediate transfer and long-term transfer. Similarly, a meta-analysis of 25 years of research on spatial ability training (Uttal et al., 2013) revealed that overall spatial training is quite effective (r = 0.47). Spatial training interventions ranged from semester-long spatial visualization courses (e.g., Sorby, 2009) to spatial training with video games with much shorter game play. For example, Feng, Spence, and Pratt (2007) investigated the effects of video game playing on spatial skills, including transfer to mental rotation tasks, and found that playing commercial off-the-shelf action videogames like *Medal of Honor* can enhance spatial thinking substantially, even when compared to a control group that played a 3D puzzle game.

Games have also been found to be useful for the training of selective attention. Chukoskie et al. (2017) developed gaze-contingent video games that provide users visual and auditory feedback in real time from a remote eye tracker designed for in-home use. The games – *Whack The Moles*, *Shroom Digger*, and *Space Race* – require players to control the distribution of their visual attention and fixate their gaze on select objects based on the rules of the game. In *Whack The Moles*, for instance, players are to look at the moles as they appear out of the ground and use their gaze to "hit" ninja moles but avoid hitting the professor mole. Playing these games has helped individuals improve both the speed of attentional orienting and duration of fixation on task-relevant stimuli (Chukoskie, Soomro, Townsend, & Westerfield, 2013).

Addressing Process-Level Differences

Unlike state differences, process-level variables fluctuate during the learning task and are notoriously difficult to measure and adapt to. Intelligent tutoring systems (ITSs) are advanced learning technologies that are well suited for adapting to process variables. They have been developed for many different content areas (e.g., reading, algebra, statistics, physics, computer science, medicine). Examples of such systems include *AnimalWatch* (Beal, 2013), *ALEKS* (Assessment and Learning in

Knowledge Spaces; San Pedro, Baker, & Rodrigo, 2014), *AutoTutor* (Graesser, 2016), *Cognitive Tutor* (Koedinger & Aleven, 2016), and *MetaTutor* (Duffy & Azevedo, 2015), among others. A recent meta-analysis compared the outcomes from students learning with ITSs to those learning with non-ITS learning environments (Ma, Adesope, Nesbit, & Liu, 2014). The use of ITS was associated with greater achievement in comparison with the traditional teacher-led, large-group instruction (g = .42), non-ITS computer-based instruction (g = .57), and learning with textbooks or workbooks (g = .35). Significant, positive effect sizes were found at all levels of education, in almost all subject domains evaluated, and whether or not the ITS provided feedback or modeled student misconceptions (Ma et al., 2014).

ITSs are adaptive in the sense that they change the presentation and navigation of learning content and the degree of system-learner interactivity (e.g., hints, questions, worked examples) based on the user model or data on the current level of learner knowledge, cognitive and metacognitive strategies used in the system, types of errors produced, and emotional responses and, more generally, based on learner actions in the system. Data on students' cognitive, affective, and engagement processes are collected during the learning task using a variety of strategies and technologies. Traditionally, online assessment has relied on experience sampling (Csikszentmihalyi & Larson, 2014), a method of providing learners with a brief self-report measure delivered in the ITS or on their smartphone asking them to indicate the amount of mental effort, level of engagement, boredom, confusion, or the types of emotions they are currently experiencing. The experience sampling methodology (ESM) allows collection of dynamic, online data relative to the variations in learners' self-reports of engagement, cognitive load, and other relevant process variables. For example, Kane et al. (2007) conducted an ESM study of undergraduate students focusing on the relation between working memory capacity (WMC) and the experience of mind wandering in their daily life. Personal digital assistants notified students eight times daily for a week to report immediately whether their thoughts had wandered from their current activity and to describe their psychological and physical context. They found that during challenging activities requiring concentration and effort, higher-WMC subjects maintained on-task thoughts better and mind-wandered less than did lower-WMC subjects. An apparent but untested implication of this study is that low-WMC learners need to be provided with adaptive scaffolding to reduce the detrimental effects of mind wandering or unintentional lapses of attention.

The benefit of using ESM in education is that online data on affective or cognitive dynamics can be collected anytime and anywhere (e.g., students reviewing study materials for an upcoming exam in their dorm room). However, because ESM relies on self-reported data, this methodology is prone to the limitations of all self-reported data such as lack of accuracy, failure to capture important changes in cognition, problems with collecting data from young children, and so on (Anderson & Beal, 1995; Antonenko & Keil, 2018; Gobert, Sao Pedro, Baker, Toto, & Montalvo, 2012; Leahy, 2018). To circumvent these limitations, scholars of learning from various disciplines have proposed a number of new methods informed by advances in psychology, computer science, and neuroscience. For instance, in the context of measuring cognitive load, which is a process variable that constantly fluctuates during the learning task and is difficult to measure, recent advances include the use of physiological techniques with a high temporal resolution, such as brain-based measures of electroencephalography (EEG; Antonenko & Keil, 2018) and functional near-infrared spectroscopy (fNIRS; Ayaz et al., 2012), as well as a combination of EEG and fNIRS (Liu, Ayaz, & Shewokis, 2017), ocular-motor measures such as eye tracking (Cook, Wei, & Preziosi, 2018), and multimodal measures that incorporate data from speech, writing, system interactions, and physiological responses (Chen, Zhou, & Yu, 2018).

A promising multimodal method for assessing engagement was proposed by D'Mello, Dieterle, & Duckworth (2017). The Advanced, Analytic, and Automated (AAA) approach employs machine-learned computational models to automatically infer mental states associated with engagement (e.g., interest, flow) from machine-readable behavioral and physiological signals (e.g., facial expressions, eye tracking, clickstream data) and from aspects of the environmental context (D'Mello et al., 2017). Other researchers have advocated for the use of sensor-free assessment that relies primarily on learning environment navigation data from server logs and analytic techniques that examine log data in the context of student performance relative to learning, problem solving, or collaboration (Antonenko, Toy, & Niederhauser, 2012; Baker & Siemens, 2014; Rowe et al., 2017).

A lot of promising research and development has recently focused on affect-aware and affect-adaptive learning technologies (Aleven et al., 2017; D'Mello & Graesser, 2014; San Pedro, Baker, & Heffernan, 2017). This line of inquiry emphasizes the role of such variables as frustration, boredom, confusion, engaged concentration, or flow because they are frequently observed during learning and influence student motivation, cognitive, and metacognitive processing (e.g., D'Mello, 2013). For example, D'Mello, Lehman, Pekrun, and Graesser (2014) explored the effects of confusion on learning within the context of an ITS (*AutoTutor*) and research design as the learning content. The system used a natural language speech interface to afford trialogs, in which a human learner, a computer learner, and a computer tutor reasoned through a challenging question. The two computer agents frequently contradicted each other and even expressed false information during the trialog, which was intended to cause confusion on the part of the human learner and drive the human learner to bridge the cognitive disequilibrium and resolve the confusion. This trialog-based learning environment did indeed lead to deeper learning, but such enhancements occurred only when the human learner was confused (D'Mello et al., 2014). Another work has focused on exploring relationships between positive and negative emotions and learning, focusing specifically on the incidence, persistence, and impact of boredom, frustration, confusion, delight, surprise, and engaged concentration (Baker, D'Mello, Rodrigo, & Graesser, 2010). They found that confusion and engaged concentration were the most common states within all three learning environments, whereas delight and surprise were rare. Boredom was very persistent across learning environments and was associated with poorer learning and problem behaviors such as gaming the system. Frustration was less persistent and less associated with poorer learning. These findings suggest that ITSs and other learning technologies should incorporate detection and adaptive scaffolding based on boredom and confusion data, in addition to the more widely used data on cognitive states and processes.

Translating Research on Individual Differences to Educator Practice: Universal Design for Learning

This chapter demonstrates the complexity associated with researching how technology may be used to address state- and process-level individual differences in learning. However, an arguably more complex dilemma relates to how to help educators translate research on technology and individual differences to their classroom practices. Universal Design for Learning (UDL) is a framework designed to support educators in this endeavor. The Center for Applied Special Technology (CAST) developed UDL as a result of efforts to help students with individual differences overcome barriers to learning. It gradually evolved into a framework educators can use to support all students by planning for learner variability in their classrooms.

The UDL framework, derived from research in education, psychology, and neuroscience, includes three main principles with associated guidelines and checklists (Meyer, Rose, & Gordon, 2014). The three main principles relate to designing learning environment to account for multiple means of (1) engagement, (2) action and expression, and (3) representation. The associated guidelines and checklists provide action-oriented strategies for implementing each principle. For example, one guideline under the Representation principle includes "providing options for perception," and checklist strategies include offering ways to customize how information is displayed and offering alternatives for auditory and visual information.

UDL is referenced in important US-based federal education policies at the K-12 (i.e., Every Student Succeeds Act (ESSA, 2015) and the National Educational Technology Plan (NETP, 2016)) and postsecondary levels (i.e., the 2008 Higher Education Opportunity Act). It is also referenced in the 2015 Educational Technology Developer's Guide for software designers published by the US Department of Education. The premise within all these documents relates to using UDL principles to minimize learning barriers and maximize student strengths by designing for individual differences, which UDL proposes are predictably variable across learners of all ages. Although UDL encompasses technology and nontechnology solutions to designing for individual differences, technology plays a major role in designing inclusive learning environments. For example, Strategic Reader, designed using UDL principles and Curriculum-Based Measurement (CBM) , is a technology intervention that supports individual differences in developing reading skills. A recent experimental study demonstrates its effectiveness in supporting comprehension, particularly when the tool was used online (Hall, Cohen, Vue, & Ganley, 2015).

Despite strong evidence for the component parts of UDL (Meyer et al., 2014), evidence that UDL-designed interventions can work and support for UDL in federal education policy, research on how to apply the framework to implementation is still emerging. A recent meta-analysis of UDL studies in PreK-12 classrooms found that UDL implementation varies considerably across studies, and importantly, the way implementation is described across studies makes it difficult to compare them or confirm that UDL is, indeed, being implemented at all. The meta-analysis also found that the success of UDL efforts, as measured by effect sizes, varied considerably although results of the overall meta-analysis suggest UDL is a promising framework to address individual differences (Ok, Rao, Bryant, & McDougall, 2017).

The UDL Implementation and Research Network (UDL-IRN) is a relatively new organization developed "to support the purposeful integration of Universal Design for Learning (UDL) and iterative design-based thinking to support the learner variability that exists in all learning environments." UDL-IRN includes strong focus on technology and on advancing research through its Research Committee which maintains a database of empirical studies on UDL (http://udl-irn.org/udl-research/).

Implications and Conclusions

The research on the problem of addressing individual differences among learners and educational technology solutions reviewed in this chapter demonstrates important contributions that have been made to individualize learning based on learner differences as well as promising directions for research and development to improve our understanding and design for differences in state and process variables that impact learning.

Perhaps the most important issue that researchers in educational technology and instructional design must address is the need to focus not only on the properties of learning materials (e.g., how a particular blend of technology, pedagogy, and content impacts learning) but, perhaps more importantly, how a particular educational technology solution affects learning relative to the important differences that exist among learners. A citation analysis conducted using terms "individual differences" or "cognitive differences" and "educational technology" revealed that (a) such studies are scarce, and (b) relevant studies are often designed and carried out by scholars with limited expertise in educational research (e.g., neuroscientists). Only one chapter in the latest edition of the *Cambridge Handbook of Multimedia Learning* explicitly focused on the issue of individual differences in multimedia learning (Wiley et al., 2014), with a focus on one important state-level variable – working memory capacity.

The most obvious contribution that addresses the issue of individual differences in learning is the extensive conceptual and empirical research on what we refer to in this chapter as state differences, that is, variables like prior knowledge, reading ability, metacognitive awareness, and so forth. This work resulted in the development of instructional design models and research paradigms such as aptitude-treatment interaction as well as educational technology products that individualize instruction based on state-level differences among learners. Research on adaptive learning technologies such as intelligent tutoring systems (Aleven et al., 2017) and using novel online assessment methodologies reflects more recent efforts to study and design individualized instruction technologies.

When it comes to the more dynamic individual differences variables, or what we referred to as process-level differences in this chapter, educational research in general and educational technology research in particular are still rather limited. Educational scholars have begun to call for more rigorous research on process differences in cognition and affect (e.g., Antonenko & Keil, 2018; Chen et al., 2018; D'Mello et al., 2017) for the design and study of educational technologies, but both empirical research and technological solutions that address process variables are scarce. This issue presents an important opportunity for the designers and scholars of technologies for learning and teaching. More translational research between neuroscience, cognitive psychology, educational psychology, computer science, and educational technology should focus on integrating physiological measures, server log and interaction analysis, self-reported instruments, and machine learning techniques for automatized analysis to devise comprehensive multimodal assessment paradigms to help study and design for individual differences in learning. This interdisciplinary research is needed to improve the sharing and cross-fertilization of conceptual frameworks, methodological approaches, and empirical findings between these diverse but complementary fields.

To summarize, the following implications for research may be worth addressing to advance the study of individuality and variation in learning and to design educational technologies that are sensitive to individual differences among learners:

- Acknowledge the important role of individual differences in learning and conduct rigorous research to understand the interplay between "system" variables that reflect the properties of the learning materials and "learner" variables that represent interindividual differences in cognition, motivation, and affect.
- Place more emphasis on the study of dynamic process-level differences in cognition and affect such as cognitive load, distraction, confusion, mind wandering, etc.
- Advance our understanding of the measurement techniques that can be used to unobtrusively assess process-level variables during the learning task.
- Employ the recently developed measurement paradigms and tools (e.g., NIH Toolbox) to explore the important interactions between:
  - State-level variables such as prior knowledge, reading ability, visuospatial skills, working memory capacity (verbal and visuospatial), and metacognitive awareness and process-level variables such as boredom and cognitive load
  - Affective, motivational, cognitive, and metacognitive variables during learning and the independent as well as combined effects they produce on the effectiveness and efficiency of learning, situational and sustained interest on the subject matter, learning self-efficacy, etc.
- Develop and test design strategies and solutions to address process-level individual differences and create more nuanced learner models for adaptive learning technologies.

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Gender and Technology: Social Context and Intersectionality

Katy Campbell

Research on gender differences in teaching and learning with, and designing for, technology has, at least, a three-decade span (c.f. Belenky, Clinchy, Goldberger, & Tarule, 1986, 1997; Winkelman, 1997). Scholars from K-12 education, higher education, adult and continuing learning, professional learning, and distance education (c.f. Anderson & Haddad, 2005; Boeren, 2011; Booth, 2010; Campbell, 2000; Caulfield, 2011; Franzway, Sharp, Mills, & Gill, 2009; Graddy, 2004; Kramarae, 2001; Maher, 1987; von Prummer, 1993, 2005); interface design and instructional design (c.f. Baylor, Shen, & Huang, 2003; Campbell, 2015; Campbell & Schwier, 2015); computer-mediated discussions and social media use (c.f. Correa, Willard Hinsley, & Gil de Zúñiga, 2010; Dwight, 2004; Gregg, 2006; Herring, 1996a, Herring, 1996b, Herring, 1999; Holmes & Meyerhoff, 2008; Raacke & Bonds-Raacke, 2008; Turkle, 1984), and other areas of focus have examined social media delivery formats, design of physical learning environments, pedagogical approaches and content, and graduate education from multiple perspectives, including access, accessibility, the digital divide, social justice, usability, effectiveness, inclusiveness, and sociocultural and political perspectives (c.f. Ball, 2007; Littlejohn, Foss, & Oetzel, 2017). The author and others have also explored gender issues in design practice (c.f. Campbell & Varnhagen, 2002), teaching, and assessment (Campbell, 2002; Lacey, Saleh, & Gorman, 1998). The literature is broad and rich.

K. Campbell (✉)
University of Alberta, Edmonton, AB, Canada
e-mail: katy.campbell@ualberta.ca

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A Turn in the Scholarship

More recently, critical scholars have become interested in, and concerned about, intersectionality, in which "multiple oppressions" influence each other and create learning and working environments that exclude or marginalize various learning communities, among them adult women, women and girls whose native language is not English, women and girls living in poverty in rural areas with limited access, Indigenous females, and so on (c.f. Belkhir & McNair Barnett, 2001; Morse, 2003; Li & Kirkup, 2007; National Science Foundation, 2004). If we use gender as a defining lens, we must also consider emerging questions about gender identity, a political, social, and cultural challenge that becomes a design consideration.

Within the past year, public and academic attention has again been directed to the essential male culture of Silicon Valley and the high-profile cases of inequitable status career opportunities, and salaries of women in IT companies like Uber and Google (c.f. Simon-Lewis, 2017). That the culture has not much changed since the 1990s, and that some critics point to biology as a limiting factor in aptitude and leadership is cause for concern for those of us who reject access to creative and managerial opportunities based on sex. Do these "chilly climates" reflect the learning experiences of girls and women in public and higher education contexts?

What do we know about gender and learning and technology, and what questions still need to be asked? Has research since 2005 identified new challenges, new understandings, and new directions? What do social media add to the mix? Has this knowledge affected how we design learning environments, and even who designs learning environments? Have we seen innovations that enhance learning for girls and women?

This chapter begins with an overview of methodology and definition of key terms, followed by a quick review of research from the 1990s and early 2000s (although this research dates even from the time of learning machines and correspondence education), and proceeds to survey the more recent research that addresses questions about gender and design; gender, age and access; gender and accessibility and economic opportunity; gender, new technologies, and pedagogical approaches; and gender and geopolitical, sociocultural, and economic contexts. Finally, the chapter will conclude with summative learnings and implications for gender-related planning; learning design; design practice; design of learning spaces; pedagogical approaches; and usability and inclusion of sociocultural factors such as first language, geopolitical context, indigeneity, and economic circumstance.

Organization

To organize this work, I re-read my work from the late 1990s and early 2000s to refresh my understanding of the gender-related issues in pedagogy and design in that era. I found I was then able to return to the literature with fresh eyes and a richer perspective, informed by technological advances (e.g., social media), increasing complexities in the research about learners (e.g., gender identity), transformations in public schooling and in higher education (e.g., increased internationalization, reduced public funding, political and cultural struggles over content and representation), critical views of formal education (e.g., decolonizing the curriculum), progress in theory and practice in educational technology and design (e.g., use of cases, designer identity, design thinking), and reengaged public interest in gender issues in multiple sectors, especially in IT workplaces like Uber.

Positionality

I believe that all human activities, like design, or learning, are socially and culturally situated. That is, the research questions that we choose to address arise from our own experiences, cultural contexts, personal philosophies, political vantage points, and biases and assumptions; the methods with which we explore these questions are also informed by our epistemologies, experiences (including educational), and current social contexts and are influenced by our preferred research constructs, relationships, funders, participants, professional environments, and so on. As Creswell (2013) notes, "interpretations of the data always incorporate the assumptions that the researcher brings to the topic" (83). Sometimes, we experience new learning that disrupts our assumptions or beliefs. Such a disruption is occurring in Canada, currently, with the release of the report of the Truth and Reconciliation Commission's 94 recommendations for reconciliation with Indigenous peoples, based on the egregious history and continuing generational trauma of the Indian Residential Schools c.f. http://www.trc.ca/websites/trcinstitution/index.php?p=3**)**. Educators, the justice system, faith-based groups, policy-makers – existing social, cultural, economic, and legal structures of society – are challenged to acknowledge and work to resolve effects of oppression and colonization on Indigenous communities. Being compelled to consider, and design with, and for, alternative ways of knowing is a fundamental challenge to one's designer identity. For the purposes of this chapter, I am positioned as a Canadian, feminist, post-structural researcher whose research always has a gendered lens. I pursue questions of identity, power, authority, and language, particularly as they unfold in instructional design practice, higher education structures and lifelong learning, and engagement scholarship. This identity is reflected in my sense-making of the literature I identified to include in this study.

So, what is included? Beginning with the research discussed in the papers I had written almost two decades earlier, I conducted a search using the names of the researchers involved in gender research at the time. Several of these researchers had moved on to different areas, but many had continued in the same area of work, connecting with new colleagues, sometimes working in different contexts (e.g., a focus on computer-mediated communication evolved into research on blogs (e.g., the work of Susan Herring). Using numerous databases held in the library at the University of Alberta, for example, ProQuest, ERIC, as well as Google Scholar, Academica.edu, and ResearchGate, delimited by the dates 2000–2017, I searched for "gender," AND learning, teaching, higher education, design, technology, learning technology, public education, educational technology, instructional design, learning design, social media, ICT, workplace, adult learning, distance education, curriculum design, blended learning, blogs, online learning, professions and disciplines (e.g., engineering, teacher education, IT), access, and digital divide. These combinations and recombinations resulted in a snowball effect, leading me to additional resources. I also searched for curriculum resources, conference programs, reports from task forces and committees, and stories from popular media sources. I included international sources in particular those from Europe, Africa, the Middle East, South Asia, and South America. Because the editors, in essence, rejected an approach of technological determinism and charged contributors to "focus on educational needs and cluster the field's scholarship around the role educational technologies play in the solution of those problems, rather than vice versa," I did not use technology-specific search terms (e.g., MOOC), although I did include terms reflecting ways of learning or learning contexts (e.g., online learning). Instead, I took a sociocultural lens to focus on issues of inclusion, access, equity, and engagement. I retrieved over 400 articles from these sources that I then examined for recurring themes and approaches, setting aside those that may have described interesting research whose focus was not repeated in other literature I surveyed.

Finally, and essential to the sociocultural lens through which I've filtered by my understanding, and presentation, of the findings of my review, it is necessary to define two important terms, "gender" and "intersectionality."

The Meaning of Gender

It is important to problematize the term "gender," as gender is understood and implicated in different ways among cultures, through language, and in time, I propose that the research and practice we appreciate in 2017 reflects evolving conceptualizations of gender. Tuula Heiskanen, University of Tampere, Finland, references the work of Joan Acker (1997) and West and Zimmerman (1987) in acknowledging that gender has consistently proved to be complicated and complex. In North American academic writing, gender and sex have almost become interchangeable when one refers to social roles, while the other refers to biological attributes. Heiskanen (2006) explains that a concept of gender that includes relevant aspects of social structure and social process is necessary to guide organizational interventions, such as design. In this view, gender is conceptualized as an activity, rather than a state. Heiskanen traces the notion that gender is something that one does, rather than something one is, back to Birdwhistell (1970) and especially Butler (1990) who "understand[s] gender as a relation among socially constituted subjects in specifiable contexts" (25). This performance notion of gender has framed the work of cybertheorists, who have studied whether online communicators are theoretically free to perform any identity, gendered or otherwise, that they can imagine…because text-based CMC filters out cues such as voice and physical appearance (suggesting that) online personae can evolve existences independent from their flesh-and-blood animators, shaped by the social interactions and the contexts they encounter online (Herring, 2004, 426).

Interested in how gender identity is implicated in different positions in social organizations (e.g., schools and workplaces), Acker (2000) understands gender as "patterned, socially produced distinctions," proposing that gender inequities occur by way of unquestioned assumptions and values "rooted in taken-for-granted assumptions, values and practices that systematically accord power and privilege to certain groups" (in Heiskanen, 2006, 524). These practices may limit the activities of organizations in multiple ways by closing out, for example, alternative arrangements in organizing work or learning (e.g., online learning, telecommuting), in defining work or learning tasks for men and women (e.g., administrative vs leadership), in arranging the relationship between work or learning and family, and in judging collaborative forms of work or learning not aligned with an individualistic and competitive ideology (c.f. Inkpen et al., 1994).

Kirkup (2002) presents Harding's model (1991), with its four aspects of gender, as a useful framework with which to understand the different kinds of interaction between women, men, and ICTs. Harding defines gender at its most simplistic as (1). a property of individuals; the ground of our gendered subjectivities, developed in the context of the other three aspects of gender: (2). Gender as a relation between groups, a property of material structures (e.g., gendered workplaces); (3). Gender as a property of symbolic systems, where representational systems, language, and imagery are gendered (e.g., the language of programming, and images like Lara Croft); and (4). Gender as identity, in all its complexities. Consider the young girl who encounters Lara Croft during gaming. And, although gender is not admitted as a way of determining how to distribute scarce resources (at least at loud), we have seen it resulting in gender-based access to ICT resources, for example.

From this point of view, a possible explanation for the status of women in ICT relates to the cultural "understanding" of technological work/skills, that is, these activities are part of what constitute masculinity (Cockburn, 1983, in Kirkup, 2002). Kirkup quips that "It is easier to change an activity with which you are simply associated than change your relationship with something that constitutes a key aspect of your identity" (5).

Consider these processes in the following description of Dr. MOOC (Box 1), a narrative-based MOOC designed to explore the role of the Internet in increasing health literacy among the general (Austrian) population, and how the physician–patient relationship is affected (Höfler, Zimmermann, & Ebner, 2017, p 107).

Kirkup (2002) points out that the rhetoric which suggests that new industries are both "gender blind" and that reward communication skills and feminine models of leadership (i.e., soft skills) is not borne out by research on the status of women in ICT professions. Woodfield's (2000) study of a new high-tech ICT company showed that men were promoted and given management responsibility despite an acknowledgment by the company that they had poor management skills, accompanied by the unwillingness to give responsibilities to similarly qualified women who were

Box 1 Dr. MOOC

A global phenomenon noticed by general practitioners and specialized physicians is the tendency for patients to come to their appointments with previously acquired medical information from online sources. While the trend has health-related risks (e.g., substituting advice from popular, invalidated sources for professional advice), there is potential to democratize the access to medical knowledge (and its understanding), which has previously been a highly restricted privilege, guarded by (predominantly male) practitioners. The narrator, a key element of the design, is male…"a person the participants can trust in, since he is an expert in this field…His appearance on a weekly basis serves as the frame that organizes the process of content reception…(he) is non-focalized, as he knows, tells, and considers the thoughts and stories of each protagonist in his personal analysis….the audience thus gets more familiar with the case studies, the general practitioner's experience, and opinion" (p 55). Even though the designers of this *suspense peak narrative* MOOC acknowledged that the audience, or learners, are the most important design aspect of any MOOC their taken-for-granted assumption that a male physician would reflect the expert, trustworthy voice to all participants, regardless of sex or gender, reflects the creation of forms and symbols and patterned social interactions that represent gender divisions.

acknowledged to have these skills. Woodfield's study, and numerous studies since (Millar & Jagger, 2001) show that "gender is re-asserted and jobs acquire gender quite quickly in some communities of practice" (4).

According to Acker (2000) what really complicates change, or the success of intervention, is that the embeddedness of gendered assumptions in organizational (pedagogical) practices makes gender both pervasive and invisible; it is difficult to see that practices actually contributing to gendered consequences have anything to do with gender. More recently, growing sensitivity to gender identity and sexual orientation in Western education systems and organizations has compounded the complexity of these issues; globally, considerations of cultural and social values and practices result in the challenge of intersectionality.

The Meaning of Intersectionality

Through intersectional theory, identities are understood to consist of multiple social dimensions of difference, such as gender, race, sexuality, and/or class, and proposes that the complex interconnections between these dimensions have significant consequences (c.f. Davis, 2008). To ignore intersectionality in discussions about gender representation in learning environments has resulted in limited understandings of disparities in fields such as health care (see Box 2, Anatomy and intersectionality). For example, the effects of gender bias are shown to increase when intersectional determinants of health such as class, ethnicity, and sexuality are taken into account (Hankivsky, 2012). Adopting intersectional theory may encourage designers and educators to consider different representations of identity, social position, and processes of oppression or privilege.

Box 2 Gender Representations in Anatomy Textbooks
In a study of 17 anatomy textbooks used in Australian medical school curriculum, Parker, Larkin, and Cockburn (2017) found that less than 1% of the 6004 images reflected intersex or transgender people, suggesting that these communities have been persistently marginalized. Citing Bauer (2014), they point out that "ignoring intersections of gender with social characteristics such as ethnicity and age, medical research lacks a comprehensive understanding of the effects that heterogeneity have on health" (p. 110). In the same study, only a single representation of an Indigenous American (male) person was found, suggesting that representing more than one degree of difference presents a challenge to designers.

Research Is Socially Situated, and So Is Gender: A Context for Emerging Trends in Educational Technology Research

In this section, I provide a quick tour of research related to the intersection of learning technologies and gender circa 1980–2000. This era was characterized by a focus on technologies or tools and reflected the cultural domination of the West. Research methods ranged from quasi-experimental to descriptive and tended to relate to educational interventions on a fairly small scale. Researchers were interested in delivery formats (e.g., distance education), computer-mediated communication (CMC), software and game design, affordances of learning management systems and related implementation issues, access to broadband and ICT at home, school, and in the workplace (digital divide), career choices, technology adoption, and psychosocial barriers to participation.

The Cultural Deficit Model

Chikunda and Chikunda (2016) point out how the discourse of "opportunities toward education for all are there, the fault is theirs (girls) not the system" is ideologically laden with functionalist, instrumentalist views. In this discourse fragment gender equality is seen in a narrow sense that "includes physical access: the belief that once girls and boys are exposed to the same curriculum, taught by the same teacher, read the same book, there is equality" (p. 17). These authors observe that the assumption that "access" is sufficient for equality overlooks existing gendered social relations in school bureaucracies, curricula, teacher preparation and assignments, and the systems of instruction in the societies of which they are part. In terms of gender issues, prevailing discourses reflected a liberal feminist liberal interpretation, that is, how the context disadvantaged girls and women, and what interventions might be effective at "narrowing" the gaps, what those looking at issues of cultural difference, disabilities, etc. have termed the " deficit model" (c.f. Tong, 2014). In other words, women were problematized rather than technology.

> "The cultural deficit model stems from negative beliefs and assumptions regarding the ability, aspirations, and work ethic of systematically marginalized peoples. It asserts that (individuals) often fail to do well in school because of perceived 'cultural deprivation' or lack of exposure to cultural models more obviously congruent with (school) success…often enter(ing) school with a lack of "cultural capital" (Bourdieu, 1997, in Izarry, 2009), cultural assets that are affirmed by schools and often shared by school agents and therefore considered valuable" (Izarry, 2009, n.d.).

Research grounded in this perspective blames the victims of institutional oppression for their own victimization, using negative stereotypes and assumptions regarding certain groups or communities, thus overlooking root causes of oppression by localizing the issue within individuals and/or their communities. Interventions are then targeted toward the passive "challenged" person by others, rather than to the environment that, by its design, supports disadvantages. In other words, in the individual deficit model is the belief that it is the "challenge," be it mental, physical, or sociocultural, which causes the continuing inability of the individual to function normally. The cultural deficit theory is one lens that we can take to the problem of intersectionality, or multiple intersecting oppressions, such as those identified by Parker and others (2017) in the Australian anatomy textbook study. Of course, institutionalized systems (of learning, work, and living) are slow to react and transform, throwing more recent researchers back onto psychologically based explanations, such as women's lack of confidence and interest in ICT, women's poor self-efficacy, a lack of role models in schools and professions. Kirkup (2002) "want(s)to place them in the wider context of social learning, and of ICT related skills as grounded in communities of practice with dynamic gender systems" (p. 5).

Methodological Issues

Criticisms of "the first two decades" of research in educational technology include the "ill-conceived and unproductive" emphasis on questions such as "Is a technology-based method better than a non-technology-based one?" (Schrum, 2005, p. 218); the focus on both the "lack of guiding theory as well as the failure to provide adequate empirical evidence on many salient outcome measures" (Bebell, O'Dwyer, Russel, & Hoffman, 2010, p. 31); the "focus on technology access instead of measuring the myriad ways that technology is being used, (assuming)s that teachers' and students' access to technology is an adequate proxy for the use of technology" (Bebell et al., 2010, p. 34), and often defining technology use as a single dimension. Bebell and others (2010) also urge researchers to "consider the statistical and substantive implications of the inherent nesting of technology-related behaviors and practices within the (school) context" (p. 46), which addresses the social situatedness of technology-based teaching and learning.

In 2002, Winn discussed educational technology research moving through four "ages": the age of content, or focus on cognitive science; the age of message design, or format, in which individual differences were considered; the age of simulation, or focus on interaction, in which learners were encouraged to take control of the material (i.e., constructivism); and, finally, the focus on learning environments, in which the environments could be either natural or artificial, "existing only through the agency of technology" (p. 335). Winn observes that an advantage of looking at social interactions is that the "conversations among students are themselves useful data sources. Thus, discourse analysis can shed light on the processes and products of learning" (p. 340). Winn cites Malarney's (2002) study showing that technology alone is not sufficient to create a successful learning environment, that "features of learning communities, where the responsibility for helping students is widely distributed, must be developed if learning is to occur" (Winn, 2002, p. 342). Reeves (2000) concurs with Winn that educational technology research has often been disconnected from practice, in that studies have been designed for laboratory settings, assuming that factors could be controlled; and practitioners have been hard-pressed to find, interpret, and actually use the information, materials, and programs of activities that the research has created. Both Reeves and Winn champion design-based, or development, research as an anecdote to this problem. Reeves locates a range of researcher goals in a simple taxonomy of six research methods that reflect various epistemologies and paradigms, in particular researchers with theoretical, empirical, interpretivist, postmodern, development, and action goals.

Goals of Research

For example, Reeves (2000) characterizes researchers with "interpretivist goals" as focused on "portraying how education works by describing and interpreting phenomena related to teaching, learning, performance, assessment, social interaction, (and) innovation" by "drawing upon naturalistic research traditions borrowed from other sciences such as anthropology and sociology" (p. 6). This perspective has only recently been evident among instructional technologists and is viewed with some suspicion (Reeves quotes a source describing qualitative research as "useless," p. 6). Interpretivist researchers use ethnographic methods such as observations, case studies, interviews, and other qualitative data.

Researchers with postmodern goals often employ critical theory methods such as deconstruction of "texts", or the technologies and systems that deliver them, to examine the assumptions underlying contemporary educational programs and practices with the ultimate aims of revealing hidden agendas, binary oppositions, and/or empowering disenfranchised minorities. Reeves (2000) describes this paradigm as "very rare" in our field although "increasingly evident among researchers with strong multicultural, gender, or political interests" (p. 6). He cites the difficulty postmodern researchers have in finding scholarly outlets for their papers as one reason for this. Incidentally, this has been my own experience as a researcher concerned with gender and power.

Researchers with development goals are focused on the dual objectives of "developing creative approaches to solving human teaching, learning, and performance problems while at the same time constructing a body of design principles that can guide future development efforts" (Reeves, 2000, p. 7), such as the theoretical model of anchored instruction developed by the Cognition and Technology Group at Vanderbilt.

The works of Martin, Diaz, Sancristobal, Gil, Castro, and Peire (2011), and of Hsu, Hung, & Ching, (2013) illustrate how interest in, research about, and subsequent development of understandings and interventions in and/or design of learning environments are socially situated. Martin and others analyzed the predictions of the *Horizon Reports* 2004–2011, studying metatrends and evolution flows of the technologies predicted to be ascendant in those reports. Hsu, Hung, and Ching completed a bibliometric study of educational technology articles published in six SSCI-indexed journals over 10 years.

Bibliometrics and Research Focus

Based on the number of technologies forecasted by *Horizon Report* (*HR*), the "SocialWeb" was the most promising technology from 2005 to 2008. However, this changed in the 2009 *HR*, as only one related technology was forecasted, namely, the personal Web, which is less related to experiencing social collaboration than to "using social-based knowledge to build user-centered content" (1896). This trend continues in the 2010 *HR* which predicted no social Web technology. The long-term forecast, 2012–2013, focused on social operating systems that organized social networks around people instead of around content, including "collective intelligence," based on knowledge generated by large groups of users, such as on Wikipedia.

The "SocialWeb" was predicated on collaborative tools for communication among learners over the short term, including virtual collaboration tools (known as social computing) and the broadcasting of user-created content such as blogs, wikis, and audio/video-based tools like YouTube. This phenomenon of social networks in the educational environment, based on the idea of providing students and educators with advanced communication and collaboration tools and the creation of a network of contacts to support a highly engaging environment, put the user actively at the center of action. "The Web 2.0 philosophy, in which content is the key driver of new media applications and collaboration and social interaction are the driving forces behind opinions (e.g., through blogs), knowledge (e.g., on wikis) or the sharing of digital artifacts…inevitably lead to the emergence of virtual communities that enable social networking" (p. 1896). Jarvis (2009) characterized audiences as having "shifted from a niche of masses to a mass of niches, in which service personalization, content creation, and knowledge acquisition are driven by social interaction" (in Martin and others, 2011, p. 1896). If the one-size-fits-all paradigm no longer fits and the learner is the center of the educational process and thus requires adequate technological support to create, communicate, collaborate on, and access personalized services, the focus must then shift from intervening with the user (the deficit model) to intervening with the social/technical environment.

Similarly, today's students have grown up with a new class of technologies that the previous generation might not have imagined, including smartphones with video capability, which deeply impacted our society, changing the way we communicate with and keep in touch with one another. These devices are changing the way we work by supporting a variety of applications (including typical office applications, the Internet, and e-mail), the way we spend our spare time (e.g., with video games, Internet videos, and podcasting), the way we obtain and share information (including through GPS navigators, augmented reality, Web surfing, and blogging), and the way we learn. Some *HR* predictions were right, for example, social networks, user-created content, virtual worlds, mobile devices, and grass-roots videos; but others did not have the expected impact, for example, learning objects and ubiquitous computing. Martin and others (2011) point out that the increasing importance of mobile devices in education is fostering all the technologies related to them because of the social and cultural transformations involved in using them. Consequently, for example, our research interests continue for gender implications in discourse analysis of social media.

In their bibliometric study of research trends, Hsu et al. (2013) use "Feenberg's Critical Theory of Technology" (2009), a framework to analyze technologies and technological systems at multiple levels, to interpret and reveal thematic cultural clusters across six journals in five countries. According to Feenberg (2009), technology is a two-sided phenomenon that involves the operator and the object. Where both the former and the latter are human beings, technical action is an exercise of power. They show that Taiwan, among the Top five prolific countries in EDTECH research, showed different research interests compared to the other four countries that showed similar research interest. They posit that research directions in Taiwan had been highly influenced (i.e., restricted) by government policies, to wit, all e-learning-related policies fell under the framework of "National Program for e-Learning" which comprised three major goals: (1) improve public welfare; (2) develop Taiwan's e-learning industry; and (3) stimulate e-learning research, especially in new learning technologies, methodologies, systems, and tools. Scholars with the aforementioned research foci could more easily obtain grant support from the government (Hung, 2012, in Hsu et al., 2013). Because the "National Program for E-learning" framework encouraged the development of new learning technologies, it resulted in the phenomenon of scholars in Taiwan generating large numbers of publications on the topic of "Automated Instructional Systems"(p. 694). In other words, government policy and/or ideology, through funding mechanisms, direct(s) research agendas, for example, in Europe (c.f. SHARE, http://www.share-project.org/home0.html).

Hsu et al. (2013) also show that articles published in a journal and the journal's aim and scope (and editorial policies) might also play the role of operator in shaping research trends in the field, supporting Reeves' (2000) observation that difficulty in getting one's research placed, in part because of research epistemology, may limit the field's exposure to emerging trends and concerns, especially where the research has postmodern (or post-structural) goals. Therefore, researchers' interests can be shaped and greatly narrowed if they want to publish in this top-ranking journal. When one journal has an exceptionally higher number of publications than others, the research trends of the field might be distorted and highly correlated with one single journal. For example, if qualitative research is not valued as credible or useful, narrative accounts of learning experiences (i.e., meaning making) may be rejected and therefore be discounted, a challenge when examining sociocultural perspectives related to technology. According to Hsu et al. (2013),

> the direction of technology development is top–down rather than bottom–up….This one-dimensional technical system (Feenberg, 2009) is likely to create resistance among the users….Feenberg suggested democratization of technology could be a solution by opening up technology to a wider range of interests, concerns, and feedback, which could lead to redesigning technology for greater compatibility with the human and natural limits on technical action….The spirit and nature of Web 2.0 generation of technologies encourage participation, creation, and sharing (and)...in general pose relatively low technical threshold for users, making it more likely to empower and involve users, which could help level the field for the operator and the object and encourage feedback that helps alleviate resistance (p. 701).

Gender and Learning Research Circa 1980–2005

At the beginning of the chapter, I recapped the work of researchers from the beginning of the so-called age of millennials, or digital natives, in terms of the issues they identified that were influencing the experience and success of girls and women with technologies for learning and work. Many of these concerns, and recommendations for amelioration, were located in individual behavior, "and not as the outcome of a network of deep and unconscious dynamic relationships" (Kirkup, 2002, p. 8). For example, in questions of who has access to the best technology at home, although the family is acknowledged as key to the production of gender and gender relations, the suggestion to create a family computer seems to forget that any technology brought into the family will acquire gender, depending on its status as a family resource and whose activities it supports (Kirkup, 2002). Findings from this period of research activity are summarized in Table 1: *Gender and technology research findings to 2005.*

In this section, I have provided a quick overview of the topics and methods related to gender and technology issues for approximately two decades, the 1980s, when personal computers became widely available; through the 1990s, and the rise of the Internet; and early 2000s, during which Web 2.0 was taken up. I have located these research trends in a sociocultural analysis of the research context(s) and have

Table 1 Research and recommendations circa 1990–2004

Issue	Findings	Recommendations
CMC	Discourse on CMC is gendered; gender preferences in discourse style exist In academic listservs, women used more hedges, politeness markers, language supportive of other participants' views; and …men made more strong assertions, violated conventional politeness norms, and adopted more adversarial stance toward their interlocutors Women's contributions are mistakenly attributed to others, or to luck more often than men's, and they receive less attention and encouragement from instructors Gendered power dynamics in an asynchronous academic discussion list, with men and high-profile members of the community dominating communication, even under conditions of pseudonymity Style of talk very dialogue-oriented, privileging the expository style most associated with male participants, reflected in adversarial relationships: Put-downs, strong, often contentious assertions, lengthy and/or frequent postings, self-promotion, and sarcasm If women contributed more than 30% of the conversation in CMC, they were perceived to be dominating conversation, by both men and women Women will behave consistently with maintenance of socio-emotional group process roles and men will behave consistently with a task-oriented role Concern about online gender harassment	Consider the effects of lack of social cues Discuss with class issues of identity, language use, and tone, acceptable ways to disagree with or challenge the views of others, and length and number of postings Facilitator modeling and support for diverse views and experiences, expressed in safety, must be explicit Swift interventions when interactions go awry

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Distance learning	Women have less access to resources Women are economically disadvantaged – Less access to higher education at a distance, less discretionary income for computers, less access to computer support Women suffer the "third shift" where their learning requirements are not valued equally Differences in the preferred learning styles of men and women make them respond differently to distributed learning methods; women less comfortable with isolation Female students use e-mail less frequently, spend less time online, and engage in fewer varied activities Families and other social structures in the community may marginalize women who are otherwise candidates for distance learning Inflexible schedules and deadlines for assignments and exams, requirements for technological tools may be out of women's economic reach Learning activities that may require travel, extra fees, and special arrangements, such as videoconferencing	Open registration Flexible deadlines Opportunities to borrow or rent IT Peer support Opportunities to meet F2F occasionally Collaborative learning activities Community-based learning centers

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Computers in the classroom	Classes are tedious and dull, too focused on productivity or programming Computer career options uninspiring and require "male" skills	Emphasize harmony with nature, concern for others, empathy, and compassion. Women show a preference for working with scientific concepts with social value, concern with consequences of action on others, and an ethic of care
		Gender-neutral, open-ended creative tasks such as collaborative writing
		Support the inter-relatedness of perspectives
		Teach about, and for, social and political activism and agency
		Avoid competitive and aggressive metaphors from games, sports, adventures, and war
		Evaluate visual imagery and design for bias
		Allowing for alternative representations through dynamic processes and the linking of verbal, visual, and aural information to support diverse learning styles, preferences, and experiences
		Include large databases of resources that invite the inclusion of experiences of women and other marginalized groups
Access, digital divide	Unequal access begins in the home and at school, ranging from a 2:1 ratio to a 3:1 ratio in favor of male ownership of computers Access becomes an effective gatekeeper for women Males have faster computers and more time on them Males dominate classroom, develop and foster community-based learning centers with guaranteed access to standardized learning technologies computing time Females feel excluded from computing environments Access relates directly to experience by influencing attitude and achievement	Place computers in accessible home spaces. Shared or family-centered activities on the computer, rather than viewing its use as an individual or isolated activity
		Cohort-based learning models
		"Rent-to-own" or "work-to-own," leasing, "evergreening," and interest-free loan

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Game design	Computer games too boring, redundant, and violent Gender ideologies are replicated in game design Girls prefer activities that are collaborative, based on narrative Computer arcades are male dominated (experience gap)	Girls as designers
		Stress characterization and relationships
		Games that feature simulation, strategy, and interaction.
		Games that are narrative-based
Interface and software design	Girls are alienated by individualistic activities based on metaphors of exploration, adventure, conflict, and competition Interface designs range along cultural dimensions, including masculinity and femininity Digital media simply replaces traditional media with no same problems in design, etc. Language and metaphor of ICT are not gender-neutral Highly structured computer-based designs available are counter-intuitive for women learners	Computing activities that are socially contextualized, that address social issues (e.g., poverty)
		Portray women as problem solvers rather than as victims or prizes
		Represent objects or issues studied holistically
		Games that are team-based
		No arcade-style designs
Post-secondary emphasis, STEM subjects	Large dropout of women students following increased recruitment Number of women diminish in STEM classrooms in upper levels	Change the first-year course curriculum Involve the most experienced teachers more with the women students in the early stages of their study.
		Unisex classrooms, female-only computer access
		Contextualize computer science
		Required computer literacy classes for all students
		Create more interdisciplinary courses

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Spaces	Computer labs are male-dominated and isolating Women feel unsafe because of design of labs and times of access Technological environments encourage autonomous learning, since cooperative learning was difficult to implement in fixed computer labs in which data could not easily be shared	Location of computing facilities in campus areas where women learners and women faculty members are concentrated
		Same-sex computer classes, as one learning option available
		Alternative designs of computer spaces, such as pods of four to encourage cooperative work
		Designated "women-only" lab time, with a less competitive climate and more personal interactions around problem-solving and computer anxieties
		Computing facilities that are supervised at all times, or especially in the evenings
Workplaces	"Chilly climate" Access to resources often status-based; women have lower status Fewer women are supported for continuing learning or training "Women's work", e.g., women hired as administrative staff	Organizational policies that explicitly address gender bias
		Mentors
		Family-friendly policies
		Clear expectations set
Models	Computers as productivity rather than creativity tools not appealing to girls Content not female-friendly Computing activities and environments are male-dominated	Teacher professional development
		Content should include female role models
		Encourage more women to major in STEM
		Encourage networking
Adoption of technology	More male than female faculty are early adopters Female faculty tend to use technology to create learning communities while male faculty tend to use technology more to support didactic approaches	Match technology use to teaching styles
		Design learning spaces to encourage collaborative uses of technology
		Ensure technical support available
		Professional development
Virtual worlds	Men have adopted female pseudonyms in order to belong to restricted conversations and once included, then have harassed participants for their views	Women must be cautious about publishing any information about themselves
		Be careful when approving pseudonymous posting

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Assessment, outcomes	Girls do not do as well in online activities (e.g., math)	Emphasize computer fluency: Girls" mastery of analytical skills, computer concepts, and their ability to imagine innovative uses for technology across a range of problems and subjects.
		Peer tutors
		Peer assessment
Identity	Feminization of the internet where women are targeted as commercial markets – As consumers rather than as citizens or learners	Women as content developers
		Networks that create opportunities for women in all areas of life
		Internet as community

proposed that the more recent research trends reflect less emphasis on experimental designs in favor of action, interpretivist, development, and postmodern goals for research (Reeves, 2000). Research since the mid-2000s, approximately 2005–2017, reflects the sociocultural context in which research in education is located in general.

Gender and Learning Research Circa 2005–2017

In the USA, the Institute for Women's Policy Research (IWPR, www.iwpr.org) tracks the gender wage gap over time in a series of fact sheets updated twice a year. Noting that in nearly every single occupation for which sufficient data are available, the gender wage gap had stayed essentially unchanged since 2001, meaning gender wage parity will not be achieved until 2059 if the pace of change remains the same (longer, if including ethnicity). Not surprisingly, projections show that equal pay would cut poverty among working women and their families by more than half and add $513 billion to the US economy. Why don't women choose higher paying jobs? There is considerable evidence of barriers to free choice of occupations, ranging from lack of unbiased information about job prospects to actual harassment and discrimination in male-dominated jobs, such as IT-related jobs under scrutiny in Silicon Valley and technology-related jobs in the "gig economy" (c.f. Priest, 2017). If we take the lens that one purpose of public and higher education, at its very best, is to even out socioeconomic and cultural disparities over time, presenting all learners with equal access to the social capital they need to acquire to succeed, and that the implementation of learning technologies in our schools is/was a tool for that purpose, research about its use accumulating over four decades, why do we not now have the outcomes that are reflected in measures such as the gender wage gap?

The answer to this question is, of course, very complex, and the question itself assumes causality. However, part of the understanding of this conundrum lies in enhanced awareness of the contexts in which research and interventions are designed, implemented, and evaluated (see the discussion of research trends, above). For example, the rapid advent of the "social Web" has contributed to global participation in social action in which knowledge is co-produced and represented quite differently than it was when print sources embodied such authority. Networks have rendered landlines almost obsolete; children in "developed" countries are born into communities in which personal computing is ubiquitous; evidence is contested; and gender roles are fluid. Technology has changed work; expectations about career trajectories have been disrupted. In fact, the "social order" is under constant disruption. In this context, gender is a social category rather than a biological determinant. Consequently, research about gender and learning technologies must become questions of sociocultural dynamics at home, in the community, at school, and at work.

Typical Research Questions

For example, in the late 1990s, as the Internet became easier to use and more accessible in education, the first learning management systems (LMS) like WebCT were developed to help manage resources and interactions with content and course participants. Research in this era was concerned with access, adoption, effectiveness and attitudes, and learning transactions. Questions reflected something akin to fatalism ("it's here, no matter what, we must use it") and an assumption that constructs, like gender, were stable and constant. "Why are female faculty slower to adopt learning technologies?"; "Why are adult female learners reluctant to approach technology?"; "Why don't girls like to play games as much as boys?"; "Do learners in an online course do as well as learners in a face-to-face setting?"; "Do women's discourse styles disadvantage them in CMC?" Questions like these focused our attention on differences, and suggested ways to narrow the so-called performance gap. For example, images representing IT careers were not "internationalized" simply by depicting a group that included a woman in a hijab working with male colleagues – such a solution did not consider how workplaces are gendered in various ways, and for various reasons, in areas of the world (see Intersectionalities, above).

For this chapter, I thought it would be useful and revealing to revisit productive areas of research, or compelling issues, over time. For some issues, this approach revealed progress in how we framed our problems, but for others, the questions were no longer relevant or significant. What emerges is a more nuanced and socially informed picture of gender-related issues in learning at all levels. These issues are interrelated in complex ways. For example, pedagogical practices must include an understanding of the influences of cultural and psychosocial factors. The same factors, plus the intersection of age, gender, access, and design must be considered in a discussion of the post-secondary learning environment. Stereotypes and implicit bias contribute to pedagogical practices, workplace climate, design, and representations in texts and language, intersecting with age, culture, and gender. In essence, though, if girls do not feel successful in science, technology, engineering, and mathematics, there will be fewer role models for artifacts such as texts and media, roles in public and post-secondary environments for girls, and gender influences on social systems and structures, such as the design of products and services and the climate in the workplace. This holds true globally. So, while I have identified seven domains of interest, they should each be read with the understanding that common threads run through them, those of unconscious (and conscious bias), cultural values, social context, political will, and unequal distribution of resources.

Culture and Gender Stereotypes: Bias and Representation

One of the enduring problems confronting educators in the disciplines.

of science, technology, engineering, and mathematics (STEM) is the disproportionate lack of involvement of females. Although females' lack of participation has been attributed to biased curriculum content, others attribute females' lack of interest to pedagogical approaches rather than to the inherent nature of the subject. Culturally grounded gender stereotyping is a significant challenge in its substantial influence on children's self-concepts. In a variety of ways, the media, peers, and adults communicate and reinforce gender-based stereotypes (Martin, Eisenbud, & Rose, 1995). For example, toys have a powerful influence on what children perceive as appropriate for boys and girls.

Toys designed for boys tend to be highly manipulative or electronic, whereas, girls' toys are less likely to be manipulative or have interchangeable parts (c.f. Caleb, 2000). Girls' toys also tend to feature interpersonal interaction, such as dolls, which encourage the development of social skills and relationships (Weber & Custer, 2005, p. 55), skills globally understood to be critical in the workplace.

Using a critical discourse analysis (CDA) approach, Ghajarieh and Salami (2016) studied Iranian educational resources, including textbooks, for English as a Foreign Language (EFL) at secondary, high school, and pre-college levels. The researchers sought to explore "whether the subversive gendered discourse of equal opportunities in male and female education as the subordinate discourses to the discourse of equal opportunities has been given sufficient backing" in Iran (p. 259). In CDA, language is considered a social practice occurring in a cultural context (be it an organization, a religious community, or a geopolitical region); issues of primary concern are those having the potential to discursively circulate power and ideology, for example "gender". As Sunderland (2004) notes, "the social issue and dramatic problem [in gender studies] is gender—an issue and often a problem for women and girls; in different ways, for men and boys; and accordingly, for gender relations" (Sunderland in Ghajarieh & Salami, 2016, p. 251). As demonstrated in the study of Australian anatomy texts, the marginalization of different minority groups and the underpinning of power imbalances in language, represented in verbal and visual texts and spoken language, ensure the dominance of powerful groups over other groups, including women. CDA focuses on text analysis to explore power, ideology, and identity, that is, the construction of knowledge, power, and identity through the close analysis of language texts (Ghajarieh & Salami, 2016). Sunderland's model of

CDA stresses the representations of male and female social actors through gendered discourses in text and reveals how instances of discourse "constructs, reiterates, or subverts ideology and social power" by examining the lexical and grammatical items that are chosen among all choices available to text producers within a gendered discourse (Ghajarieh & Salami, 2016). For example, would female actors be individualized and functionalized in spheres that were not "traditional?"

Employing this approach, Ghajarieh and Salami (2016) compared different samples from one Iranian EFL textbook, finding that no female actors were functionalized as "college student," but that male actors were individualized through masculine pronouns (e.g., "he") and functionalized as perspective college students, as in the following example, "He is working hard. He wants to go to university. He plans to study physics. I think this is a good end" (High school level, Book III, p. 23). In this case, female social actors functionalized as students were not assimilated as a group of students studying together with male students; the related images featured male and female students as separate groups. "This notion indicates that the functionalization of male and female social actors was defined only within a narrow perspective in line with the notion that women and men should be separated in public places, including educational settings" (p. 266). Furthermore, in the textbooks, female social actors were not individualized and functionalized in high-level jobs. Male social actors were represented in 89 cases as engineers, bus drivers, policemen, scientists, and dentists/doctors, while female actors were not represented at all in these professions, for example, "Mr. Amini is a doctor"; "Even though he was a computer engineer, he didn't know how to fix the computer." Furthermore, these representations support the discourse of "Women's marginalization in sciences, technology, and medicine" and resist the discourse of "equal education opportunities for both men and women." This is important to note since distorted representation of reality may convince the reader that the excluded identities and groups are not important. "The resistance against the discourse of equal education opportunities for men and women in Iranian EFL textbooks show inclusive education has yet to be achieved in the education system of Iran" (Ghajarieh & Salami, 2016, 267). Since school educational materials can mirror curricula used in the education systems of many countries, curriculum designers and textbooks writers need to consider policies, school textbooks, and material for intersections in gender, sexuality, race, ethnicity, religion, and other individual differences in education.

The "Gender Schema Theory" is another frame for understanding and intervening in how learners may actively seek gender-related information which will serve as a guide for their own conduct (Navarro, Martínez, Yubero, & Larrañaga, 2014). For example, with regard to gendered color preferences, girls can develop a stronger preference for pinks, purples, or reds when they notice that other girls wear clothes and accessories in these colors, whereas when boys make the same observations, they can reach the conclusion that pinks or purples are not suitable for boys and will avoid wearing these colors. Navarro and his colleagues (2014) observed that learning and the interiorization of these gender schemata "may influence social information processing, the undertaking of tasks and decisions making related with colors" that should be taken into account when planning educational actions, such as developing visuals, intended to modify gender stereotypes (p. 160).

Woods, Comber, and Iyer (2015) found their approach to inclusive educational design on principles of social justice, which require that "the curriculum and pedagogy offered recognises the unique and community characteristics and strengths of all children, their languages, ways of knowing, cultural and social beliefs, values and practices" (p. 46). They describe the foundations of their work coming from approaches broadly conceived as sociocultural, critical theorizations of literacy, including feminist, postcolonial, and post-structuralist orientations to issues of race, gender, sexuality, class, locale, and disability, or a "three-dimensional approach to social justice" (c.f. Fraser, 2009). In terms of curriculum design, learners will see their own languages, values, ideologies, interests, and communities reflected in the curriculum and pedagogical approach. The approach requires recognitive, redistributive, and representational action, with the intent of widening access "to the dominant skills, knowledges and understandings of education systems and society more broadly" (Woods, Comber, and Iyer, p. 50). The authors utilize this critical lens in their approach to game-based learning (GBTL), in which they use games as objects of study of cultural phenomenon, as well as learning products designed by students. "Activities Frame," one of the four pedagogical models they describe, includes studying an element of a game, for example, a critical analysis of gender representation, as well as playing the game to learn something, for example, cooperative play. An obvious response is for teachers in programs of curriculum design to learn about these approaches and exemplify them in their own practice. GBTL thus can be based on a "multiliteracies" framework that reflects on, and is reflexive about, designing for difference. An explanation of this framework for learning design is described in Box 3, *Multiliteracies*.

With regard to stereotypes about math and science, two are prevalent, that is, that girls are not as good as boys in math, and scientific work is better suited to boys and men. As early as elementary school, children are aware of these stereotypes and can express stereotypical beliefs about which science courses are suitable for females and males (c.f. Nosek, Banaji, & Greenwald, 2002). Furthermore, Buck and colleagues found that girls and young women have been found to be aware of, and negatively affected by, the stereotypical image of a scientist as a man (Buck, Plano Clark, Leslie-Pelecky, Lu, & Cerda-Lizarraga, 2008).

Discussing the cultural construction of computers as male, Sherry Turkle (2001) recounted a story about negative stereotypes.

> When I was a girl, I once wanted to build a crystal radio. My mother, usually very encouraging, said no, don't touch it, you'll get a shock. And I began to become reticent about such things as building crystal radios. It wasn't that I didn't want to build it-I wasn't phobic. But somehow, this just wasn't what girls did. I became reticent. Interview with Sherry Turkle. http://www.priory.com/ital/turkleeng.htm

Research has consistently found that "stereotype threat" adversely affects women's math performance to a modest degree (Nguyen & Ryan, 2008), accounting for as

Box 3 Multiliteracies
In 2000, the *New London Group* proposed "multiliteracies" as a framework that could provide a socially just and inclusive approach to teaching literacy. The framework supports transformative learning that takes into account the personal resources that learners bring to knowledge construction. A designer using this approach develops "grammars" that are learned along with elements of visual, audio, gestural, spatial and multimodal designs. A key element to this design practice actively engages learners in both designing texts and redesigning them to reflect new meanings. Four pedagogical components are involved: (1) situated practice, which situates learning in meaningful sociocultural contexts; (2) overt instruction, involving the teacher to make explicit links; (3) critical framing, "denaturalizing" concepts learned; and (4) transformed practice, which encourages learners to apply new learning in different contexts or sociocultural routines (c.f. Giampapa, 2010; Leman, Macedo, Bluschke, Hudson, Rawling, & Wright, 2011; Macedo, 2005; Prasad, 2013). Kalantzis and Cope (2005) present the multiliteracies framework as "learning by design," for example, where students produce a variety of multimodal texts, which are then used as learning resources so that their peers can use critical framing leading to the redesign of the texts. Imagine a group of learners designing a storyboard to create a digital text, perhaps a video, during which the teacher may ask them to reframe their thinking about the gendered archetypes they encounter in many videogames. How might these narratives be transformed to be inclusive? Woods et al. (2015) promote this kind of learning for taking into account individual differences, "along with differences in values, lived experiences, different ways of gaining knowledge as it takes account of individual meaning making and student life worlds… (and reflects) learning as being about transforming thinking and enacting a cultural transformation" (p. 68).

much as 20 points on the math portion of the SAT (Walton & Spencer, 2009). Stereotype threat suggests that a female student taking a math test experiences an extra cognitive and emotional burden of worry related to the stereotype that women are not good at math. For a visual representation of the effect of stereotype threat, see Fig. 1, below (Cooper, 2006).

However, Goode and others (2005) found that when the burden is removed by telling students that women and men performed equally well on the SAT, the women performed significantly better than the men. Of interest, culturally speaking, in South and East Asian cultures, where the numbers of STEM graduates de Corte (2010) are high, including women, the basis of success is generally attributed less to inherent ability and more to effort (Stevenson & Stigler, 1992). See the discussion of post-secondary education, below, for more research about "stereotype threat."

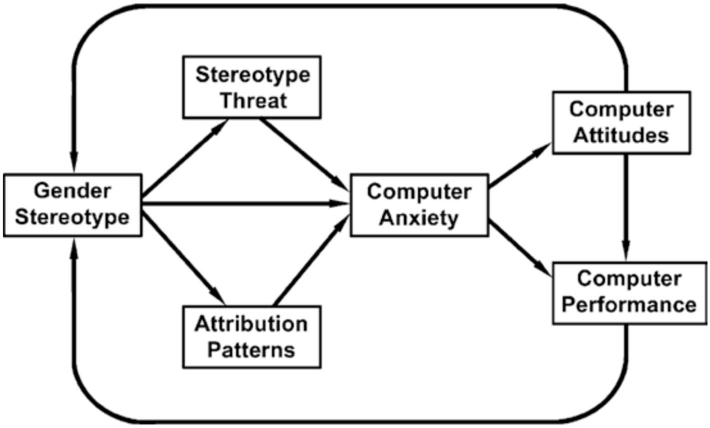

Fig. 1 Stereotype threat. (From Cooper, 2006, 334)

Discussion

This section presented several theoretical frames for understanding prevalent discourses that may influence a designer's decisions about curriculum, pedagogical approaches, design of educational materials, and structures of learning activities. For example, the intersectional analysis of the Australian anatomy textbooks presented earlier revealed a dearth of images of women in professional environments, portrayed indigenous actors in least powerful and stereotypical roles, and ignored the presence of LBGTQ+ individuals as exemplars.

Critical discourse analysis (CDA) focuses on text analysis, including visual representations, to explore the construction of knowledge, power, and identity. This approach considers language as a social practice occurring in a cultural context. Language construction, while intentional, reveals unconscious bias.

Gender Schema Theory assesses how learners may actively seek gender-related information which will serve as a guide for their own behaviors. Navarro and others (2014) observed that gender schemas are interiorized and should be considered when designing educational activities. While they were silent on the influence of culture, ethnicity, age, sexual orientation on gender schemas, they concluded that schemas may be "disrupted" or challenged during the design process.

Other researchers, like Fraser (2009) use critical theory to understand, evaluate and design curriculum. Feminist, postcolonial, and post-structuralist orientations to issues of race, gender, sexuality, class, locale, and disability are examples of "social justice" approaches to constructivist design. A case study of a design approach to a graduate course for indigenous learners, in which the design approach and resulting design reflect a postcolonial orientation is presented in Chapter (?) Note that this is the chapter by Janes, Makokis and Campbell.

Designers should be careful not to trivialize cultural norms in an effort to disrupt gender schemas and other discourses. The author witnessed this mistake firsthand when, during a professional meeting, a participant was advised to simply "put a hijab" on an image of a female computer engineer working closely with make colleagues in order to render the image acceptable to Muslim learners. The sociocultural context (women working with men in a professional context) was not considered.

Jacob Neilson and his colleagues have developed guidelines for internationalizing, and localizing websites (c.f. 2001 Neilsen & Tahir, 2001). His work on usability has been foundational for designing user interfaces that consider cross-cultural concerns (c.f. Chakraborty, 2009; Kaasgaard, 2000 ; Kompf, 2006; Mushtaha & De Troyer, 2009, 2012; Pawlowski, 2008). Likewise, the work of psychologist Geert Hofstede (1984, 1990, 2001) identifies six dimensions for distinguishing one culture from another. The dimensions are 1) Power Distance Index (high versus low); 2) Individualism Versus Collectivism; 3) Masculinity Versus Femininity; 4) Uncertainty Avoidance Index (high versus low); 5) Long- Versus Short-Term Orientation, and 6) Indulgence Versus Restraint (https://www.mindtools.com/pages/article/newLDR_66.htm).

Hofstede's work has been revisited by many researchers over three decades, recently demonstrating that cultural values can change over time in response to economic, environmental, political and social events (c.f. Wu, 2006). However, if used carefully his framework provides frames for designing for international learners, or for critically analyzing designs that already exist. The education of designers would benefit from activities to explore one's own tacit cultural assumptions and unconscious biases so as to be aware of inappropriate, or unhelpful, design decisions.

Gender and Psychosocial Factors

Goal 5 of the United Nations' "Education for All" policy aimed to provide equal opportunities for education, regardless of gender and place, by the year 2015 (Grimus, 2014). One might think that the present digital generation would be attracted to technology use regardless of gender. However, even once people cross the initial connectivity divide, differences such as level of education of the user and the user's parents, gender and ethnicity influence adoption. Studies across Europe and North America persistently show that levels of computer and Internet use are lower among rural youth, female youth, and youth from families with low levels of parental education (c.f. Jackson et al., 2008; Vandewater et al., 2007). Boys, older children, and middle-class children in developed countries benefit from more, and better, quality access to the Internet than girls, younger and working-class children. These benefits, including the development of writing skills, ability to conduct research, collaborate with others and create multimodal presentations depend not only on age, gender, socioeconomic status (SES), and geographical location, but also on amount of use and online expertise, for example, skills and self-efficacy shape and define the opportunities taken up by young people (Clark, 2013).

The vast majority of children at all grade levels in the developed world have access to mobile devices, but while boys report using mobile phones as gadgets, girls traditionally have perceived themselves as less skilled in terms of technology. Cotton argued in 2009 that "if this perception continues, it…can impact the types of jobs and courses that girls take…it could lead to a different type of digital divide" (in Grimus, 2014, np). They point out that much has to be done to teach girls about the technical and more advanced multimedia features of their mobile devices Further evidence was provided by a 2013 survey, of 2500 children (aged 9–16) and their parents, in Denmark, Italy, Romania, the UK, and Ireland, referring to gender differences in the daily use of smartphones (Mascheroni, 2013). The gap persists in higher education, where males show higher positive attitudes toward using technology for learning than females (c.f. Yau & Cheng, 2012). The mobile phone gender gap, in terms of usage, is observed as a symptom of broader gender inequalities, and is an issue to those concerned with gender stereotyping, because those that do own mobile phones encounter more gender stereotypes through sharing of digital content and images.

Schools and the post-secondary sector continue to challenge researchers in the slow uptake of teaching/learning technologies and practices. Global investment in learning technologies in schools has been initiated by many governments, including the UK ($2.5 billion GBP in 2008–2009), USA ($10.7 billion in 2009), and New Zealand ($410 million annually on infrastructure); yet, ICT adoption in education has lagged far behind that of the business sector (Nut, 2010, in Buabeng-Andoh, 2012). Recent research studies continue to highlight the difficulties that teachers face when using ICT in their daily educational practices (Vrasidas, 2015; Ward & Parr, 2010; Wastiau et al., 2013). Personal characteristics such as educational level, age, educational experience, experience with the computer for educational purposes, attitude toward computers, and gender can influence the adoption of a technology (Schiler, 2003). Among the factors that influence successful integration of ICT into teaching are teachers' attitudes and beliefs toward technology (c.f. Keengwe & Onchwari, 2008; Teo, 2008). Bachmair, Pachler, & Cook (2011) warn that "fossilized" practices of schools militate the opportunities for learning as meaning-making, or situated learning, afforded by mobile technologies. For example, in one study, 363 teachers were assessed for their perceptions about approaching technology. Results indicated that teachers who embrace creative teaching methods tend to have higher positive attitudes toward technology use in the classroom. Similar results have occurred in studies of mathematics teaching and innovation (Holden & Rada, 2011).

While recent research shows that teachers with a positive attitude toward ICT are much more likely to use ICT in their teaching and for students' learning, the implementation of ICT in teaching is also influenced by social norms and expectations (Gardner & Davis, 2013). Thus, according to Fransson (2016), who explores the notion of "dilemmatic spaces" in relation to social media, "understanding the everyday practices in which teachers try to manoeuvre between the expectations of others and their own beliefs, concerns, emotions and knowledge about the advantages and disadvantages of using ICT for teaching and learning would seem to be vital" (p. 186).

It appears that a teacher's sense of control is related to their digital competence, but there are differences in relation to gender and the use of ICT in different school subjects (Vrasidas, 2015). The research is mixed, with some studies finding no significant differences in teachers' attitude toward technology adoption with respect to their gender (Anduwa-Ogiegbaen and Isah, 2005; Gerlich, 2005; Rana, 2013; Verma & Dahiya, 2016) and others finding that males tended to show higher perceived efficacy in using ICT in learning and teaching, as opposed to females who believed that ICT could benefit mathematics pedagogy more (Ardies, De Maeyer, Gijbels, van Keulen, 2015; Chevers & Whyte, 2015; Lau & Yuen, 2013). Culture and place play a role, as do gender role expectations (Davis, 2008). For example, Kimbrough, Guadagno, Muscanell, and Dill (2013) found that women, relative to men, are connecting more and are using mediated technology to a larger extent, and men rate their technology self-efficacy higher than women. Performance expectancy, effort expectancy, social influence, perceived playfulness, and self-management of learning predict behavioral intention to use mLearning, and that gender differences moderate the effects of social influence and self-management of learning on mLearning use intention. For example, one study conducted in Saudi Arabia found a significant difference between male and female teachers in the use of ICT in language teaching and learning. However, the situation was unique, in that female teachers and students had their own campuses. Continuous breakdowns hindered the use of ICTs, as they had to wait for male ICT expert to fix the problem in the evenings. Further, the male teachers had twice as much access to computers as the females. This story reflects how context and culture significantly affect the ways that female teachers use ICT in their teaching (Saleh Mahdi & Sa'ad Al-Dera, 2013).

Likewise, the relation between students' self-efficacy and values and beliefs regrading ICT and teacher expectations, gender, and socioeconomic factors correlate with students' views of ICT for learning and confidence in their ICT skills (Vekiri, 2010). In an "increasingly marketized" educational sector, those from low socioeconomic backgrounds tend to rate their skills as lower than their peers, partly due to a lack of access to the technology (Pate, 2016). Females are more vulnerable than males to all these factors. Research before 2000 revealed that male teachers used more ICT in their teaching and learning processes than their female counterparts, with female teachers reporting lower confidence and capability (c.f. Jimoyiannis & Komis, 2007; Kay, 2006; Markauskaite, 2006; Wozney, Venkatesh, & Abrami, 2006). However, more recent studies have found that the situation is changing and that, in fact, a greater number of female than male teachers used internet and web 2.0 technologies in their classrooms (c.f. Breisser, 2006; Yukselturk and Bulut, (2009). While male teachers report higher levels of experience, ability and confidence using computers in education, after training and implementation of ICT infrastructure, there was no difference between female teachers and their male peers (Kay, 2006).

Self-Efficacy

Bandura (2001) is the researcher most associated with social cognitive theory, which highlights the interactions among personal factors, environmental conditions, and behaviors. A key construct grounded in this theory is self-efficacy, which refers to an individual's belief in his/her capability to organize and implement actions to reach a certain level of performance. The concept of self-efficacy can be defined along two lines: (1) as the judgments each individual makes about his/her own abilities; based on these judgments he/she organizes, performs, and assesses activities to achieve desired outcomes, and (2) as one's beliefs about the ability to carry out the activities at the required performance level required by expected situations (Aguirre Chavez et al., 2014). Self-efficacy is a significant factor in one's performance at school and work because it affects one's goals, values, motivation, and perceived obstacles in the social environment; higher self-efficacy results in higher expectations for and beliefs in one's ability to achieve success.

Self-efficacy beliefs are influenced by a number of different sources, including social modeling, but with previous performances the main source of influence. The experiences of those perceived as having similar attributes, for example, gender, can be powerful sources of self-efficacy information (Usher & Pajares, 2008). Teaching self-efficacy has been typically described in terms of preparation, delivery, and assessment (Hemmings & Kay, 2009). A large literature base explores the effects of gender on self-efficacy; the interest here is whether gender-related differences in self-efficacy are significant for purposes of the design of learning environments and activities. For example, Hemmings and Kay (2009) tried to determine gender patterns in Twitter use among assistant, associate, and full professors in Australian universities, and found that in the lower ranks, Twitter use was consistent among male and female faculty. Similarly, while Aguire Chavez and others (2014, who used the "Self-Efficacy Academic Behaviors Scale," a 13-item scale, with 1995 university undergraduates at a Mexican university, found significant global gender differences in the communication, attention, and excellence variables. Women consistently scored higher in perceived, desired, and reachable self-efficacy, but lower perceived self-efficacy improvement possibility on the excellence scale, suggesting that the women showed a greater need and lower possibility for improving self-efficacy. The authors conclude that that any mediation designed to improve perceived self-efficacy should take gender into consideration, particularly in the Mexican context where few studies of this nature have been completed. In other words, the sociocultural context is a significant factor in the development of self-efficacy on various scales.

Looking for influences on self-efficacy, a study of how gender and gender–personality interactions separately affect self-efficacy, conducted with business students at a Norwegian university of science and technology, found that female students had significantly lower self-efficacy levels and self-efficacy strength than their male peers (Fallan & Opstad, 2016). However, personality effects varied, suggesting that the notion of gender-based self-efficacy alone is too simplistic. The participants completed questionnaires based on Meyer-Briggs Type Indicator

(MMBTI)) and questions about their perceived self-efficacy in a "Principles of Economics" course. The authors concluded, "the general conclusion of lower perceived self-efficacy level among female students does only include those having NF (intuition/feeling) and NT (intuition/thinking) temperaments…(and) self-efficacy strength is only affected by females having NT and SP (sensing/judging) temperament" (p. 40). NF temperaments tend to be sensitive to hostility and conflict, prefer a democratically run classroom with bountiful interaction with instructors and peers, collaborative rather than competitive group work, pedagogical approaches using class discussions, case study assignments, and paper/essay assessments. NF learners are motivated by personal recognition and approval on papers or tests rather than good grades (Fallan & Opstad, 2016). Many studies on the preferred learning styles of females support this description of classroom culture (c.f. Sanders' overview, 2007).

By contrast, Gunn and others (2002) found gender differences in the self-reported levels of confidence, the ability to work successfully with technology, the use of support systems, and different patterns of interaction. Irani (2004) reported that female learners felt frustration, particularly because of lacking support in technology-related tasks, such as completion of computer programming tasks. The root cause gender disparity in computing science and practice may be attributed to the mainstream social construction of computing-related identities that discourage or limit female participation (Kaplan, 2014). Mikk and Luik (2005) analyzed the perceptions of adolescent girls and boys regarding the use of electronic textbooks and found that "electronic textbooks with a high complexity of navigation and design of information endanger the learning efficiency of girls" (178, in Richter & Zelenkauskaite, 2014)); Yukselturk and Bulut (2009) found "test-anxiety" to be significant variable for female learners. Richter and Zelenkauskaite (2014) also found cultural differences in learner perceptions related to gender-related fairness regarding teacher treatment after completed tasks in general, and particularly after failed tasks using technology. For example, German and South Korean learners perceived gender-related lack of fairness, while Ghanian participants perceived a "higher divergence between the genders was found regarding the treatment after failing a task but both groups expressed a positive impression of fair treatment" (p. 10). The authors concluded that gender-related differences in perceptions of education might be quite significant and "need to be considered in the educational design to reduce conflicts in educational scenarios and support students to keep their motivation on the highest possible level" (p. 10).

Self-efficacy can be affected by symbolic modeling, such as those in the media, and verbal and social persuasions, such as encouragement from teachers, parents, and peers. For example, Kekelis, Ancheta, Wepsic & Heber (2005) found that American parents, especially white and high-SES parents, were found to give less computer-related support to girls than to boys. Usher and Pajares (2008) found that it may be easier to undermine an individual's self-efficacy through social persuasions than it is to enhance it. This is relevant to the messages females receive about their abilities and future in math-related subjects and careers, such as engineering or IT. Self-efficacy is also affected by emotional and physiological states, such as high anxiety and stress. A lack of confidence in one's abilities may lead to a false interpretation of anxiety as a sign of incompetence. Further, learners tend to trust assessments of their ability made by someone they trust, or that is seen to have power and influence. Garber (2009) reminded researchers "in the tendency to gender the disciplines…the quantitative social sciences have sometimes been stereotypically regarded as 'masculine', serious, and hard…(and so) a belief develops in a class of persons, based on perceived inferiority: another class of persons, already more socially or politically powerful and more highly esteemed, is thought to possess the real thing… that this structure of thinking that dominates much of academic life, both within and among the disciplines…will not strike many as astonishing" (p. 69). This plays out as a significant gap between female and male levels of self-confidence in using computers, which may explain why male students are five times more likely to pursue a career in computer programming compared to females.

Cultural Differences

Gender differences in self-efficacy have some cultural basis, although in most cultures where research has been conducted, the results hold. For example, Viekiri and Chronaki (2008) found that in a study of 340 Greek elementary school students, there were significant gender differences in frequency and type of computer use. Furthermore, boys reported more perceived support from their parents and peers to use computers and more positive computer self-efficacy and value beliefs than girls. A GSMA (2013) survey provided a detailed picture of children's (aged 8–18 years) mobile phone behavior and gender differences across five countries: Japan, India, Indonesia, Egypt, and Chile. Gender differences were found with boys' higher use than girls' in Indonesia, India, and Egypt, the opposite being true in Japan and Chile. In this study, girls used health apps considerably more than boys; no gender difference was found when examining confidence and insecurity In Peru, efforts have been made to enhance the use of mobile phones in formal education (Barkham & Moss, 2012).

Valderrama-Bahamondez, Kauko, Jonna, and Schmidt (2011) reported on adoption of mobile phones in the 4th–6th grades in Panama, finding that boys were faster to adopt mobile technologies and explore more functionality, while girls took more time to familiarize themselves with the phone itself, perhaps choosing to explore the social aspects first. In this study, girls seemed to maintain a better focus on the learning activities using the mobile phones, suggesting different adoption and exploration strategies that are important to keep in mind when designing tools for mobile learning.

The impact of gender on learner's participation, motivation, and achievement in mobile game-based learning (GBL) in older children (aged 9–10 years) in Taiwan was analyzed in an ecological game. The findings showed that the girls asked fewer questions and spoke less than the boys, but no gender difference was observed in achievements and motivation. The authors of this study concluded that integrating mobile technologies and game design into classroom instruction may reduce the gender gap in learning participation in a traditional classroom environment, although they observed a gender difference in self-confidence pertaining to mobile technology use (Jung-Chuan, Jeng-Yu, & I-Jung, 2011).

In developing countries, the "Jokko Initiative" (Senegal), "Project ABC" (Niger), the "Somali Youth Livelihoods Project" (Somalia), "Nokia Life Tools" (Nigeria), and "M4Girls" (South Africa) are interventions using mobile devices to teach literacy, numeracy, maths, and/or employability skills and provide learning opportunities for people, who may not have been able to access formal education opportunities, primarily women (Zelezny-Green, 2012). In India, cellphones pre-loaded with applications that target English as a Second Language were used in a project with rural children (aged 7–18 years), showing a reasonable level of academic learning and motivation, although gender differences in attitude remained a challenge. Finally, it was found that gender attitudes remain a significant challenge (Kumar et al., 2010). However, Mobilink, a basic literacy program in Pakistan, was quite successful once parents and community leaders became less resistant to the idea of allowing girls to have mobile phones.

In Africa, girls remain marginalized. Chikunda and Chikunda (2016) share that every country needs "to harness the intellectual and scientific capacity of both men and women for sustainable social, ecological and economic development. Yet, SMTs constitute the areas within the educational system where gender disparity is greatest, in several of the poorest countries of the world" including Zimbabwe (p. 11). Even though the Zimbabwe National Gender Policy (2004) specifically identified strategies such as "promote and encourage girls to take on science, mathematics and technology at all levels of education and introduce gender awareness programmes to pre- and post-training teacher courses" (p. 13) patriarchal values embedded in the hidden curriculum remain, such as the gender typing of school subjects and occupations, low expectations of female teachers for female students, undervaluing of female students' work, as well as "mocking, humiliation, verbal abuse and the unnecessary ridicule of girls" in STEM subjects in school, cited as some of the prevalent practices that bolster patriarchal values by Mutekwe and Mutekwe (2012) in Chikunda & Chikunda (2016).

Because informal learning activities based on mobile technologies are more accessible for girls who are excluded from formal learning environments, cellphones may support better outcomes such as life skills, health care and personal development. In all these studies, parental support and, to a lesser extent, peer support were the factors more strongly associated with boys' and girls' computer self-efficacy and value beliefs, while home computer access was not related to students' motivation, highlighting the role of socialization in the gender gap. Social practices continue to communicate gendered expectations to boys and girls. Also, the preponderance of males in the academic field of computer science and the resultant male dominant culture in this area of study has been identified as one of the barriers that female computer science undergraduates face (Rajagopal & Bojin, 2003).

Sharpe's (2014) review of learner attributes reflects growing interest in "learner experience research" within the field of learning technology. Learner experience approaches use "qualitative, exploratory and participatory research methods to elicit learner experiences and generate rich descriptions which foreground learners' perspectives, beliefs and behaviors" (p. 126) while acknowledging that contextual factors such as course design (Kirkwood & Price, 2005) and sociocultural influences shape learners' use of technology. Being skilled includes issues of voice, identity, and awareness of self-presentation. Sharpe's (2014) review includes connectedness; confidence, including included digital identity and privacy; self-efficacy; and collaborativeness as key attributes, although females tend to underestimate their "abilities" self-reporting confidence, which does not relate to appropriate technology use (Masterman and Shuyska, 2012, in Sharpe, 2014).

Farah's (2011) doctoral research revealed that gender may play a role in influencing one's technology self-efficacy. The self-efficacy survey results showed that males, overall, had higher technology self-efficacy than did females who responded to the survey. An overwhelming percentage, 81.8%, of male survey respondents scored in the very high range, while only 16.3% of female respondents scored in the very high range. This finding indicates that males may tend to have higher technology self-efficacy than females. (107). Jun and Freeman (2010) add that individuals learn society's gender role standards and expectations, and they accordingly develop attitudes and conduct behaviors that society deems gender appropriate. If females perceive that society expects them to know and use less technology, then they are more likely to adopt this same expectation for themselves. In another study by Mackay and Parkinson (2010) involving South African technology teacher trainees, they too found that females had lower self-efficacy than did males. Beyond society creating norms or expectations that may play a part in the differences between females and males in regard to self-efficacy, so too might the different mindsets each gender has when they are self-reporting their self-efficacy, as was suggested by Schunk and Pajares (2002): "A second factor that may be responsible for gender differences in self-efficacy and in confidence to use self-regulated learning strategies is the tendency of boys and girls to respond to self-report(ing) instruments with a different 'mind set'…boys tend to be more 'self-congratulatory' in their responses whereas girls tend to be more modest…boys are more likely to express confidence in skills they may not possess and to express overconfidence in skills they do possess" (p. 119).

Culture and Beliefs About STEM

Cultural beliefs about superior masculine abilities and skills, girls and women tend to judge themselves by a higher standard, assess their abilities lower, and show less interest in pursuing a related career (Correll, 2004). This relates to self-efficacy because we often use stereotypes as "cognitive crutches," especially in areas where we do not know how to assess our performance. Correll (2004) refers to research specifically in math classrooms that shows when a girl believes that most other people in the environment think boys are better than girls at math, even if she does not herself believe that, the thought is going to affect her, even if she does not believe it herself. In other words, what other people think is what matters. As evidence, Correll (2004) points to the damage done by the 2005 comments of Larry Summers, the former president of Harvard, when from a position of power and influence he publicly doubted that women could succeed at the highest levels of science and engineering: not in every domain, just in masculine domains.

Pajares (2005) found that gender differences in self-confidence in STEM subjects begin in middle school and increase in high school and college, partly because boys develop greater confidence in STEM through experience developing relevant skills. But, gender differences in self-confidence start to disappear when variables such as previous achievement or opportunity to learn are controlled. In other words, students who lack confidence in their skills are less likely to engage in related tasks, giving up more easily in the face of failure. Good, Rattan, and Dweck (2009) showed that when a girl believes she can become smarter and learn what she needs to know in STEM subjects, as opposed to having innate ability, she is more likely to succeed.

Higher self-efficacy related to mathematics has been shown to increase the odds of enrolling in high school calculus and choosing a STEM major in college, including computer science. These findings suggest that cultural beliefs about the appropriateness of one career choice over another can influences self-assessment and may partially account for the disproportionately high numbers of men in technology-related professions, over and above measures of actual ability (Correll, 2004). In addition, Lubinski and Benbow (2006) found that girls who excel at math tend to score highly on measure of verbal abilities; combined with societal expectations about masculine and feminine domains, they tend to consider future education and careers in the humanities or social sciences, rather than science and engineering fields. One possible explanation for this lies in the well-documented gender differences that exist in the value that women and men place on doing work that contributes to society, with women more likely than men to prefer work with a clear social purpose (Eccles, 2006; Lubinski & Benbow, 2006; Margolis and others, 2002), whether the difference is innate or socialized. If society does not view formal learning that leads to credentials in STEM careers being of direct benefit to society or individuals, these paths often do not appeal to women (or men) who value making a social contribution (Diekman, Brown, Johnston, & Clark, 2010; National Academy of Engineering, 2008). Zeldin, Britner, and Pajares (2008) found that "social persuasions and vicarious experiences" were the key to women's self-efficacy beliefs in male-dominated domains, while the self-efficacy beliefs of men were created primarily through their interpretations of their ongoing achievements. The authors concluded, "women…rely on relational episodes in their lives to create and buttress the confidence that they can succeed in male-dominated domains" (p. 1039). In another study, Diekman and others Diekman et al. (2010) found that STEM careers, relative to other careers presented, were perceived to impede communal goals, and that communal-goal endorsement negatively predicted interest in STEM careers, even when controlling for past experience and self-efficacy in science and mathematics.

Discussion

What lessons can we take from this, sometimes, contradictory research? First, when cultural beliefs support male superiority on a task, women tend to use a higher standard to judge their own abilities. However, if no gender difference in ability or performance is suggested, men and women and men tend to assess themselves by approximately the same standard. This suggests the important influence teachers, parents, and peers have on the development of self-efficacy (Hill, Corbett, & St. Rose, 2010; Vekiri, 2010). The research of Michie and Nelson (2006), and Tomte and Hatlevikb (2011) supports this view, finding that traditional work role expectations concerning women's efficacy for careers in IT still persist, affecting self-efficacy. Ceci, Williams, and Barnett (2009) conclude that "evidence for a hormonal basis of the dearth of female scientists is weaker than the evidence for other factors," such as gender differences in preferences and sociocultural influences on girls' performance on gatekeeper tests (p. 224).

Research related to self-efficacy and related factors such as motivation and test anxiety have shown these issues amenable to interventions that have been designed and evaluated. For example, in the "Bring Your Own Device" approach, utilized in education and industry, learners are invited to bring personal mobile learning devices into the learning environment. While disparities exist by socioeconomic status and culture, eighth-grade females enrolled in math classes using MLDs scored 65.95 points higher on average on an annual assessment compared to their peers who did not use MLDs in their classes (Cristol & Gimbert, 2013).

Grimus (2014) also saw that the increasing adoption of mobile devices was helpful for girls to break through the perception of technology as a "male thing." However, while both males and females use mobile devices such as smartphones, parents and teachers do not point out that girls as well as boys can create sophisticated applications with them. One program developed for teenagers in the UK ("Apps for Good," http://www.appsforgood.org/) mitigates against this notion by promoting creative learning programs, such as mobile app development, to build skills and confidence of young people aspiring to become technology experts. This is consistent with findings that females may prefer to design creative activities over learn how to program.

Finally, challenges observed in education in developing countries need similar research in the developed world with regard to children from marginalized groups, particularly girls and immigrants, who live in extreme poverty, in slums, in remote communities, or are from ethnic minorities.

Gender and Generational Differences

While the prevalence of social media is having a significant impact on how we socialize, work, and learn, young people use new technologies for social ends that are much the same as for earlier generations using old technologies. For example, Baby Boomers talked on landlines, just as this generation uses texting, blogs, and social media sites. They signal in-group identity, not by handshakes or adornment, but by using language creatively while texting. Herring (2008) observes that the ends are more important than the technological means, that is, the focus is on social functionality rather than on the technologies themselves. The difference is in the scope of participation, from one-to-one, to one-to-many, or many-to-many. Personal diaries were at one time fiercely protected from prying eyes, now little is private.

Much has been made of a "generational digital divide" as it pertains to media consumption and communications. The divide refers to millennials (so-called digital natives), on the lower end, and older learners (so-called digital immigrants), the generations born from the 1940s (or earlier) to 1982 (c.f. Tapscott, 2009). Because digital natives have one foot in the TV world of earlier generations and the other in the digital world, Susan Herring (2008) maintains that the first true digital native generation has yet to be born (perhaps it will be Generation Z). In a critique of the generational digital divide, Herring suggests that millennials be viewed as a transitional generation astride the predigital and digital worlds, a world that is still controlled by older adults. Calling for a paradigm shift, she proposes a research agenda toward a more nuanced understanding about how young people use and express themselves through new media, focusing on identity formation (c.f. Jenson, Dahya, & Fisher, 2014). Identity formation is clearly related to gender identity and its development in new media environments.

Judge and Tuite (2017) make this point strongly with regard to media education and youths' aspirational identities that "are tied up in visions of themselves as future media professionals facing an uncertain employment future in the Age of Austerity" (p. 46) in Ireland, where their study of students' work in media studies over a 12-year period (2003–2014) in a university setting is located. Referencing the work of Wajcman (2000), Hargittai and Walejko (2008), and Clegg (2010), Judge and Tuite (2017) identify issues of power, control, privilege, gender, and social inequality "when three powerful industries comprising computing, telecommunications and the media amalgamate." They were particularly interested in how gender construction, representation, and inequality present themselves across all three industries, in that they are male-dominated and embody a masculine identity. As we have seen, the masculine culture of technology, through its symbols (language), metaphors, expectations, and values in all stages at which it is encountered, has sustained the alienation of girls and women from early school preparation to structural barriers to full participation in STEM fields (c.f. Wajcman, 2007). Judge and Tuite point out that structural barriers become systemic, as underrepresentation in these industries perpetuates itself and results in "a big opportunity miss for gender and ethnic diversity in the industry" that would provide different perspectives in social issues that are the basis for storytelling. Research on the new digital media sector confirms that "despite its cool, creative and egalitarian cultural economy image (there is continuity) ...with the old economy in terms of some enduring gender inequality and discrimination practices" (Banks & Milestone, 2011, in Judge & Tuite, 2017, p. 30). However, a fair caution in this type of research is to avoid normative readings of femininity and masculinity, taking into account the ways in which context, culture, knowledge, and prior experience influence technological competence (40). We can observe this in studies of girls and women who have been given an "equalizing" amount of time to "tinker" with technology (c.f. Sorby, 2009).

Box 4 Male and Female Choices in Multimedia Education

Judge and Tuite (2017) studied the multimedia projects created by students' final-year multimedia productions over a 12-year period (2003–2014) at Dublin University. They analyzed the gender distribution of production teams, and the content and media decisions for finished productions by genre, media type, audience, and purpose, through the lens of gender. Overall, they found that the productions were influenced by "multilayered voices encompassing internal, external, personal, public and institutional forces…both overt and covert, such as the curriculum and the academy" (p. 48), drawing attention to "the institutional setting and how the power dynamics within can inform what can be produced, by whom and how it is shaped" (p. 48). The authors discovered that student-produced new media reflected many gendered qualities, especially regarding the type of media to produce, the choice of audience to talk to, and the composition of groups. For example, as the female-only groups self-selected administrative or caring roles rather than at the cutting edge of technology and creative practice. Groups taught by a female instructor produced different artifacts than those taught by a male, or mixed-sex teams of instructors, resulting in more "educational" artifacts such as eLearning and documentaries, geared toward younger audiences. Judge and Truit (2017) speculated that such products are framed by a sense of 'others' rather than a sense of 'selves', reflecting students' desires to produce something useful for others (a gendered trait). They also found the inclination of female students to work with print media and not just online media of interest, perhaps reflecting the role that books play in the lives of young girls. The researchers were apparently *not* surprised to find that that males (in a disproportionate number of male-only groups) dominated the UI/UX and storytelling spaces. Argued that projects such as

> Judge and Truit concluded that elements of the "hacker culture" and women's dislike of the 'tinkering' (Sax, Jacobs, and Riggers, 2010, in Judge & Tuite, 2017) aspects of digital media, "which has traditionally acted as barriers to women pursuing computer studies, are clearly in play here, as the UI/UX projects are more technically demanding involving programming" (p. 46). They compare the self-selection of student teams to the formation of male subcultures (i.e., "old boys network") that act as "gendered social enclosures" that create barriers for women in such creative and technical fields. The authors ruefully ask if one should be surprised at this finding, as men outnumber women 3 to 1 in family films on screen (which has remained unchanged since 1946), in front of and behind the camera, so when it comes to creating stories and using the technical tools to do so, female students see themselves as less capable and less creative, with "less valuable stories to tell" (p. 47).

A robust Information Society is considered to be economically more competitive, and fosters greater social cohesion, participation, and control of citizens (Aroldi, Colombo, & Carlo, 2015). Accordingly, the EU sponsored the SHARE study (Survey of Health, Ageing and Retirement in Europe), a "multidisciplinary and cross-national panel database of micro data on health, socio-economic status and social and family networks of more than 120,000 individuals aged 50 or older," across 27 European countries, and Israel (http://www.share-project.org/home0.html).

In the fourth wave of the study (2010–2011), 8639 individuals, aged 50 years and over, in Portugal and Estonia, were surveyed. These two countries were chosen as they had different welfare systems and relevant public policies. Previous studies have identified senior citizens as very vulnerable to the digital divide. Digital access divide is one factor among many: other factors include types of use of technology, knowledge about Internet features, and understanding of and ability to access information online. Studies of older age groups have shown, in general, that certain sociodemographic characteristics of individuals (age, gender, education, mental and physical health status, mobility, and income) condition the use of technology (Silva, Matos, & Martinez-Pecino, 2017). While earlier research concluded that age was a singular factor in the digital divide, SHARE participants revealed the reflection of inequalities in social structures was related to the economic, political, historical, and social characteristics of the respective countries in the study. In general, however, the group of Internet users was mainly composed of males (59.30%) while the group of nonusers was essentially composed of females (Silva et al., 2017). The Internet users group also reported having more years of schooling and fewer financial problems. Socioeconomic status was related to level of education and limited pensions (an historical political artifact), factors related to gender. However, the study suggested that the number of females using the Internet tends to increase, moving toward growing gender parity (c.f. Fox, 2004). SHARE included 16 European countries in the survey, finding that macro-social variables such as public social policy (e.g., broadband access) may have the most influence on the e-inclusion of seniors. For example, Silva et al. (2017) point to significant investments made in Portugal over the past decade in technology programs, adult education, the provision of specific IT training by senior citizen universities, parish councils, and NPOs, often available free of charge, and the creation of public spaces for free Internet access; as well as incentives to use the Internet such as banking and access to eGovernment.

Discussion

With regard to social media, designers and educators are experiencing a "dilemmatic space" (Fransson, 2016), while those in the user experience area are challenged to keep up with gender, generational, and cultural differences. Describing the digital dilemmatic space, Fransson (2016) "offers ideas about how to relate to a digital society in a way that on the one hand takes its point of departure in the options, risks and dilemmas of a digitised society and the use of the Internet, but that on the other hand also emphasises relational aspects, positions and the dilemmas of dealing with the different values, norms, tasks, options and loyalties that can emerge in a digitised society" (p. 187). Uncertainty is then a key component in constructing dilemmas. Exploring Fransson's (2016) dilemmatic space suggested a connection with Mezirow's theory of "disorienting dilemmas," which may lead to perspectives transformation. In other words, experiencing learning in a dilemmatic space may encourage transformative learning.

For example, social networking sites such as Twitter, Facebook, or LinkedIn are dilemmatic spaces because while participation may help seniors actively engage with members of their own or different communities across time and place, they are also spaces of miscommunication, misinterpretation, and harassment, that is, risk. Issues like these present challenges to designers of online learning, as one example.

Online access, and the digital access divide, is reflected in cultural differences no matter the region, and women are consistently more social on the Web than their regional, male counterparts: in Asia Pacific, Europe, and Latin America, women are underrepresented online. India and Indonesia are two countries where women's presence online is very low compared to men. Globally, women spent an average of 16.3% of their online time on social networks in April 2010 compared to only 11.7% for the men (p. 9). Apparently, the over-45 years-of-age segment of women drives the greatest proportion of growth for social networking; in the over-55 years of age group, women have embraced social media by 10 percentage points over males (p. 10). In the 15–24 age range, social media use is similar among males and females, although the search behaviors and interests differ, with males more inclined to post on sites such as Twitter, while women are more inclined to follow conversations. The rates of adoption of social media in Singapore and Australia were the highest. On average, males conduct more searches per user than women. In all regions, males are the heaviest users of mobile technologies, owning more "smartphones" and subscribing to more services. One possible explanation for this is that men tend to be higher earners than women, and employed in workplaces at higher status levels, affording them the opportunity to purchase, thus affording them the ability to purchase the technology and enjoy employer-paid services.

For the next section, consider the issues of gender, culture, and place in a digitized world as a case of dilemmatic space, acknowledging the processes of power, positioning, and negotiation in the work involved in navigating access and equitable participation in the online world.

From Digital Access Divide to Social Inclusion: Gender and Digital Fluency

The phrase digital divide was coined in the 1990s referring to the divide between those who had access to ICTs and various forms of digital technologies and those who did not. In other words, digital divide was ununderstood to mean "digital access divide." Determinants included financial status, household income, educational level, type of occupation, and geographical location. In this definition, or understanding, communities with lower educational attainment, for example, which is often tied to lower financial status, would likely have limited or no material access to ICTs and digital media compounding the effect (Adhikari, Mathrani, and Scogings, 2016, p. 325). Today, "digital divide" has new meaning. It refers to the gap in the intensity and nature of IT use rather than to the gap in access to it. For example, research consistently indicates that adult females are more likely to use the Internet's communication tools, whereas adult males are more likely to use the Internet for information, entertainment, and commerce (Jackson et al., 2008).

New data released by ITU, the United Nations specialized agency for information and communication technologies (ICTs), show that 830 million young people are online, representing 80% of the youth population in 104 countries. ITU's "ICT Facts and Figures 2017" also shows a significant increase in broadband access and subscriptions, with China leading the way.

This annual release of global ICT data shows that youths (15–24-year olds) are at the forefront of Internet adoption. In Least Developed Countries (LDCs), up to 35% of individuals using the Internet are aged 15–24, compared with 13% in developed countries and 23% globally. In China and India alone, up to 320 million young people use the Internet.

Since the world is fluid and continuously transforming, a shift in the digital divide research has been occurring. For example, the focus is shifting from institutions to the appropriate use of technology, for example, as in participation and meaning-making, to the individual, facilitating individuals to make more personal use of flexible and mobile platforms in daily as well as constrained contexts. Technological advances in the past decade have highlighted the use of social media access and use, as well as ubiquitous cell-phone usage for gaming and other applications. This increase in technology use focuses attention on the sociocultural contexts in which it takes place; issues of a social digital divide continue to reflect challenges related to race, age, gender, and geopolitical location. We have seen that the manifestations of this divide are clear now and have been since the 1980s, in the underrepresentation of women in the ownership and use of computers, uneven demographics in high school and university STEM classes, and in the persistence of social stereotypes (c.f. Pinkard, 2001; Mitra, 2001).

Access as a Human Right

The "Human Rights, Big Data and Technology Project" at the Human Rights Centre of the University of Essex submitted a comprehensive report, *Ways to Bridge the Gender Digital Divide from a Human Rights Perspective* (2016), in which they stated as follows:

> While…technologies offer unprecedented opportunities for advancement in areas ranging from education to political participation and employment, they have also been pinpointed as a key factor in social and economic disparities. Existing inequalities are reflected in

> discrepancies in the access to and use of ICTs, thereby transposing offline divides into the digital space. Due to the negative impact of lack of free access to use of and benefit from ICTs, the digital revolution risks significantly amplifying the gender divide across different social and economic groups. This constitutes a barrier to the emergence of an equitable information society by perpetuating, and even exacerbating, gender inequality, gender inequality being both the cause of and aggravated by the gender digital divide…. Throughout the world, economic, social and cultural obstacles prevent or limit women's access to, use of, and benefits from ICTs, a phenomenon referred to as the gender digital divide (p. 2).

The report lists a number of impediments to ICT access and effective use, including the distinct socioeconomic disadvantages faced by women leading to cost barriers; influences of physical and social/cultural impediments; geographical isolation and poor technological infrastructure; lack of content relevant to their experience, context and language; filtering policies that block access to health and sexuality information (e.g., LGBTQ+ issues) affecting women's health and reproductive rights; an education gap resulting in lower levels of literacy, numeracy and technological skills; a hostile and unsafe online environment marked by negative stereotypes, attitudinal biases linked to conservative gender roles, harassment, and hate speech. In addition to preventing women from taking full advantage of education and work opportunities, these barriers may result in women's lower presence in online political discourse.

The report suggests an intervention to the digital divide challenge based on human rights, referencing a number of related international declarations: the "International Covenant on Civil and Political Rights" (ICCPR); the "International Covenant on Economic, Social and Cultural Rights" (ICESCR); the "Beijing Declaration and Platform for Action"; the "Universal Declaration of Human Rights" with the sustainable development goal (5) on gender equality outlining targets for every country to make gender equality a reality; the 2003 "Declaration of Principles on Building the Information Society" adopted by the World Summit on the Information Society (WSIS); and "The Tunis Commitments and the Tunis Agenda" (2005), among others. The authors conclude that the "implications for States are clear. Ensuring equal access to the benefits provided by ICTs is an important part of their fulfilling their obligations under international human rights law, including achieving full respect for women's human rights."

Referring to the role played by the private sector in women's rights to access, the "UN Guiding Principles on Business and Human Rights" (UNGP) declared that corporations are responsible to respect internationally recognized human rights, addressing negative impacts when they occur, and implying that international businesses could contribute to the education gap in regions in which they are conducting business.

"It is society's dilemma that the path to computer efficacy is more difficult for the poor, for ethnic minorities and for women" (Wilson, Wallin, & Reiser, 2003, in Cooper, 2006, p. 320). A digital divide for gender has an impact on if and how women are reaping the benefits of a society based on ICT use, as well as affecting the economy itself. Research indicates that media use habits are formed early in life, foreshadowing IT use in adulthood. Children's IT use predicts their academic performance: those who had been using IT longer had higher grades in school than those who were more recent users. The longer an individual has been using IT, particularly the Internet, the more intensely it is used and the more diverse the user's activities become. For example, the development of Internet skills, such as navigational skills, as well as motivation, is directly related to the amount of time online. This outcome is correlated with parents' attitudes and socioeconomic status. Low-income children, especially girls, used the Internet less often than Caucasian children (Jackson et al., 2008).

Although, while Jackson and others (2008), in their study of race and gender differences in the intensity and nature of IT use, found that white children had been using a computer longer than African American children and that African American males used computers and the Internet for less time when compared to other groups, they also found that females were more likely than males to use the Internet for academic purposes, and for communication purposes. Females were more likely than males to instant message with friends, create documents for school, save images/graphics, take a survey online, take a test online, read mailing list messages, and use e-mail. In fact, African American females were found to use the Internet more intensely and in more diverse ways than any other group, whereas African American males used it less intensely and in fewer ways than any other group. Other race by gender interactions indicated that African American females were most likely, and Caucasian American males least likely, to search for information about health, diet, and fitness. All females were most likely compared to all other groups to search for information about depression, mood, and mental illness; to search for news and current events; and to exchange photos. However, African American males lagged behind all other groups in their IT use except in online gaming. In other studies, females of color were subject to the "double discriminatory burden of femaleness and minority status" (Sanders, 2007). Morrell and his colleagues (2004) found that a day-long Saturday program for middle school girls had a stronger effect on girls of color than white girls, suggesting that the white participants had had more exposure to computers before joining the activity (Morrell et al., 2004). In another extracurricular program, Techbridge in California, girls self-segregated by race which generated racial tensions. Intervention activities revealed that it was noted that girls with lesser technical skills and lower self-confidence were at particular risk of dropping out from attempts to force them to cross racial lines (Kekelis et al., 2005).

While more current research suggests that the digital access divide, in terms of ownership, may be narrowing, Jackson and others (2008) suggest that the issue of Internet access remains hidden among higher usage of some ICTs by African American youth, who spend more time watching television, playing video games, and using a cell phone), two of which have been linked to negative academic outcomes (Rideout, Foehr, & Roberts, 2010). This highlights the challenge of Intersectionalities, where early access may lead to more positive outcomes. As white youth have been found to have earlier access, overall, than African American youth, the social digital divide may potentially contribute to long-term inequality in education and quite possibly psychological well-being (O'Neal Coleman, Hale, Cotten, & Gibson, 2015).

Digital Inclusion and Place

While global Internet use has increased – from 20.6% of the world online in 2007, to an estimated 47.1% in 2016 – it has been uneven both between and within countries. According to the World Wide Web Foundation (https://webfoundation.org/2016/10/digging-into-data-on-the-gender-digital-divide/), "One of the most pernicious aspects of the global digital divide is the digital gender gap and unfortunately, new data reveals that this digital gender gap is growing wider." In their report of October, 2016, *Digging into Data on the Gender Digital Divide*, the Foundation identified two noteworthy points to consider: (1). There is an urban–rural divide related to the gender gap in Internet use, and (2). Age is also a factor in the digital gender gap.

For example, in rural areas, the gender gap is higher in high-income countries (9.4%), whereas in urban areas, the gap is slightly higher (at 6.6%) in low- and middle-income countries. However, a survey of the ten low- and middle-income countries revealed that, in urban poor communities, women were nearly 50% less likely to access the Internet than men in the same communities.

The digital gender gap increases as age increases and is more significant in low- and middle-income countries. Among 15–24-year olds, the gender gap is 2.9% in low- and middle-income countries. But, when we consider age (i.e., age 75+), there is an average gender gap of 45.8% across all countries. Although age and location are certainly important factors (see Generational Divide, above), unequal access is also related to systemic and other sources of discrimination in society, such as patriarchal systems of power that may restrict women's access to technology through the gender wage gap, unpaid work and care, uneven and unequal access to education, and the so-called "triple burden" (i.e., the view of a woman's simultaneous responsibilities to her family, job, and community, c.f. Kramarae, 2001). Worldwide, there is a gender gap of 12% in male and female access to the Internet. This rises to almost 31% in "Least Developed Countries" (LDC). According to Irina Bokova, Director-General of UNESCO,

> Women are still left behind from the growth in mobile phone ownership, the most prevalent means of access to the Internet in developing countries. Mobile phones are important tools for enhancing the lives of women in low- and middle-income countries. They help women feel safer and more connected, save time and money, and access life- enhancing services such as mobile money, or potential education and employment opportunities (UNESCO, 2017a, p. 7).

Women's digital inclusion can help to catalyze broader gender equality in social, economic, and political dimensions – benefiting not only women themselves, but also their communities and the broader economy. Internet penetration rates are higher for men and boys than women and girls in all regions. While the Internet user gender gap has narrowed in most regions since 2013, the proportion of men using the Internet remains slightly higher than the proportion of women using the Internet in two-thirds of countries worldwide. In 2017, the global Internet penetration rate for men stands at 50.9% compared to 44.9% for women. The research of the International Telecommunication Union (ITU, 2017) has estimated that in low- and middle-income countries, there are 200 million fewer women than men who own a mobile phone, and that even when women do own a mobile device, they are less likely to use it for transformative services such as mobile Internet, further widening the divide (p. 6). The ITU concludes by warning readers that the digital divide will never close on its own because the root causes are driven by a complex set of social, economic, and cultural barriers, that is, structural inequalities. As women's digital access can contribute significantly to the global economy and society, formal educational environments, along with the corporate and government sectors, are implicated in targeted intervention including design research.

The Accenture "Digital Fluency Model" (2016) reflects the extent to which both men and women have embraced digital technologies to become more knowledgeable, connected, and effective, and examines the impact of digital technologies across women's entire career lifecycle. The authors surveyed nearly 5000 women and men in 31 countries to gauge their familiarity with digital technologies, seeking specifics about education and career choices, for example, whether they had ever taken virtual coursework through an online university, how they used digital collaboration tools for work, and whether their company increased efforts to recruit more women for senior management roles. They found that, while men outscore women in digital fluency across almost all of the 31 countries studied, the gap is narrowing. The study also found that digital fluency acts as an accelerant in every stage of a person's career, in education, the workplace, and especially as an individual advances toward leadership. Digital fluency supports better time management and enables greater work flexibility, from which women may derive greater value. Combined data from the ITU with the survey results revealed a "digital fluency score" for each country, suggesting how digital fluency might drive positive changes in women's education, employment experience and work advancement. The results are revealing of sociocultural norms and expectations, as well as political practices and, in some cases, are surprising. Overall, men scored better than women in three quarters of the surveyed countries.

For example, Japanese men outscored women in all metrics, including education, and Japan's advancement scores are among the lowest. India had the largest gaps in the overall score between men and women, and the lowest overall score of all the countries surveyed. Indonesia also scored low, affecting women's progress in employment. The largest gaps between the digital fluency of men and women appeared in Japan, Singapore, France, and Switzerland. Saudi Arabia and the UAE were the only countries that scored lower than India overall. What accounts for these gaps?

In over half of the surveyed countries, women attained higher levels of education than men. It appeared that digital fluency had a more positive impact on the education of women in developing countries than in developed ones: 68% of women in developing countries, to 44% of women in developed countries, believed the Internet was important to their education. Apparently, where men and women have the same level of digital fluency, women have achieved a higher rate of education. However, access to higher education in different countries reflects sociocultural practices.

The study also found that millennial men used digital channels for education and work at the rate of 80% to 75% for millennial women. All men were more proactive than women in learning new digital skills at 52% vs 45%. Accenture claims that the Digital Fluency Model "shows that nations with higher rates of digital fluency among women have higher rates of gender equality in the workplace" (np) identifying the USA, the Netherlands, the UK, and Nordic countries among the top performers on workplace equality.

Discussion

While digital access divide appears to be narrowing, at least in developed countries, gender differences are reflected in the nature of use of ICTs. For example, younger women were more likely to use social media to socialize, develop, or maintain relationships; seek health and beauty advice; and participate in online educational activities, younger men tended to use ICTs for gaming. Older women in certain geopolitical regions were not equally represented online. Developing countries continue to show gender disparities implicated in socioeconomic and political differences. A particularly interesting theory came from the analysis of data from 21 countries: women's ICT representation tends to be relatively high in countries that score low as liberal egalitarian societies (Charles & Bradley, 2005). They speculated that in countries where women have a freer choice of careers, gender stereotypes lead them to make stereotyped career choices, and that "[R]estrictive government practices that minimize choice and prioritize merit may actually result in more gender-neutral distribution across fields of study." They conclude that sex segregation in computing is linked to "deeply rooted cultural assumptions about gender difference" (Charles & Bradley, 2005, in Sanders, 2007, p. 9).

The global picture in 2017 has implications for educators and policymakers, particularly those of us working with adult learners, distance and online learners, and learners marginalized by race and socioeconomic status. For example, as many regions are increasingly invested in eGovernment, how can we encourage the participation of those without daily, personal access to the Internet? If women's participation in formal, and informal, educational opportunities improves the socioeconomic and health benefits of families, how can we compensate for constrained access to online learning environments? If the global economy depends on the full participation of women in STEM careers, how can we attract and encourage women into STEM-related programs, widen opportunities, and retain women in these sectors?

The next section follows on from this discussion of the digital divide, reviewing participation in social media platforms. Previous research in this area focused on computer-mediated communications (CMC), especially discourse patterns and characteristics of females and males. Because CMC was a mainstay of online programs, an understanding of these patterns was important not only to the design of learning activities, but also to the professional development and support of facilitators of online discussions. The advent of the "social Web," which encourages peer-to-peer and co-construction of content, has raised new questions about ethical behavior; safe online environments in which to learn; the role of teachers; the quality, source, and reliability of information; and the social effects of global, mostly unregulated access to social media platforms. Concern about gendered interaction continues, as do questions about political and economic contexts of use.

Gender Online: Social Media, Age, and Culture

The study of gender differences in computer-mediated communication (CMC), or online discourse, has a long history. The first viable asynchronous online discussions occurred in the 1990s; as early as 1991, Selfe and Meyer reported gendered power dynamics in an asynchronous academic discussion list, with men and high-profile members of the community dominating communication, even under conditions of pseudonymity. Subsequently, gender differences in public online discussion forums and chats showed males to be more assertive, self-promoting, rhetorical, argumentative, insulting, impatient, adversarial, sarcastic, and profane and females to be more accommodating, supportive, attenuating, courteous, affectionate, accepting of others' views, and upbeat (c.f. Cherny, 1994; Herring 1993, 2003a, Thomson & Murachver, 2001). Herring (2012) points out these online patterns reflected gender styles in spoken conversation (c.f. Tannen, 1990, 1994, 1996), and that "conventionally gendered ways of communicating are deeply embedded in people's social identities, and…differences tend to persist even in conscious attempts to manipulate gendered language" (Herring & Martinson, 2004, p. 444).

Herring also observes that, contrary to academic and public beliefs that these patterns are outmoded or disappearing as social media becomes ubiquitous, Kapidzic and Herring (2011) found similar message tones in a teenage chat room. The social exchanges initiated by males were significantly more aggressive, profane, and flirtatious than those of girls, who used more hedges and friendly phrasing and emoticons that represented smiles and good humor; were more apologetic; and thanked other participants for their messages.

Kapidzic and Herring (2011) conclude that the findings indicate that "despite changes in technology and purported feminist advances in society over the past 20 years, traditional gender patterns in communication style and self-presentation persist in CMC, at least in heterosexual teen chat sites" (39). The researchers suggest that patterns are perceived by the teens who employ them to serve useful purposes. In fact, "symbolic gender differentiation via language and images" are socially facilitative and aim to "heighten mutual…attractiveness in teen chatrooms, in which direct physical actions are unavailable, (and that) …what constitutes female and male attractiveness are not random; rather, they are ingrained in western society and reinforced by mass media representations" (Durham, 2008, in Kapidzic & Herring, 2011, p. 41). However, relatively little empirical evidence exists on "how people perform a different gender online, to what behavioral cues other participants attend in assessing others' real-life gender" and "the relationship among claimed gender, actual gender, and language use" (Herring & Martinson, 2004, p. 425).

Synchronous environments have been harder to characterize. Some early researchers contended that traditional gender binaries were blurring and breaking down due to the greater anonymity and "safety" afforded by text-based technological environments (c.f. McRae, 1996). Pseudonymous chat environments were thought to bring out the inherently fluid, performative nature of gender identity (Butler, 1990), in keeping with a trend toward the deconstruction of gender categories in postmodern society. For example, Gross (2004) found that male and female teenagers did not differ greatly in their online habits or behavior. These last observations raise an important issue, which is that times – and technologies – have changed since the gender and CMC research conducted in the 1990s. Herring describes the development of Web 2.0 technologies, with their convergence of multimodal, communicative, and collaborative features, which have given rise to massive social networking sites such as Facebook and weblogs, or blogs, incorporating asynchronous discussion forums, polls, testimonials; avatars, and personal user profiles, with photographs of self, friends, and family. These sites encourage the widespread circulation of real and fake news, popular culture sites, marketing, and cultural memes. Interestingly, on these sites, anonymity has given way to sharing, and provides many possibilities for determining how gender identity is expressed. In one study of teenage chatrooms, Herring (2004) found that word choice and some speech acts appeared to be determined more by the topic of conversation than by participants' gender. However, significant differences were found for the use of other speech acts and overall message tone; and physical stance, dress, and social distance in profile images, functioning as broader, more stable signals of gender identity. Genre also appears to have an influence: Huffaker and Calvert (2005) found few gender differences in lexical choice in teen blogs but were studying only online diaries. Similarly, Koch, Mueller, Kruse, and Zumbach (2005) found few gender differences in their experimental study of gender construction in chat groups, where all the undergraduate subjects were discussing the same topic. It appears that stylistic variables may be more gendered than actual textual acts. Guiller & Durndell, (2007), and Thelwall, Wilkinson, and Uppal (2010) found that males were more likely to use authoritative language and to respond negatively in interactions, while females were more likely to agree explicitly, support others, use more positive tones and make more personal and emotional contributions.

Cultural Differences

Before 2000, most users of online chats were young, male Americans, and although American users now only make up only one-third of the online population, the percentage of English-language Web pages remains disproportionately high (Lavoie, O'Neill, & Bennett, 2003). Conversely, the gender gap appears to be closing even though men still spend more time online per visit and dominate public discussion forums (Herring, 2003; Pastore, 2001). For example, Herring, Kouper, Scheidt, & Wright (2004) found ordinary bloggers were found to be female nearly as often as male, and young (teens or young adults) as often as adult. However, gender and age of bloggers varied according to blog type, with adult males writing almost all filter blogs, and young females writing the largest proportion of personal journals or diary-type blogs.

There appear to be cultural differences in blogging practices, with more users in Spain than Germany, and young, female Poles out blogging males (by 75%) and older adults (Trammell, Tarkowski, & Hofmokl, 2006). Again, genre was related as the Polish girls blogged more frequently about their emotional reactions to events than any of the other groups. However, the blogger profile still tends to be young adult males residing in the USA, followed by Singapore, the UK, Canada, and Australia, many of whom held technology-related jobs such as Web developer, system administrator, and computer programmer. As these occupations are male-dominated a gender disparity continues to emerge.

Herring (2004) acknowledges the "earlier utopian views of the internet as a gender equalizer" that enjoyed a renaissance as the number of female internet users climbed, while "others pointed to a by-then irrefutable body of evidence of online gender harassment." She acknowledges that we "surrendered to the internet, nervously accepted our dependence on it, as the extent of that dependency sunk in." And, even though internet access was rapidly spreading across the globe, including ostensibly flattening boundaries of race and class, "at the same time, for some, the novelty of CMC had already worn off…and some users who had been enthusiastic participants earlier had subsequently scaled back their use, disenchanted with the flame wars, repetitiousness, incoherence, and banality of online public discourse" (p. 28).

Certain gender patterns have been continuously and persistently reproduced over more than two decades of research. While socially facilitative, that is, tacitly understood, gendered power dimensions underlie patterns of discourse (performance): males – dominant and in control, and females – accommodating and anxious to please males. Online environments evidently make gender more salient, manifesting in terms of assertiveness, expression of emotion, politeness, etc. in other types of engagement, including online academic discussions (Guiller & Durndell, 2007, in Kapidzic & Herring, 2011). The question for educators is how the gender identities are performed for better or worse in different communicative settings, and how these environments may be designed to facilitate social equity (Kapidzic & Herring, 2011).

Apart from English-language blogs, the choice of linguistic code in multilingual computer-mediated groups has also been observed to serve different discourse functions (Georgakopoulou, 2011). "Language variety" includes dialect, and the register of the language used. Register refers to specialized "sub-languages" associated with conventional social roles and contexts, such as academic discourse or teacher talk. In these sites, the default dialect is the standard, educated, written variety of the language (e.g., Oxford English), although regional, social class, or ethnic dialects may sometimes be used (Androutsopoulos & Ziegler, 2004). These registers reflect gendered performances in the same way that lexical and stylistic discourse does.

Discussion

While the digital access divide may be narrowing, to date, the greater presence of women has not substantially affected gendered discourse patterns online. Gender identities are revealed through lexical and stylistic patterns, register, and code, regardless of culture. This points to the persistent, fundamental, sociocultural expectations of gender performance. Ferenczi, Marshall and Bejanyan (2017) investigated differences between 573 men and women in social (anti and pro) uses of Facebook. Participants completed measures of narcissism, relational self-construct, and motives for using Facebook, revealing that men reported more antisocial motives than did women, which was explained by men's greater narcissism. Conversely, women reported stronger prosocial motives for using Facebook, which was explained by their more relational self-construct. Gendered behavior has been illustrated in uses to which social media is put, that is, females of all ages trending to more personal uses, while males dominate filtered blogs and "news" sites. Many communities are concerned with the emergence of internet "trolls" who appear to be overwhelmingly male. In a study of 1215 "trolls," Buckels, Trapnell, and Paulhus (2014) found strong positive associations among online commenting frequency, trolling enjoyment, and troll identity, revealing "similar patterns of relations between trolling and the 'Dark Tetrad' (Međedović & Petrović, 2015) of personality: trolling correlated positively with sadism, psychopathy, and Machiavellianism, using both enjoyment ratings and identity scores" (abstract). Frighteningly, of all the personality measures, sadism showed the most robust associations with trolling and was specific to trolling behavior. This behavior has disproportionately targeted females, ethnicities, and sexual orientation (c.f. Ryall, 2017; Wente, 2017). Of concern to educators, as Internet use increases, is whether we can design interventions to promote more prosocial behavior in users of social media.

The seminal work of Susan Herring and her colleagues has been highlighted in the previous section. Herring first examined conversations among adults using computer-mediated tools, more recently, exploring the blogosphere. While this work is not exclusively gendered, the research has consistently shown that the online space is a gendered space in which gendered discourse styles remain consistent through several decades of work. In terms of online learning, we see that dilemmatic spaces in educational contexts have been developed in the tensions between "societal expectations and the historical, cultural, institutional…political and economic prerequisites and the ongoing social, relational and communicative processes" that occur in both structured and unstructured discourses (Fransson, 2016, p. 194). These tensions are very publicly played out in the twelve (or so) years that individuals attend school. In the next section, I share both foundational and more current research about gendered practices related to learning with technology and in the STEM subjects that both reflect and lead to structural social issues of marginalization.

Gender and Pedagogical Practices: Schools and Curriculum

Three decades of research on instructional methods, learning styles, and interests have found that females tend to prefer pedagogies and curriculum design and content that connect in meaningful ways with learners' prior experiences and the world in which they live (c.f. Belenky et al., 1986; Brunner, 1997; Jacobs & Becker, 1997; McIntosh, 1983; Rosser, 1985, 1989). We have seen that these research outcomes, dominated by Western cultures, have focused on "gendered" characteristics rather than the sociocultural contexts that influence learning. However, more current research (see the discussion on self-efficacy, above) suggests that it is particularly important that teachers and curriculum designers in the STEM disciplines attend to the

experience base of female students, connecting learners through their life experiences (c.f. Markert, 2003). For example, a thoughtful curation of OERs (Open Educational Resources) with which learners can identify through gendered lenses may be more relevant than textbooks (Weber & Custer, 2005).

In Canada, performance gaps between boys and girls in science are relatively low compared to those in other Organisation for Economic Co-operation and Development (OECD) countries; however, the OECD highlights that a gap exists between girls and boys in mathematics: Boys' average scores in mathematics were nine points higher than girls' scores. Is this a result of innate ability or a complex weaving of cognitive abilities and sociocultural influences?

Several studies surveyed for this chapter support that belief that females prefer collaboration over competition (c.f. Caleb, 2000; Chapman, 2000) consistent with contemporary trends in technology education, where the "historic use" of individual projects is shifting toward small, collaborative group work (Weber & Custer, 2005, p. 56) With regard to classroom computer use, it is well documented that females' preference for design, especially when activities focus on socially relevant problem-solving, and males' preference for utilization, especially when the activity involves building with tools, is generally consistent with gender stereotypes (Weber & Custer, 2005). Weber and Custer also found that developing engaging construction-related activities for females remains a significant challenge for curriculum developers, observing that the "construction" activities in this study reflected pedagogical strategies favoring debate, research, and evaluation, strategies that are typically utilized by traditional discipline. They concluded that strategies might have as much influence as content. Welty and Puck (2001), for example, found that females' interest increased if the computer was used as a tool to create something like a multimedia presentation, but not if the focus was on learning how to program computers, and that both females and males ranked "lecture" and "lecture with discussion" as the least preferred methods of instruction. The foregoing has implications for gender-balanced topic selection in technology education. An increased emphasis on design in contemporary technology education courses could provide some balance between this design and make/utilize dichotomy (Weber & Custer, 2005). In the public school years, girls and boys take math and science courses in roughly the same numbers. However, by the time they are to choose majors at university, fewer women than men choose these areas of study. By the time they graduate, men far outnumber women in bachelor's degrees awarded, fewer women than men enter graduate programs in these areas, and participation further declines in the transition to the workplace. Students from historically disadvantaged groups, both female and male, are also less likely to have access to advanced courses in math and science in high school, which negatively affects their ability to enter and successfully complete STEM majors at post-secondary level (c.f. Tyson, Lee, Borman, & Hanson, 2007; Perna et al., 2009).

Hill, Corbett, and St. Rose (2010) found that societal beliefs (and discourse), reflected in decisions at home and in school, affect girls' beliefs about their intelligence and ability to succeed in STEM subjects. For example, there is evidence that girls assess their mathematical abilities lower than do boys with similar mathematical achievements while holding themselves to higher standards of achievement. In other words, girls believe that they have to be exceptional in order to find success in "male" subjects or fields. For example, while no definitive evidence proves that strong spatial abilities are required for achievement in STEM careers (Ceci et al., 2009), many people, including science and engineering professors, view them as important for success in fields like engineering and classes like organic chemistry. Girls rate themselves lower on spatial-visualization ability. However, in one pilot study, Sorby (2009) found that middle school girls who took a spatial-visualization course took more advanced-level math and science courses in high school than did girls who did not take the course and recommends that this training happen by middle school or earlier to make a difference in girls' choices.

One outcome of gendered belief is that fewer girls than boys aspire to STEM careers. Many young men in computer science report having had an immediate and strong engagement with the computer from an early age, intensifying in middle and high school. On the other hand, many women who are interested in computer science and have similar talent do not report a similar experience (Singh, Allen, Scheckler, & Darlington, 2007). As STEM jobs are critical to the global economy, women's participation in these fields, currently at 25% overall, is of concern (Lacey & Wright, 2009). Practically, if the design of products and services such as airbags, buildings, cars, and medical interventions does not take into account the differences between men and women (size, voice timbre, hormones, etc.), the consequences can be dire, for example, deaths of women and children in vehicular accidents caused by airbags designed by and tested on male engineers (Hill et al., 2010).

While the Western classroom has dominated research on gender issues, research in Eastern Europe, Africa, Asia, and the Middle East has examined gender differences in approach to technology for learning. For example, traditional Iranian laws hold education accountable for the support of girls' social and political status, emphasizing gender equality in education, and requiring the Iranian Ministry of education to modify educational materials in order to present a gender-neutral picture of women (Ghajarieh & Salami, 2016). The "equal education opportunities" discourse, initially encouraged by many educational institutes in the UK and the US, supports the notion that education should be for both boys and girls; the support of this discourse depends on social and cultural considerations (p. 258).

Learning Spaces

Dominant design practices that, for decades, have centered on 40-year-old, able-bodied males have ignored the needs of groups typically marginalized by design such as women, the aged, the infirm, and the young. Universal design emerged from the political work done by the accessibility movement activists in the 1960s and 1970s. Universal designers advocate for a more diverse range of abilities when designing built environments, thinking systematically about inclusion (Nieusma, 2004, p. 14). Universal scholars from all design fields, including instructional design, are reflecting on how technologies and other designed artifacts, including curriculum and learning resources, are implicated in larger social problems, such as sexism, lack of user participation and autonomy, and restricted access to built environments.

Rendell, Penner, and Borden (2000, in Lång, 2010) describe the built environment as "a cultural artefact that is embedded in the process through which individuals build and form their identities." Consequently, learning facilities will embody cultural values and imply standards of behavior that are transmitted to designers through authoritative voices of planners, and architects. Designing a gender-neutral learning space is challenged by the domination of male decision makers at design and policy levels, and the need to design spaces that respond to different and gendered needs, including those who feel excluded by binary categories (Blaise, 2005). This suggests that planners should consider social intersections that include gender differences (Becker, 2009).

A UNESCO (2017b) study of learning facilities in different geopolitical regions found that, while schools are intended to be places of learning, growth, and empowerment, they can often be sites of intolerance, discrimination, and violence, in which girls are disproportionately at risk. Parents concerned for their child's safety in this study were anxious about mixed gender classes, and the poor educational outcomes of girls in these situations (Lång, 2010). For the most part, classrooms, including computer labs, have not been designed to be gender-neutral, as designers may not be aware of their assumptions about space. For example, spaces that are flexible, allowing for collaborative work; lighting that accounts for security concerns; learning stations that are designed with smaller physiques in mind; technologies that adapt to multiple users' inputs instead of one (usually a male) operator; spaces with extended hours of support and security; open spaces where activity is always visible; even single-sex groupings (although not accounting for Intersectionalities) contribute to more accessible, safer, and inclusive learning environments.

Discussion

Intersecting factors such as gender, identity (e.g., Indigenous), socioeconomic background, culture, language, and ability can affect equitable learning opportunities (c.f. Lee, Kotsopoulos, & Zambrzycka, 2012). In Canada, the disparity is particularly acute for Indigenous children, who, due to a range of social determinants, experience gaps in academic achievement that emerge in elementary school and intensify at higher grades (Richards & Scott, 2009). Evidence points to a range of factors that affect representation by field of study, occupation, and rank, ranging from personal preferences to discrimination and structural barriers (Actua, 2014; NAS, 2007; Hill et al., 2010).

Educational contexts are social constructions reflecting history, economics, politics, cultural values and expectations, policy, and place. Teaching is an incredibly complex activity and teachers, as actors, perform in these multi-layered spaces as curriculum makers and negotiators between parents, learners, colleagues, administrators, and society. Global expectations of schools as safe, effective, and efficient sites of learning have increased, certainly in view of the financial, political, and social investments made in learning technologies. Fransson (2016) speaks about teachers as "manoeuverers" in a context in which "digital technologies construct new dimensions of everyday practice," pressuring them to design with and for these technological environments, even though "this may be at odds with their own knowledge, beliefs, emotion and doubts about their potential" (p. 194). Research about teacher education and classroom teaching has shown that gender is an identity construction that is reflected in an individual's approach to technology and to their beliefs and expectations about gender and technology. For example, parents and teachers alike have expected less of girls in technology environments; in turn, girls expect less of themselves or of their potential for success.

While teachers can do little to intervene in the early childhood years, they can acknowledge the sociocultural forces that have shaped children before they come to school and evaluate their pedagogical spaces, approaches, activities, and curriculum for bias. For example, bias in representation can be detected, and replaced, in learning resources, perhaps with a careful and critical curation of OERs. There has been some success in BYOD interventions, although not all children will easily have access to mobile devices, certainly of the same quality. Learning activities that reflect prior experiences, involve creativity, include narrative, and utilize technologies as tools to solve problems rather than as a focus of interest in themselves has been shown to underlie inclusive classrooms. Critical theoretical models such as "Multiliteracies" above, where learners co-create curriculum out of their own cultural understandings is one evidence-based approach.

We have seen that structural bias influences self-efficacy and attitudes toward STEM subjects. Research has consistently demonstrated that there are no biological barriers to females succeeding in STEM subjects. Self-efficacy can be influenced, though, in a number of ways. Fundamentally, identification of "stumbling blocks" to a successful learning experience, a planned intervention (design), and sufficient attempts to practice with a metacognitive emphasis may begin to shift personal doubts. For example, the work of Sorby (2009) with females who describe themselves as being visually spatially challenged demonstrates that skills can be taught, narrowing or eliminating performance gaps.

Globally, teachers obviously need to be alert to cultural expectations that influence the self-efficacy and performance of girls and women. In many areas of the world, women are already disadvantaged by religion, cultural assumptions, socioeconomic status, and other factors. Western research about same-sex groupings has had mixed results (c.f. Arms, 2010), although there is evidence that same-sex classes remove some performance pressure for girls.

Next, if structural "discrimination" in the K-12 sector has not discouraged them, we will see that females actually outnumber male students in the post-secondary sector, at least in the Western world. What happens to them when they enter programs that are technology-heavy at college, university, and professional education?

Gender and the Post-secondary Learning Environment: Disciplinary Cultures

Statistics Canada reports that, as of 2014, women made up just over one quarter (25.4%) of enrolment in mathematics, computer and information sciences and less than one-fifth (19%) of enrolment in engineering and architecture (MacLean, 2017). In fact, women's representation in computer science is actually declining. While more Indigenous women than men held a university degree in 2011 (13.2% to 7.6%), they make up a proportionately lower portion of STEM-related degrees. The Canadian Council of Academies (CCA) points out that Canada is missing out on an important supply of skilled talent. In a report tabled in 2015, the CCA concluded that increasing the STEM participation of underrepresented populations, including women and Aboriginal peoples, was an important strategy for diversifying the economy. Interestingly, at the higher levels of education, a large proportion of STEM graduates were immigrants (39%); however, women and immigrants tended to have lower incomes and poorer economic outcomes than men and Canadian-born workers overall (Drummond & Fong, 2010). Disparities in Canada are mirrored in the USA where Asian women earn far more STEM degrees (12%) than do African American and Hispanic women (5%), and more Asian women earn master's degrees in STEM (12%) than in other fields (4.5%) (Hewlett et al., 2008).

Many of the men in this, and other surveys, report increasing interest in computer science as they progress through school. Females report more moderate interest in computer science, especially early on, that builds only gradually. Singh and her colleagues (2007) caution that distinguishing between an interest in computer science and an interest in computers and technology is important: Women and men are interested in and equally likely to use computers and technology for educational and communication purposes, but the gender gap in the study of computer science remains. Margolis and Fisher (2002) found that among women and men who had similar grades, women in computer-related majors were less confident than their male peers about their ability to succeed in their major. The group of female computer science majors in the study who were "brimming with confidence and excitement about their major in the earliest interviews were no longer 'buzzing' by the second and third semester" (92), expressing dissatisfaction with the culture of the discipline, and leading the researchers to argue that the decline in women's confidence is a problem of student experience in the institutional culture. Computer science, with its emphasis on basic skills as opposed to problem-solving (Goode, Estrella, & Margolis, 2005), and the fact that complex and more interesting projects are often reserved for advanced courses that come too late for most women (Linn, 2005) may also speak to women's higher dropout rate. Jahren's (2016) research supports this finding, reporting that while 23% of freshmen women in the study of 191 female fellowship recipients reported never experiencing isolation and intimidation as barriers, 12% indicated that they had been sexually harassed as a student or early professional.

As in the public school years, curriculum can signal who belongs in a major. Computer science programs that initially emphasize technical aspects of programming before considering the broader multidisciplinary applications can be a deterrent to students of both sexes, but especially to women, who are more likely to report interest in the use of computing to address larger social issues. Certain STEM subdisciplines with a clearer social purpose, such as biomedical engineering and environmental engineering, have succeeded in attracting higher percentages of women than have other subdisciplines like mechanical or electrical engineering (Gibbons, 2009). Sorby and Baartmans (2000) speculated that the belief that perceived inability in tasks requiring spatial skills, which is emphasized in early engineering education, may discourage women from choosing engineering as a major. Whether or not well-developed spatial skills are necessary for success in science and engineering, they found that spatial skills were improved fairly easily with training, by designing and implementing a successful course to improve the spatial-visualization skills of first-year engineering students who had poorly developed spatial skills. More than three-quarters of female engineering students who took the course remained in the school of engineering, compared with about one-half of the female students who did not take the course. Poor or underdeveloped spatial skills may deter girls from pursuing math or science courses or careers, but these skills can be improved fairly easily.

In terms of pedagogy, some work has been done on cognitive style and computing, with Turkle and Papert recommending "bricolage" as an approach to programming that may be more appropriate to females (1992). Blackwell (2006) explored social context and programming, noting that with differing degrees of self-efficacy, bricolage seems likely to become a feature of end-user programming in the home, for example, but might be framed in a way that is predominantly masculine, that is, the male activity of "tinkering." Finally, while the "single-sex" approach to teaching coding has had mixed success, Werner and her colleagues have found that both female and male pairs of university students, but especially women, were more likely to complete their computer course and major in computer science than mixed-sex pairs or students working solo (Denner, Werner, Bean, & Campe, 2005; Werner, Hanks, & McDowell, 2004). Margolis and Fisher (2002) insist that the goal of curriculum reform should not be to lure "women into computer science but rather to change computer science" (p. 6).

Departmental culture includes the expectations, assumptions, and values that guide the actions of professors, staff, and students; the culture is often implicit. Decisions about how to design and teach classes, assess learning, advise students, and organize activities reflect the norms, expectations and interests of the subset of males who take an early interest in computing and pursue it with passion during adolescence and into college. Margolis and Fisher (2002) illustrate how this pattern of behavior is influenced by a Western culture that associates success in computing with boys and men, excluding girls and women. Within the computing science environment, this male model of "doing" computer science (doing gender?) becomes the measure of success, alienating women who have had a different experience.

These findings are supported by Kugler (200, in Role, 2017), who studied computer science majors at Carnegie Mellon University, showed that while women and men are equally likely to change out of college majors in response to poor grades, the exceptions to that rule are STEM programs, in which women are more responsive than men to the negative feedback of low grades. The authors suggest that STEM disciplines are branded as "too-male"; female students that see their numerical minority status are more likely to perceive low grades as confirmation of their inherent unfitness for a STEM discipline.

When considering the underrepresentation of women in science and technology disciplines and careers, another factor may be that they may find better opportunities elsewhere. Several researchers found that more women than men tended to show aptitude in both math and language skills, and yet, the rate of women choosing STEM careers remained low, perhaps because "people tend to play to their strengths." A longitudinal (1992–2007) study of 1500 college-bound students of above-average intelligence, from the University of Pittsburgh (Wang, Eccles, & Kenny, 2013), concluded that women have broader intellectual talents, which provide them with more occupational options. Among those who had highest scores on both the verbal and the math sections of the SAT, for example, nearly two-thirds were female, while only 37% were male. However, among those who excelled in one area but not the other, 70% of those with high math and lower verbal scores were male, while 30% were female, and vice versa. Of those who scored best across the board, 34% choose a STEM career, but 49% of those who did better in math than in language skills chose a STEM career, showing that a breakdown between verbal and math skills remained a strong predictor of career choice. The gender difference among those scoring higher in math than in language, meant fewer capable women wound up in science and mathematical fields. This seems true even when controlling for other factors such as the socioeconomic status of the participants' parents, their own values when it came to balancing work and family, and their personal perceptions about their skills and interests. Cultural stereotypes may be indirectly pushing women away from scientific fields. Addressing the gender gap in STEM careers may not be so much a pipeline problem or one of intellectual ability but in making these fields more welcoming, accessible, and financially attractive.

In fact, data from nearly 300,000 students in 40 countries who took an international test showed that where women are treated more equally, no gender gap exists in math and science scores, and in a few countries, women even do better (Szalavitz, 2013). In countries such as those in northern Europe, not only are women seen as equally capable of math performance, but both genders have government-required paid family leave available to them, as well as free or cheap access to high-quality day care, making the pursuit of demanding careers in science and technology easier and female role models who do it more visible. However, in countries where those opportunities are rarer, where "using words to win is seen as a more appropriate career for a woman and where women's confidence in their math skills is consistently undermined, then women may find the support and options in non-STEM fields more appealing" (Szalavitz, 2013). Wang et al. (2013) believe that their study provides evidence that females with high math ability also have high verbal ability and thus can consider a wider range of occupations than their male peers, instead of having lower abilities in the first place (Athena factor).

There are cases in which institutions are doing a better job of recruiting and retaining female STEM majors. For example, Whitten, Dorato, Duncombe, Allen, Blaha, Butler, Shaw, Taylor, & Williams (2007) were especially impressed with the model of historically black colleges and universities (HBCUs) for creating electives and building supportive departmental cultures in which a disproportionate number of African American female physicists, and more than one-half of all African American physics degree holders, female and male at all levels, graduate (Whitten et al., 2007). For example, HBCUs did one crucial thing by using electives and other activities providing a path toward a degree for students who did not come to college fully prepared to be physics majors.

Discussion

As this section shows, the underrepresentation of women and girls in STEM education can be attributed, in large part, to the persistence of gender stereotypes that lead to "chilly climates" at school and work. A 2017 UNESCO report concluded that "girls' disadvantage is not based on cognitive ability, but in the socialisation and learning processes within which girls are raised and which shape their identity, beliefs, behaviors and choices" (p. 72), from childhood through tertiary education. The report made a number of suggestions to alleviate this problem, including the following:

- Increasing the representation of women in STEM in the media.
- Making STEM curricula gender-responsive.
- Ensuring girls have female role models in STEM fields and.
- Increasing mentorship opportunities for girls and women in STEM.

Finally, the notion of gender (and equality) has implications for adult and distance learning, in which values like empowerment, emancipation, personal growth, and agency meet the understanding of gendered social practices and include the possibility of individual or collective social action. Heiskanen (2006) proposes "adult education as agency might be a site for understanding, and acting on, structural relations of work and learning that are transactional and always changing" (p. 532) particularly in a "post-truth" society.

Referencing the discussion of the experience of post-secondary education curriculum, structures, and cultures, the final section of this review examines STEM workplaces (although all workplaces use technology in some way). It is reasonable to include this overview of more recent research because arguably the gendered experiences at home, in society, and in school lead resolve into career decisions and worklife. The questions here relate to workplace culture, career progression, and the gender wage gap.

If the path from elementary school to a STEM career is a "pipeline," we would expect that as the number of girls who study STEM subjects in elementary, middle, and secondary school increases, the number of women who emerge from the pipeline into scientific and technical careers will also increase; gender disparities in representation will disappear. However, the next section presents a less positive outcome than we might have expected.

Gender in STEM Workplaces: Intersections with Race and Culture

In the spring of 2006, the Hidden Brain Drain, a 43-company global task force, launched a research project targeting women with degrees in science, technology, engineering and mathematics (STEM) who had embarked on careers in the private sector. The Athena Project, as it was dubbed, conducted four major surveys and 28 focus groups in Boston, Chicago, Geneva, Hong Kong, London, Moscow, New Jersey, New York, Palo Alto, Pittsburgh, Seattle, Shanghai, and Sydney over an 18-month period. The data showed that that 41% of highly qualified scientists, engineers, and technologists on the lower rungs of corporate career ladders were female. Despite the challenges they face at school and in our culture, a significant number of girls begin careers in science. Their dedication is impressive: Two-thirds of female scientists choose their fields to contribute to the well-being of society. But something happens between the early years and the mid-career point: 52% of highly qualified females working for STEM companies quit their jobs, driven out by hostile work environments, including sexual harassment, and extreme job pressures. The Athena Project researchers called these factors the "antigens" – hostile macho culture, individuality, isolation, mysterious career paths, and the "diving catch" culture that rewarded risk-taking.

In most STEM fields, the drop-off is pronounced. For example, women earned 12% of the doctorates in engineering in 1996, but were only 7% of the tenured faculty in engineering in US colleges and universities in 2006 (Hewlett et al., 2008). Even in fields like life sciences, where women now receive about one-half of doctorates awarded, women made up less than one-quarter of tenured faculty and only 34% of tenure-track faculty in 2006 (National Science Foundation, 2008, 2009). The numbers for women of color, Canadian Indigenous and Native American women, and immigrants are more dire. For example, in 2011, female immigrants were the majority of women aged 25–34 years with degrees in mathematics and computer science (65%), and engineering (54%), whereas Canadian-born women represented 70% of all female science and technology degree holders. The data available for Indigenous women in STEM fields indicate similar trends to those for non-Indigenous female STEM degree holders in Canada; in 2011, both Indigenous and non-Indigenous women with STEM degrees were more likely to hold degrees in the science and technology fields. However, only 27% of STEM professionals are women.

Professional Workplaces

Currently, women make up only 27% of the workforce in Canadian.

communications and technology industries, leaving these industries at an alarming rate. In the USA, Hewlitt and others (2008) found that over time, over half of highly qualified women working in science, engineering, and technology companies quit their jobs. In 2013, just 26% of computing jobs in the USA were held by women, down from 35% in 1990, according to a study by the American Association of University Women (Hill et al., 2010). Engineers are the second largest STEM occupational group, but only about one out of every seven engineers is female. In physical and life sciences jobs, however, women made up about 40% of the workforce in 2009, up from 36% in 2000. Another area that has shown growth is STEM management, with women in management positions increasing to 25% overall.

The so-called pipeline problem does not entirely account for these low numbers of participation. Among STEM majors in college, about 57% of female STEM majors study physical and life sciences, while about 31% of men choose these fields. The share of women choosing math majors is also higher than men: 10% versus 6%. However, two and a half times the number of men choose engineering degrees. About equal numbers of male and female STEM majors enter computer science, but men in the workforce with STEM degrees outnumber women across all four fields of study. In short, women with a STEM degree are less likely than their male counterparts to work in a STEM occupation; they are more likely to work in education or health care. There are many possible factors contributing to the discrepancy of women and men in STEM jobs, including a lack of female role models and less family-friendly flexibility in the STEM fields (Beede et al., 2011).

Gender stereotypes contribute to this situation. A 2005 Gallup poll of 1008 adults, aged 18 and older, found that 21% of Americans believed men were better than women in terms of their math and science abilities (though 68% believed men and women were about the same). The higher the education level of the respondent, the lower the belief that men were better, but of the 21% of respondents who believe men have an advantage say it is due to “differences between boys and girls that are present at birth” as say the perceived advantage is due to “differences in the way society and the educational system treat boys and girls” (Jones, 2005). There are gender differences in the participation of men and women in some STEM fields among students, and these differences do contribute to the underrepresentation of women in skilled technical positions as well as in leadership positions: One study places the gender gap at 80% (men) to 20%, whereas about 29% of executive positions in industry overall are held by women (Jones, 2005). Recent commentary in *Inside Higher Education* (Jaschik, 2018) relates unconscious bias in hiring practices of companies that contributed to the gender gap from the beginning of one’s career.

Meta-analytic evidence on gender differences in leadership aspirations showed that differences are decreasing over time, suggesting that the gap is more due to society than to biology, although cultural differences do exist (c.f. Gneezy, Leonard, & List, 2009; Li, 2002). In his unfortunate memo to Google staff in 2017, describing Google’s culture as an “ideological echo chamber”, James Damore cited one study that did find gender differences in personality across cultures, but the researchers described the differences as relatively small to moderate and concluded that “human development—long and healthy life, access to education, and economic wealth—is a primary correlate of the gap between men and women in their personality traits. (Schmitt, Realo, Voracek, & Allik, 2008, p. 180).” At Google, women make up 30% of the company’s overall workforce, but hold only 17% of the company’s tech jobs. At Facebook, 15% of technical roles are staffed by women. At Twitter, it is 10%. For non-technical jobs at Twitter (e.g., marketing, HR, and sales), the gender split is 50–50, while only 10% of leadership roles are held by women. (Hill et al., 2010).

The underrepresentation of women in STEM majors and jobs may be attributable to a variety of factors, including different choices men and women typically make in response to incentives in STEM education and STEM employment. For example, STEM career paths may be less accommodating to people cycling in and out of the work-force to raise a family – or it may be because there are relatively few female STEM role models. First, let us acknowledge that gender has proved to be a complicated issue for both research and practice. Arguing that action research has the potential of making a contribution to understanding gender issues, Heiskanen (2006) emphasizes that “(change) projects need a concept of gender which includes the relevant aspects of social structure and social process” (p. 519). In the action research, she proposes there is often a tension between organizations who may understand gender as a biological concept, resulting in efforts to remove barriers to equal opportunity. By contrast, Heiskanen (2006) suggests that understanding gender as an activity might “overcome the stable and essentialistic sex/gender dichotomy” (p. 525), including social processes into a “gendered role” (e.g., processes involved in socialization), and taking into account cultural definitions.

Drejhammar (2002) tackles the belief that organizations are, for the most part, gender neutral, although organizations such as schools and workplaces are based on a male norm, "prevent(ing) people from seeing how power and gender are related to each other and what consequences this relationship has for women's working conditions" (Drejhammar, 2002, in Heiskanen, 2006, p. 526). We have seen this in the stubborn gender wage gap, and access to career progression encountered by women in many engineering and IT-related careers (e.g., Silicon Valley organizations like Uber and Google).

Recruitment and Retention in STEM Jobs

While engineering graduates tend to earn more than in other STEM fields, women with a degree or certificate in mathematics and computer sciences may earn almost as much as women engineers. While differences in earnings among fields of STEM education have been relatively stable over time, they do vary by education level and gender. Graduates in engineering, mathematics, and computer sciences have generally enjoyed higher earnings than non-STEM graduates. However, men are more likely than women to graduate from a STEM field. At each level of education, marked differences exist between the proportion of women and men graduates in STEM. Engineering programs are the most popular choice among men and science programs among women. The ratio of women to men graduates is the most balanced in science programs and at the doctoral level overall (p. 104).

Studies of STEM graduates find that women in these fields have higher attrition rates than do both their male peers and women in other occupations, especially at mid-career (c.f. Hewlett and others, 2008). High-tech companies in particular lost 41% of their female employees, compared with only 17% of their male employees. In engineering, women have higher attrition rates than their male peers have, despite similar levels of stated satisfaction and education. The Society of Women Engineers (c.f. Powell, Bagilhole & Daintey, 2009) conducted a retention study of more than 6000 individuals who earned an engineering degree between 1985 and 2003. One-quarter of female engineers surveyed were either not employed at all or not employed in engineering or a related field, while only one-tenth of men surveyed had left the engineering field. Three themes emerge from the literature. First, the notion that men are mathematically superior and innately better suited to STEM fields than women are remains a common belief, with a large number of articles addressing cognitive gender differences as an explanation for the small numbers of women in STEM. A second theme revolves around girls' lack of interest in STEM. A third theme involves the STEM workplace, with issues ranging from work–life balance to bias. An example of how bias and cultural expectations intersect was provided by Heilman and Okimoto (2007), who found that successful women in masculine occupations were less likely to be disliked if they were seen as possessing communal traits such as being understanding, caring, and concerned about others. These authors showed that the negativity directed at successful women in male occupations lessened when the women were viewed as "communal."

McKinsey and Company released a report "Why Diversity Matters" (2015) released new research that shows that US women working in STEM fields are 45%

more likely than their male peers to leave the industry within a year. Over 80% of these women report “loving” what they do. In Brazil, China, and India, the numbers are close to 90%. These women state that they were interested in leadership positions within their fields, but feel marginalized, stalled, stymied by bias and a double standard, and prevented from contributing to their full potential. Similarly, in an online poll of ISACA female members worldwide (2016), 33% explained that the underrepresentation of women in STEM fields was due to information technology role models and leaders being predominantly male (33%). Other explanations were the perception that information technology is a male-dominated field (22%), and the observation that educational institutions do not encourage girls to pursue technology careers (14%). Respondents shared experiences of being overlooked in meetings, having ideas dismissed only to be usurped by male colleagues later, receiving work below their skill and experience levels, and inexplicably being passed over for promotions. Only 22% of the women believed their employers were very committed to hiring and advancing women in technology roles. Even in workplaces with flexible work arrangements, the “flexibility stigma” was observed when women who were encouraged to take maternity leaves were “punished” for deciding to do so. If, within 2 years, 1.2 million jobs in the USA alone require IT skills, at the current rates of recruitment and retention, women will fill only 3% of them (HillsNotes, 2017).

Academic Workplaces

A study on attrition among STEM faculty showed that female and male faculty leave at similar rates; however, women are more likely than men to consider changing jobs within academia. Xue (2008) found that women’s higher turnover was mainly due to dissatisfaction with departmental culture, advancement opportunities, faculty leadership, and research support. Lower satisfaction leads to higher turnover and a loss of talent in science and engineering. The climate of science and engineering departments is closely related to satisfaction of female faculty; providing selective mentoring and work–life policies can enhance the retention of female STEM faculty (Trower, 2008). The climate in STEM departments may be discouraging women with families: Mason et al. (2009) found that the women were 35% less likely to enter a tenure-track position after receiving a doctorate. Former Canadian federal industry minister Tony Clement commissioned a report by the Canadian Council of Academies, that found female academics at all levels earned less than men, and that many promotion and tenure processes lacked exit and re-entry procedures that allow women who take time off to raise children to be considered.

Research has consistently pointed to bias in peer review and hiring. For example, Wenneras and Wold (1997) found that a female postdoctoral applicant had to be significantly more productive than a male applicant to receive the same peer-review score. The female candidate had to publish at least three more papers in a prestigious science journal or an additional 20 papers in lesser known specialty journals to be judged as productive as a male applicant. Similarly, Trix and Psenka (2003) found systematic differences in letters of recommendation for academic positions:

selection committees, the majority of whom were male, relied on accepted gender schema in which, for example, women are not expected to have significant accomplishments. For example, letters written for women were more likely to refer to their compassion, teaching, and service as opposed to their achievements, research, and ability, which are the characteristics highlighted for male applicants, "unknowingly us(ing) selective categorization and perception, also known as stereotyping, in choosing what features to include in their profiles of the female applicants" (p. 215). Studies have shown that employers, and academic peers, do discriminate against women and minorities in hiring, and also in promotion rates, performance evaluations, getting credit for good work, and project assignments. In one study (Moss-Racusin, Dovidio, Brescoll, Graham and Handelsman, 2012), professors rated the identical applications of fictional male or female students. When a male name was used, faculty members rated them as significantly more competent and hirable than the female applicant, and they offered the male applicant a higher starting salary and more career mentoring. The reason for this was that women were perceived as less competent by the faculty members; faculty who had greater bias against women rated female students worse. Intersections with ethnicity paint a bleaker picture: African American women make up less than 1% of faculty in engineering. Even in the life sciences, women of color held about 0.3% of faculty positions (c.f. Frehill, Di Fabio & Hill, 2008).

In October 2014, the Canada Research Chair program published new guidelines for reference letters that provided tips on how to ensure unconscious biases do not undermine female candidates. Referees are encouraged to keep feedback specific to the position and avoid adjectives that characterize women as maternal or agreeable.

Recently, a pan-Canadian expert panel of senior academics analyzed data from Statistics Canada, and other sources (e.g., National Household Survey), concluding

> the reasons to support diversity in Canada's science departments are many, but perhaps the most practical is simply one of global competitiveness. It is no secret that math and science skills are becoming more important to a thriving economy, and while countries like India and China are churning out ever more science and engineering grads, the numbers in Canada are stagnating. We need all hands-on deck, and that begins at our universities. Council of Canadian Academies, 2015

Sadly, in one study of 20 Canadian research universities, almost all computing science and mathematics departments had women comprising fewer than a quarter of regular faculty. The University of McGill's mathematics department had only two women among 40 professors, while Laval University's had only two out of 24. The University of Alberta had fewer than 10% women in any of its STEM departments. Only two universities – the University of Victoria and the University of Ottawa – exceeded the 25% threshold (Kuzmin, Motskin and Gallinger, 2015). The authors point out that in many Canadian universities, a math, computing science, or engineering student "would be lucky to encounter even a single woman professor at the front of the class in any given year — perhaps even over an entire academic career" (nd).

Research Awards

The women who do tough it out are consistently passed over for recognition, and a number of scientists are raising concerns about the lack of female winners of top awards and what it says about women in science in Canada. For example, the National Science and Engineering Research Council (NSERC)'s Hertzberg medal, which is given to Canada's top scientist or engineer each year "for sustained excellence and overall influence of research work" and comes with a $1-million purse, has never been awarded to a woman.

Dr. Kirsty Duncan, Canada's Minister of Science, made headlines in 2016 when she expressed frustration over the fact that female scientists occupy only 30% of the 1612 positions in the Canada Research Chairs Program (CRCP), which is funded by the (federal) Tri-Research-Councils. The statistics for the CRC program are actually (marginally) higher than those for women in STEM fields in general. In 1987, only 20% were female, whereas in 2016, that number had increased to 22%.

At Canadian universities, only 12% of full professors in STEM are female; women are much more likely to be working as contract faculty or as assistant professors. Only 18% of members of the Canadian Science and Engineering Hall of Fame; just 22 out of 186 prizes worth more than $200,000 were given to women by the Natural Sciences and Engineering Research Council (NSERC) between 2004 and 2014; and only 11% of those named to the Royal Society of Canada's Academy of Sciences in the past 4 years were female (Kingston, 2017). Of 22 Canada Excellence Research Chairs, 21 are men and one is a woman. In 2010, the Canadian government named 19 men to the highest tier, and no woman, to the Canada Excellence Research Chairs, which come with a $10-million prize. In the 24 years since the Canadian Science and Engineering Hall of Fame was created, 11 out of its 60 inductees have been women, sparking criticism that because the majority of nominators are male, unconscious bias plays a part in that low number. While the data are from Canadian surveys, they reflect the situation across the Western world.

How can we address this bias in nomination processes? Kuzmin, Motskin, and Gallager (2015) suggest that incentivizing change with resources may result in better outcomes. For example, under the Athena SWAN Charter in the UK., universities are given ratings of bronze, silver, or gold based on their efforts to promote gender equality and racial diversity. In 2011, the UK's chief medical officer announced that the National Institute for Health Research would reserve major funding for schools with a silver or gold rank; the program was so successful in the sciences that it was extended to arts, humanities, business, and law faculties. Ironically, they recount, "even when national governments support systemic change, bias is nearly impossible to eradicate. Maintaining an Athena SWAN award requires a significant amount of paperwork. In 80% of cases, that burden fell on female scientists, and in 49% of cases, they described it as excessive" (np).

Discussion

Women enter STEM disciplines at the same rate as men, but experience a much higher attrition rate. Consistent with research on the "chilly climate" (c.f. Rosser, 1989; Sandler, Silverberg & Hall, 1996), the reasons for the loss of women in these jobs, as well as the low rate of women in leadership positions, are related to workplace culture. Culture embodies social values and assumptions, deleterious to females from childhood through professional training. The issues are acknowledged and policy development reflects, at least, the economic concern that half of a nation's available workforce is underrepresented in key economic drivers such as IT. The so-called "pipeline" problem is less one of recruitment than of retention.

Trower's research (2008) focused on female faculty's satisfaction with the climate in academic workplaces. She identified ten attributes for a supportive environment:

1. Fairness of evaluation by immediate supervisor
2. Interest senior faculty take in professional development
3. Opportunities to collaborate with senior colleagues
4. Quality of professional interaction with senior colleagues
5. Quality of personal interaction with senior colleagues
6. Quality of professional interaction with junior colleagues
7. Quality of personal interaction with junior colleagues
8. "Fit" (i.e., sense of belonging) in the department
9. Intellectual vitality of the senior colleagues in the department
10. Fairness of junior faculty treatment within the department

In essence, female STEM faculty were less satisfied than their male peers were with all 10 factors and significantly less satisfied with three, that is, sense of fit, opportunities to collaborate with senior colleagues, and the perception of fair treatment of junior faculty in one's department; sense of fit was seen as most important in terms of retention and success. The findings from similar surveys in other STEM workplaces indicate that several of these factors can be addressed through initiatives such as awareness training (for unconscious bias), mentoring, and coaching, examination of criteria for advancement, low or zero tolerance for harassment, policies to encourage community engagement, and flexible working conditions, among others. Society benefits from these efforts, as with a more diverse workforce, scientific and technological products, services, and solutions are likely to be better designed and more likely to represent a wider community of users and learners.

Emerging Challenges and Research Directions Beyond 2018

Jo Sanders (2007, p. 23) summarized questions germane to scholars interested in gender and technology research, and impacts on practice such as curriculum development, learning design, pedagogical models, learning spaces, global issues of inclusion, sociocultural influences on school program and career choices, workplace support, and other issues raised in this chapter, several of which I have updated and shared below (dubbed "dissertation topics"):

- We know that parental influence on daughters' technology interests and behavior varies by SES and educational level, but how does it vary by racial/ethnic group?
- There is a great deal of research on attitudes and on behavior, but what is the causative direction? Does it vary by student characteristics? If so, which characteristics are relevant?
- Does computer game-playing in childhood lead to technology competence and careers as adults? What kinds of games? In what circumstances?
- If game-playing is gendered, what are the implications for design and use in educational settings?
- Is stereotype threat a consistent factor in females' computer technology behavior and performance? How can we intervene successfully?
- What is the relationship, if any, between role models and females' academic achievement and persistence in technology? How does this vary by race/ethnicity, geopolitical location, access, policy environment, and other characteristics?
- What is the relationship, if any, between support groups and females' academic achievement and persistence in technology? Does this vary by race/ethnicity, socioeconomic status, or other characteristics?
- What is the relationship, if any, between collaborative learning and females' academic achievement and persistence in technology? Does this vary by race/ethnicity or other characteristics? Is this inherently gendered?
- What is the relationship, if any, between single-sex learning environments and females' academic achievement and persistence in technology? Why is this model controversial?
- Are there curricular approaches that correlate with persistence in technology?
- What curricular approaches are better for different groups of learners, and which characteristics are relevant in light of females' (and males') multiple learning styles?
- Is gender neutrality a desirable design goal? Is it even possible?
- How should learning facilities be designed to support gender differences?
- What approaches to professional development are most effective with different groups of instructors, and which characteristics are relevant?
- What is it that makes teachers want to help close the computer gender gap? Could that motivation or skill set be more widely shared with their colleagues on a global scale?
- If gender differences in learning are seen to exist and persist, how can we prepare instructors and designers to account for them?
- How can we educate our graduate students in educational technology and learning design to be aware of and include global perspectives?
- What can we learn from different cultural perspectives and research?
- How can we move from short-term research design and intervention to longer term investments? How can we persuade funders to support this research?

- How can we open the conversation about epistemology so that scholars are able to better match their own understandings and values to significant research questions and forms of inquiry?
- How can we refocus research away from the "female deficit model?"
- How can we include the value of "intersectional" research to expand the scope of the questions asked and paths followed?
- Will technological disciplines change if they are approached from different points of view, with different desired outcomes, indeed, with different understandings of the disciplines themselves?

This chapter has tried to reorient our usual habits of scholarship away from well-defined categories and frameworks of educational technology research by focusing on the wider sociocultural impacts of technology on the intersections of gender, race, age, culture, disability, access, socioeconomic status, and politics. Sanders (2007) describes a need to "re-imagine technology, to shift it from what it can do to what it can serve, and in so doing to free ourselves from the conceptual constraints posed by 'business as usual' according to the male model" (p. 24).

At the beginning of this chapter, I provided the briefest of overviews of this research before 2005, proposing that it emphasized the "deficit model" and relied on what Reeves characterizes as "disconnected" thinking. Table 1 summarized this period of scholarship.

Similarly, Table 2 identifies scholars, research questions, outcomes, and recommendations for research and practice from 2005 to 2017, and hopefully points to emerging trends in research and understanding.

Gender and Design Thinking

Bronwen Rees, a designer of user experiences, declares, "as designers our … responsibility is to make the (user) experience as inclusive as possible; when we fail to do that it may be a hurtful reminder to some people of how their journey/identity is not reflected in the world. However, gender sensitive designs offer alternative possibilities for a world respectful of gender diversity" (2017, https://uxplanet.org/when-no-gender-fits-33301c3cab53). Unfortunately, our world continues to be designed with the male user in mind, more often than not, unconsciously. Rees offers the example of Virtual Reality (VR) as an example, where headsets that do not fit smaller female heads, too-large augmented reality glasses whose lenses are too far apart for the average female eye, and the gloves are too big for easy movement. The choice of avatar is another example implicated in the use of pedagogical agents, which default to a white male "norm." Rees offers "identicons," unique geometric patterns generated based on a hash of user's IP addresses, as an alternative. Similarly, and as we saw earlier in research (Navarro, Martı'nez, Yubero, & Larran˜aga, 2014), Rees urges designers to eliminate thoughtless association of colors with gender, which "means resolving the tension between current conventions

Table 2 Research and recommendations circa 2005–2017

Issue	Findings	Recommendations
Culture and gender stereotypes: Bias and representation	Stereotype threat	When threat was removed by telling the students that women and men performed equally well on the test, the women performed significantly better than the men
		Stereotype threat can be alleviated by teaching students about it, reassuring students that tests are fair and exposing students to female role models in math and science
		Encouraging students to think of their math abilities as expandable can lift stereotype threat and have a significant positive effect on students' grades and test scores
		Encourage students to have a more flexible or growth mindset about intelligence
		Teach students and teachers about stereotype threat
Gender and psychosocial factors	Schools, departments, and workplaces can cultivate a culture of respect Females prefer design, especially when activities focus on socially relevant problem-solving, and males prefer utilization, especially when activity involves building with tools Fewer girls than boys aspire to STEM careers Girls believe that they have to be exceptional in order to find success in "male" subjects or fields Structural bias influences self-efficacy and attitudes toward STEM subjects Self-efficacy beliefs are influenced by different sources, including social modeling; with previous performances the main source of influence	Teachers and professors can reduce reliance on stereotypes by making performance standards and expectations clear
		Skills can be taught, narrowing or eliminating performance gap
		Experiential learning activities trump lectures
		Design more collaborative activities
		Identify of "stumbling blocks" to a successful learning experience, plan an intervention (design), and provide sufficient attempts to practice with a metacognitive emphasis

Table 2 (continued)

Issue	Findings	Recommendations
Gender and generational differences	More females than males use social networking sites, especially ages 12–24 Males make more posts to blogs while females tend to follow conversations Older women (55+) have embraced social media at a greater pace than men in the same age group Culture, e.g., social demographics, influences social media (and other uses of IT), females lag males in all but highly developed countries Males are the biggest users of mobile technologies While adolescent males and females use social media equally, males spend more time gaming	Macro-social variables (such as public policy) influence inclusion of seniors
		Increase public spaces available for seniors to use ICT
		Public investments in access, security, etc. encourage wider adoption by seniors
		User experience designers should be aware that 45+ women drive the greatest proportion of growth for social networking,

From digital access divide to social inclusion: Gender and digital fluency	Stakeholders will gain a better understanding of relevant contexts by supporting the collection, tracking and analysis of sex-disaggregated data on Internet access and use	Make sure gender advocates and experts are involved in the development of broadband, ICT, and other policy – and that they are involved from the outset of this process.
		Integrate gender perspectives in relevant strategies, policies, plans, and budgets.
		Address barriers related to affordability, threats that hamper access and use, digital literacy and confidence, and the availability of relevant content, applications and services
		Supporting stakeholders to collaborate more effectively in addressing digital gender gaps by sharing good practices and lessons learned.
		Use big data to measure women's and girls' Internet use.
		Establish time-bound targets to achieve gender equality in access *and* use, and ensure that sufficient money and resources are allocated to achieve these targets
		Work with government, private sector, and civil society to invest in early intervention digital skills training for women and girls, and that educational opportunities are available at all levels on subjects ranging from basic training to more advanced programming and design
		Focus on public access solutions that will enable women and other populations that might not be able to afford a broadband connection to participate online
		Ensure and communicate efforts to ensure security and privacy of users, with particular focus on groups that are at heightened risk of online abuse, such as women, girls, and LGBT+ persons.

(continued)

Table 2 (continued)

Issue	Findings	Recommendations
Gender online: Social media, age and culture	Gendered discourse patterns have not substantially changed over three decades of study The patterns are observed even in teen chats Gender differentiation by language and style serves a socially facilitative purpose Males dominate news blogs and make more postings, while females write the largest proportion of personal-type blogs Social media use is influenced by culture Women and other marginalized groups are disproportionately targeted by internet trolls	Develop baseline indicators for all strategies, policies and plans related to Internet access and use
		Conduct consumer insights research to better understand the needs, circumstances, and preferences of women and girls, and the factors limiting women's and girls' access to and use of the internet, including for the different women in each market
		Companies should set up, in consultation with their users (including users belonging to marginalized groups), monitoring complaint and redress mechanisms to duly address abusive use of their platforms and services
		As a matter of policy, companies should also strive toward including content that challenges gender stereotypes and provide equitable space for women-curated online content

Gender and pedagogical practices: Schools and curriculum	Girls with a *growth* mindset are more likely than girls with a *fixed* mindset to maintain their confidence and not succumb to stereotypes Spatial skills are not innate but developed and can be taught Carnegie Mellon University is combatting the gender biases that often discourage women from joining the tech world In CMU's 2017 incoming class, 48% of female first-year undergraduates enrolled in School of Computer Science; 43% in College of Engineering	Teach children that intellectual skills can be acquired.
		Encourage children and students to play with construction toys, take things apart, and put them back together again, play games that involve fitting objects into different places, draw, and work with their hands.
		Attend to the experience base of female students, connecting learners through their life experiences.
		Teach girls that intellectual skills, including spatial skills, are acquired.
		Use handheld models when possible (rather than computer models) to help students visualize what they see on paper in front of them.
		Praise children for effort; highlight the struggle.
		Spread the word about girls' and women's achievements in math and science.
		Explore programs like Summer Engineering Experience for Girls (SEE, 2007), run by Engineering Research Accelerator, bringing 27th & eighth grade girls to campus to foster their curiosity in STEM. SEE program aims to reveal influence middle school girls can have on the world by acquiring advanced math and science skills early on. Mentors include undergraduates, *like Mechanical Engineering* (MechE) *and Biomedical Engineering* working alongside faculty
		Help girls recognize their career-relevant skills
		Encourage high school girls to take calculus, physics, chemistry, computer science, and engineering classes when available
		Girls Who Code organization gives internships, fellowships and encourages girls to explore computer science degrees

(continued)

Table 2 (continued)

Issue	Findings	Recommendations
Gender and the postsecondary learning environment: Disciplinary cultures	Women's representation in computer science is actually declining Implicit bias is common and influences girls' and women's likelihood of cultivating an interest in math and science The number of doctoral degrees in STEM disciplines earned by women from underrepresented racial-ethnic backgrounds increased during the past four decades… …but still remains a small proportion of the total. E.g., (2007) African American women earned 2.2% of the doctorates awarded in the biological sciences, <2% awarded in engineering, computer sciences, physical sciences, mathematics and statistics; even smaller for Hispanic American women and smaller again for indigenous women The culture of academic departments has been identified as critical issue for women's success in earning college degrees in STEM fields Teacher education faculty must urge students to scrutinize their practices as it relates to establishing gender responsive pedagogy in SMTs education	Provide a broader overview of the field in introductory courses
		Address peer culture
		Create an environment that supports retention with strategies like same-sex groupings, using "wicked problems" as curriculum, sponsoring departmental social activities, provide a student lounge, actively recruiting students into the major, sponsoring a "women-in-physics" (or computing science, or chemistry, or engineering, etc.) group
		Use a design thinking approach
		Send an inclusive message about who makes a good science or engineering student
		Emphasize real-life applications in early STEM courses
		Broaden the scope of early course work
		Pathways rather than pipelines challenges the notion of a singular, linear route to becoming a (computer scientist, engineer, physicist), which is more likely to reflect a white male experience
		Teach professors about stereotype threat and the benefits of a growth mindset
		Make performance standards and expectations clear in STEM courses
		Raise awareness about bias against women in STEM fields
		Send an inclusive message about who makes a good computer science student

Gender in STEM workplaces: Intersections with race and culture	Women are less satisfied with the academic workplace and more likely to leave it earlier in their careers than their male counterparts Female STEM faculty less satisfied with how well they "fit" in their departments, opportunities to work with senior faculty; institutional support (including funding councils) for having children family while on tenure track Social disapproval, i.e., *double bind*: women seen to be less competent in STEM fields unless they are very successful, BUT Competent women in STEM are seen as less "likeable" Likeability and competence are factors in success in workplace One overarching key factor identified as necessary for improving gender diversity Is ensuring that corporate policy and culture fully align Recruit at universities on an internship basis for roles that clearly are targeting women technologists to apply Successful technology internships will encourage a new level of confidence in ability to succeed *Flexibility stigma*: It is not enough to simply offer flexible options; the options must be exercisable without consequence	Implement mentoring programs and elective work-life policies for all faculty members Ensure mentoring for all faculty Conduct departmental reviews to assess the climate for female faculty Improve departmental culture to promote the integration of female faculty Recruit and retain women by making changes such as gender-blind recruitment and promotion practices, setting targets for women's engagement, and tying mentorship outcomes to performance compensation

and our desires for inclusive design." She concludes with a tenant of universal design, that is, creating inclusive digital environments that embrace inclusivity, understanding, and acceptance is empowering for all users, not just those that are "excluded" by the norm.

Designing for gender equity – in learning, playing, and working – is a "wicked problem." Brown (1992) describes a wicked problem as ill-defined, complex, and usually involving multiple stakeholders and decision makers with competing values. While with decades of research and practice we are learning more about multiple oppressions and their impact on learning, social constructions of gender have proved stubbornly immune to intervention. In this chapter, I have tried to lay out the effect of these constructions on the experiences of girls and women throughout their early learning encounters to their choices of careers that are technology-based, as all careers are trending to be. Comfort and success with technology will be essential in a world with "unaffordable or unavailable health care, billions of people trying to live on just a few dollars a day, energy usage that outpaces the planet's ability to support it, education systems that fail many students…(and) companies whose traditional markets are disrupted by new technologies or demographic shifts" (Brown, 1992, in Blizzard, 2013, p. 30). While formal education is not the only environment in which we can challenge hidden assumptions, unconscious bias, gender stereotyping, cultural beliefs, and social structures that have prevented women from experiencing satisfying, sustainable, and impactful lives, it is an environment amenable to design thinking. Design thinking employs both divergent and convergent thinking to ensure that many possible solutions are explored, and then narrowed down to a preferred solution. Meinel and Leifer (2011) describe a 5-stage process: (re)defining the problem, need-finding, and benchmarking, ideating, building, and testing.

Design thinkers are able to tolerate ambiguity, handle uncertainty, make decisions, collaborate, and think and communicate in the several languages of design, and imagine the world from multiple perspectives (empathy). Their practice is human-centered, iterative, creative, and practical. They bring these characteristics to problem-solving (c.f. Dym, Agogino, Eris, Frey, & Leifer, 2005).

The focus of this last section is designer education for design thinking. Scheer, Noweski and Meinel (2012) describe design thinking as constructivist learning design, "because of its qualities in training certain skills, which are predispositions for a constructive way of learning: motivation for exploration, openness for new ideas, creative thinking and other metacognitive competences" (p. 11). Design thinkers will be more likely to consider the wicked problems underlying the design and delivery of high-quality and equitable learning environments, and to design *for* design thinking in their own work.

Scheer and others (2012) promote constructivist design that is participatory and interdisciplinary. Blizzard (2013) suggests four pedagogical forms that contribute to the development of design thinking: (1) make content and learning objectives relevant to learners' lives, that is, authenticity; (2) provide the opportunity for learners to choose their own topics or projects; (3) include γ group work and activities that encourage learners to not only work together but also learn from each other; and (4). support peer-teaching (p. 36). de Corte (2010) adds that learning should be con-

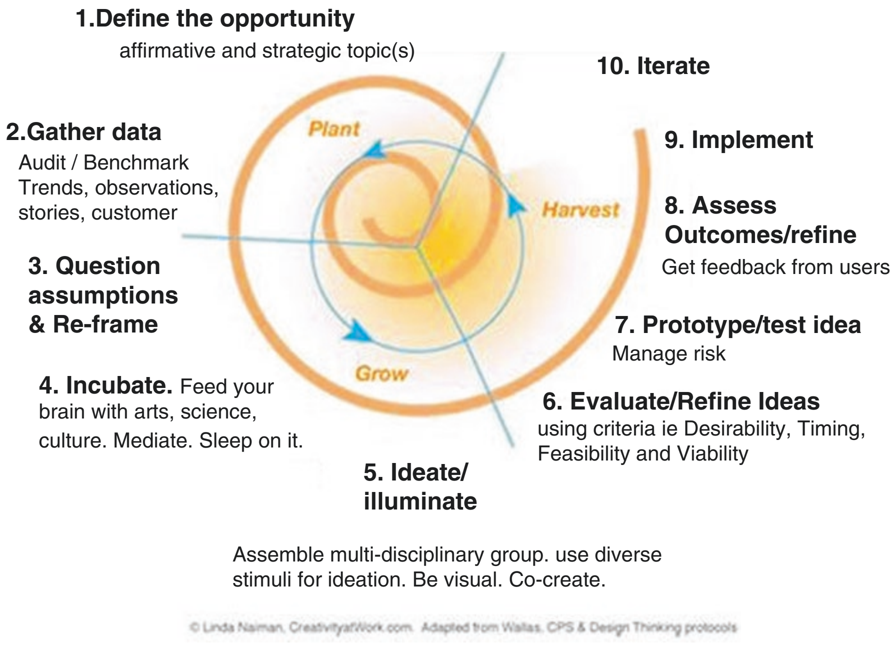

Fig. 2 A framework for creativity and innovation

structed, situated in context, self-regulated, and collaborative. Likewise, David Jonassen's seminal work in problem-based learning (PBL) is foundational for design thinking in its move away from didactic teaching in which learners accept received wisdom, that is, the canon. PBL helps students participate in change, make critical, creative, and reasoned decisions in unfamiliar situations, adopt a more universal or holistic approach, play the "believing game," develop resiliency, and collaborate productively with others.

Design thinking brings Fransson's (2016) notion of dilemmatic space and Mezirow's (2009) theory of transformative learning together with pedagogical models (e.g., PBL, experiential learning) that nurture uncertainty, perspective-taking, and critical thinking. Figure 2, (CreativityWork.com) illustrates the process of design thinking. Compare this process with the assumptions underlying ADDIE.

Applied to design education that acknowledges gender differences, gendered identities, and socially constructed environments (such as schools) that are gendered, design thinking encourages asking critical questions about learners' cultures, relevant societal problems that might form cases, perspectives to include in understanding and seeking solutions to issues at hand, adaptable tools that can be used to design interventions and outcomes, alternative assessment approaches, and opportunities to interrogate one's own assumptions and biases, as well as those of others.

It is important for design educators to be aware of the deep and rich, and often contradictory, literature base about gender and technology. As design is socially constructed, perhaps we can also be agents of disruption of the prevailing design discourses. For example, can we disrupt the notion of design as neutral?

Although it is difficult to imagine that designers can, themselves, fundamentally affect the changes in educational environments, workplaces, and acts of daily living that would contribute to gender equity in these places, we can at the very least be critical of the way we practice and the assumptions that are hidden from view. No checklist of design principles will help with that and reflect the urgency of designing for social inclusion.

In his article for Harvard Business Review, Tim Brown of IDEO offered insight into the "personality profile" of a design thinker. Characteristics to look for include empathy – they imagine the world from multiple perspectives, integrative thinking – they can analyze at a detailed and holistic level to develop novel solutions, optimism – they do not back down from challenging problems, experimentalism – they ask questions and take new approaches to problem-solving, and collaboration – they work with many different disciplines and often have experience in more than just one field (Brown, 2008) Blizzard, p. 11.

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Designing for Accessibility: The Intersection of Instructional Design and Disability

Michele D. Estes, Cheryl L. Beverly, and Marco Castillo

Introduction

In this chapter, the authors address the concept of access, especially in terms of persons with disabilities. The authors focus on persons with disabilities, rather than special needs, for two reasons. First, access for persons with disabilities is specifically mandated by the Americans with Disabilities Act (ADA), Section 504 of the Rehabilitation Act, and the Individuals with Disabilities Education Improvement Act (IDEA). Second, although the Elementary and Secondary Education Act (United States Department of Education, n.d.-b) addresses students in poverty, minorities, those receiving special education services, and those with limited English language skills, issues of access that are relevant to persons with disabilities are often similar to the needs of individuals identified in ESEA. Indeed, provisions for access for persons with disabilities may benefit all learners including the nondisabled population.

The multiple and varied understandings of the concept and process of access, by education professionals, complicate any discussion of designing for access for individuals with and without disabilities. In the peer-reviewed literature, educational technology articles on the topic of access and disability tend to be limited, clustered in a few journals, with attention mostly given to physical access to content and resources, meeting legal access requirements, and introducing custom tools and apps in inclusive classrooms. In the persons with disabilities literature, these types of articles, on the topic of technology and access, tend to appear in very small

M. D. Estes (✉) · C. L. Beverly
Learning, Technology, and Leadership Education, College of Education,
James Madison University, Harrisonburg, VA, USA
e-mail: estesmd@jmu.edu

M. Castillo
Universidad Catolica Silva Henriquez, Santiago, Región Metropolitana, Chile

M. J. Bishop et al. (eds.), *Handbook of Research in Educational Communications and Technology*, https://doi.org/10.1007/978-3-030-36119-8_8

numbers in a wide range of journals, with access described in terms of physical, communication, cognitive, social/behavioral, and daily living access. In both bodies of literature, there are research articles about the role of technology in supporting learning for learners with disabilities. However, lack of physical access to technologies and resources and the impact this has on communications, social/behavioral issues, and independent daily living continue to be a theme.

Understanding similarities and differences in instructional design and disability is important. Professionals in these disciplines share a similar aim to ensure access to meaningful learning experiences that occur in a variety of environments, formats, and contexts. To that end, experts in these areas use terminologies and processes that may inform and enhance current practices. The problem driving this review of research was how instructional designers address access to meaningful learning experiences for persons with disabilities. The guiding question for this review was as follows: *What does the recent research literature tell us about how instructional designs and technology are made accessible for learners with disabilities?* To answer this question, the authors reviewed social sciences peer-reviewed research journal articles published from 2012 to 2018, with keywords relating to access, instructional design, and persons with disabilities. Findings addressed ways instructional design may be used to facilitate access to, and through, technology; as well as approaches to conducting relevant research and to sustaining solutions in practice. Central concepts emerging from a summary of this research include those defined in Table 1.

In addition to federal laws, policies such as the 2017 National Education Technology Plan Update, a core US policy document, articulate a vision for "... equity, active use, and collaborative leadership to make everywhere, all-the-time learning possible" (U. S. Department of Education, n.d.-f, para. 2). Collaborative research among experts in instructional design and technology, and disability, is needed to better understand how instructional design and technologies may be made more accessible. Such efforts may help expand the use of instructional design processes, and technologies, as tools that provide access to meaningful learning experiences and functioning of persons with disabilities.

Review Process

Both *disability* and *handicapped* were used as these terms are often used interchangeably and the authors did not want to exclude relevant research. The term *handicapped* has limited use in disciplines that focus on persons with disabilities such as occupational therapy, physical therapy, special education, rehabilitation, communication and speech, social work, counseling, nursing, and disability studies. However, the term is present in early US education and civil rights legislation, in disciplines with less engagement and/or knowledge of persons with disabilities, and in some international systems as evidenced in a SCOPUS search that yielded 14 articles, 5 of which were relevant to the topic of this paper. To ensure a broad look

Table 1 Central concepts emerging from the recent research literature

Concept	Definition
Access	"1 The means or opportunity to approach or enter a place" or "1.1 The right or opportunity to use or benefit from something" (English Oxford Living Dictionaries, 2018)
Accommodation and intervention for adult learners	Adaptation or adjustment to the learning and functioning contexts of adults with disabilities
Collaboration	"1 The action of working with someone to produce something" (English Oxford Living Dictionaries, 2018)
Disability	"The definition of disability varies depending on the purpose of its use. For purposes of nondiscrimination laws (e.g., the Americans with Disabilities Act, Section 503 of the Rehabilitation Act of 1973, and Section 188 of the Workforce Investment Act), a person with a disability is generally defined as someone who (1) has a physical or mental impairment that substantially limits one or more 'major life activities,' (2) has a record of such an impairment, or (3) is regarded as having such an impairment" (U. S. Department of Labor, n.d.-b) "Major life activities include, but are not limited to, caring for oneself, performing manual tasks, seeing, hearing, eating, sleeping, walking, standing, lifting, bending, speaking, breathing, learning, reading, concentrating, thinking, communicating, and working" (U. S. Congress, 2009, Sec. 12161. Definitions section) For purposes of special education, "Child with a disability means a child evaluated in accordance with §§300.304 through 300.311 as having an intellectual disability, a hearing impairment (including deafness), a speech or language impairment, a visual impairment (including blindness), a serious emotional disturbance (referred to in this part as 'emotional disturbance'), an orthopedic impairment, autism, traumatic brain injury, an other health impairment, a specific learning disability, deaf-blindness, or multiple disabilities, and who, by reason thereof, needs special education and related services" (U. S. Department of Education, n.d.-e)
Inclusive classrooms	"The fundamental principle of the inclusive school, as proposed in the Salamanca Statement, is that all students should learn together, where possible, and that ordinary schools must recognise and respond to the diverse needs of their students while also having a continuum of support and services to match those needs" (as cited in the Department of Education and Science, 2007, p. 15)
Instructional design process	"...The systematic development of instructional specifications using learning and instructional theory to ensure the quality of instruction. It is the entire process of analysis of learning needs and goals and the development of a delivery system to meet those needs. It includes development of instructional materials and activities; and tryout and evaluation of all instruction and learner activities" (University of Michigan, 2003, para. 1)
Professional development	"The development of competence or expertise in one's profession; the process of acquiring the skills needed to improve performance in a job" (English Oxford Living Dictionaries, 2018)

(continued)

Table 1 (continued)

Concept	Definition
Special education	IDEA defines special education as: 1. "...Specially designed instruction, at no cost to the parents, to meet the unique needs of a child with a disability, including— (i) Instruction conducted in the classroom, in the home, in hospitals and institutions, and in other settings; and (ii) instruction in physical education" (U. S. Department of Education, n.d.-a, Sec. 300.39 (a) (1) (i)) 2. Special education includes each of the following, if the services otherwise meet the requirements of paragraph (a)(1) of this section— (i) Speech-language pathology services, or any other related service, if the service is considered special education rather than a related service under State standards; (ii) Travel training; and (iii) Vocational education" (U. S. Department of Education, n.d.-a, Individuals with Disabilities Education Act, Part B, Subpart A, Section 300.39 Special Education)
Universal Design for Learning (UDL)	"A scientifically valid framework for guiding educational practice that — (A) provides flexibility in the ways information is presented, in the ways students respond or demonstrate knowledge and skills, and in the ways students are engaged; and (B) reduces barriers in instruction, provides appropriate accommodations, supports, and challenges, and maintains high achievement expectations for all students, including students with disabilities and students who are limited English proficient" (U. S. Department of Education, n.d.-b, para. 3)

at relevant research, the authors included both *disability* and *handicapped* as search terms.

The search term *special education* was not used as the authors did not want to limit the parameters of this chapter to special education. Special education addresses a more limited audience of learners with disabilities than occurs in the general population and under specific procedural identification and service requirements that are not reflected in broader practices of educating/providing access to persons with disabilities. *Universal Design for Learning* (UDL) was used, as this framework is specifically mentioned in the 2015 reauthorization of ESEA and the US Office of Educational Technology's *National Education Technology Plan*; however, the authors did not focus this review solely to UDL as a tool for access to learning. *Instructional design*, *technology*, and *access* were used as research terms as they are subjects of interest for this review. The quality of the articles reviewed was established by limiting the search criteria to research only, peer reviewed, journals, conference proceedings, and current (2012–2018). The authors did limit the studies to English language but did not limit them to the United States.

The authors searched SCOPUS open access articles in the social sciences, for this review of research literature published between 2012 and 2018. Descriptors used were *disability* and *access* and *technology* (30 articles found in SCOPUS although only a few were relevant), *disability* and *access* and *instructional design* (two relevant practice articles found in SCOPUS), *disability* and *access* and *UDL* (six relevant SCOPUS documents/four unique), *handicapped* and *access* and *technology* (14 found in SCOPUS/five relevant), *handicapped* and *access* and *instructional design* (zero found in SCOPUS), and *handicapped* and *access* and *UDL* (zero found in SCOPUS).

Fifty-three journal articles were identified in disability-related literature using Education Resources Information Center (ERIC) and Education Research Complete search engines using the same descriptor chains as with SCOPUS. Thirty-two of the articles met the search criteria of research, peer reviewed and published between 2012 and 2018. *Disability and Rehabilitation: Assistive Technology* had the most articles (six), and the *Journal of Special Education Technology* had the second most articles (five). Three international journals, *Canadian Journal of Higher Education* (2), *Africa Education Review* (1), and *British Journal of Educational Technology* (1), were also identified as having research regarding the topic.

Starcic and Bagon (2014) conducted an extensive review of the information and communications technology (ICT) and disability literature in seven different educational technology journals, between 1970 and 2011. ICT, information and communications technology, is described by UNESCO as "including mainstream technologies, assistive technologies, media and accessible formats, educational software, and virtual learning environments" (as cited in Ramos & de Andrade, 2016, p. 626). One interesting finding they reported was that of these journals, the *British Journal of Educational Technology* (BJET) had published the most articles in this area. In this review, a keyword search for the term *accessibility* in the *British Journal of Educational Technology* (BJET) yielded seven results within the last 5 years. A keyword search for *access* in this same journal led to articles referring to access to computers and digital technologies and access to information such as that afforded by use of the Internet and massive open online courses (MOOCs), as opposed to access in relation to disability. A search of the *BJET* for keyword *disability* led to three relevant research articles between 2012 and 2018. Two of these reported results from studies involving information and communications technologies (ICTs) and children with disabilities.

Summary of Research Literature

Persons with Disability Literature

A review of sample research regarding education of persons with disabilities showed a variety of research designs, from review of the research/professional literature to surveys, focus groups, case studies, interviews, mixed methods, multiple baselines across participants to single subject. This research tended to address access and use of technology and barriers to its use.

Nonexperimental research involved large groups of persons with disabilities and/or their service providers and carers. Experimental research tended to focus on a specific technology or Universal Design for Learning (UDL), specific disability population, specific skill set, and specific age group (elementary, high school, adults) in a clinical setting, with one-on-one treatments and small sample sizes. For example, the iPad with adaptive technology and/or stand-alone technology was used with learners who are on the autism spectrum, as a tool to build requesting of an object or activity (Couper et al., 2014; Sigafoos et al., 2013), lowering levels of challenging behavior and increasing levels of academic engagement (Neely, Rispoli, Camargo, Davis, & Boles, 2013), performing communication sequences (Waddington et al., 2014), learning engagement (Arthanat, Curtin, & Knotak, 2013), engaging in intentional communication (McEwen, 2014), and identifying, maintaining, and generalizing a picture vocabulary. Dallas, McCarthy, and Long (2016) cautioned that "Assessing educational technology for effectiveness is important prior to making recommendations for widespread use" (p. 3).

Educational Technology Literature

A cursory look at educational technology articles published in leading journals, issued 2012–2018, shows that researchers have published in the area of accessibility and/or disability to a limited degree. Research designs vary; participant disabilities range in complexity across studies, as do the tools and learning environments of interest.

Experimental research existed but was uncommon in the educational technology literature, in the area of disabilities. One such study was conducted in China. Researchers Zhang and Zhou (2016) recruited 142 children with math learning difficulties (MLD) to participate. Students in the experimental group used an online learning system at home over time and showed significant gains in achievement. In another example, this time in Mexico, Felix, Mena, Ostos, and Maestre (2017) conducted a pilot study of computer-based learning tool HATLE which was designed to support reading and writing therapies with children determined to have moderate intellectual disabilities. The software design was informed by multimedia principles and learning theories with careful attention paid to instructional design that supports individual learning needs. Significant improvements were found in the experimental group in areas of single-word reading and in handwriting form, with improvement in letter identification, handwriting legibility, and spelling. The researchers described some of the affordances of HATLE as having "a more personal and responsive interface, offering instant gratification to students with limited patience" (p. 621).

Published, nonexperimental research in the current review typically involved qualitative methods such as case study, observation, and interview and/or survey, mixed methods, and/or explanatory sequential mixed methods. In Slovenia, for example, Starcic, Cotic, and Zajc (2013) tested the use of a tangible user interface in an inclusive math classroom. Through the interface, geometric concepts were taught to students who were considered typical students, students with learning difficulties, and students with fine motor challenges. While all learners showed some improvements, participants with fine motor skill issues appeared to benefit most from the tangible user interface, over paper and pencil. They were able to draw accurately and without assistance and could collaborate with others using the computer, with confidence. This study involved an iterative, design-based research methodology where the tangible user interface was adapted for students with special needs.

Summary of Research Findings

Perhaps the major result of this review of the literature is the understanding that issues of accessibility for persons with disabilities are complicated and complex. For example, the term *access* appears to be more narrowly defined in educational technology literature than in the disability literature. Educational technology literature addressing *access* tends to offer implications for policies and practices that support physical access and/or help overcome a digital divide (Bharuthram & Kies, 2013; Hartnett, 2017; Taylor, Taylor, & Vlaev, 2017; Vrasidas, 2015) and/or report issues with technology reliability (Hartnett, 2017; Rehn, Maor, & McConney, 2017; Scott, Nerminathan, Alexander, & Phelps, 2015) but not necessarily in relation to disability, special needs, or even learning. Educational technology research could define access more broadly in relation to technology and instructional design, to also include levels of social access (Cano & Sanchez-Iborra, 2015; Foley & Ferri, 2012; Hayhoe, Roger, Eldritch-Böersen, & Kelland, 2015; Rieber & Estes, 2017) and cognitive access (Monteiro Cruz & Monteiro, 2013; Rieber & Estes, 2017) for learners with and without disabilities.

Universal Design for Learning (UDL)

Research addressing access often focuses on Universal Design for Learning principles and models. However, as Rao, Ok, and Bryant (2014) discovered through a review of research on universal design models in education, researchers use a range of research designs and report their application of UD principles in various ways with no standard formats for UD use. The researchers also reported that UD principles are used for a variety of purposes, to examine a variety of learning factors and to influence accommodation decisions and technology-based environment design, and are used in professional development and classroom practice. The degree of variation in research of UD principles proves challenging for analysis, interpretation, and effective use of UD in educational practice (Rao et al., 2014). Further, it is important to recognize that generic UDL practices may not be the least restrictive for every learner with a disability. An analysis of the learner's abilities and disabilities, context, experience, and motivation will be key to the success of any learning or functioning with technology. Analysis of the instructor's knowledge of UDL, understanding of UDL in context, and skills in applying UDL principles is also necessary. Effective implementation of UDL (see CAST.org) requires collaboration between the learner, the instructor, and an instructional designer.

An example where collaboration with an instructional designer could have improved UDL outcomes is the exploratory study of UDL conducted by King-Sears et al. (2015) in an inclusive high school chemistry classroom populated by learners without disabilities and learners with high-incidence disabilities (HID). Learners with HID in both UDL and comparison groups retained less knowledge at delayed post-assessment. Learners with HID who were taught with UDL performed higher than did the comparison group of persons with HID, but the learners without disabilities in the UDL group performed more poorly than did those without UDL instruction. In her work with adult basic education (ABE) learners with specific learning disabilities (one of thirteen disabilities defined in IDEA), Gregg (2012) noted that “Access to learning for the ABE learner with LD will also depend on universally designed technology instruction and testing environments so that the accommodations will be built into systems and available for all individuals” (p. 59). UDL principles and models typically are used to create inclusive classrooms, supporting the learning of all students. Not all research on supporting learners’ access to and in inclusive classrooms focuses on UDL. Research using educational technology as an aide to access and inclusion is being conducted.

Inclusive Classrooms

Zhang, Trussell, Gallegos, and Asam (2015) conducted an exploratory study of the use of three math apps on mobile devices in an inclusive, fourth-grade classroom. Eighteen participants were students considered at risk, diagnosed with one or more disabilities—autism, emotional disorder, dyslexia, and/or learning disability—or considered nondisabled and not at risk. The math topics of interest were decimals and multiplication. Participants used related apps during four 80–90 minute sessions, over the period of a month. In each session, the teacher first taught students how to use the apps. Mobile devices were selected to reduce barriers to learning gains such as difficulty a student may experience when otherwise using a mouse, having to keep pace with others during group instruction, and/or struggling without immediate feedback afforded by the technology. Results showed gains for all students but particularly for those who were considered at risk or disabled which helped shrink the achievement gap between that group and the students who were considered typical for the purposes of this study.

In Spain, Cano and Sanchez-Iborra (2015) involved teachers in the design and research of a software application called PLAIME, to help teach students music skills. Rather than group students by disability, researchers conducted a pretest and used the results to divide students into two groups according to intellectual capacity. Groups were created to ensure participants could make sufficient progress and keep pace. The teachers delivered ten sessions for one hour a week and made adjustments after the first session to adapt the "content to each group's learning progress in subsequent sessions" (p. 265). Researchers used mixed methods including but not limited to case study observation. "...Students showed a high improvement in their music knowledge, an enhancement in their perceptual, cognitive, and social skills, and were able to perfectly manage the computer program by themselves" (p. 273). Findings also suggested that "...teachers must first actively adopt and learn the technology for this to be successful...teachers should be an active part in the development of ICT education tools" (p. 274). As illustrated by these two studies, designing training for the teacher and student on how to use the technology is a key to successful inclusion. Although there is a growing body of research focusing on K–12 and higher education inclusion, there is a lack of research focusing on inclusion across functional life domains for adults with disabilities.

Adult Learners: Accommodation and Intervention

Several researchers (Chadwick, Wesson, & Fullwood, 2013; Hoppestad, 2013) reported that although various technology devices and interventions have been developed for persons with all types of disabilities, there is a lack of research into methods to help persons, especially adults, with severe developmental and intellectual disabilities. These persons have been shown to underutilize computers and the Internet. Accommodations should be made for not only children but also adult learners (Terblanché, 2012). Bouck and Flanagan (2016); Flanagan, Bouck, and Richardson (2013); Hoppestad, Stephenson, and Limbrick (2015); and Tanis et al. (2012) reported an overall underutilization of devices across functional life domains for adults with severe disabilities and a need for research on using the technology in informal contexts. The review identified barriers to access as costs, assessment, usability, breakage and repair of the device, replacement of the device, assistance using the device, amount of time needed to procure the right device, insufficient evidence of safety and outcomes, adapting technology to other treatments and information, and lack of experience of providers (Flanagan et al., 2013; Hook, Verbaan, Durrant, Olivier, & Wright, 2014; Tanis et al., 2012).

Rivera, Hudson, Weiss, and Zambone (2017) connect access and inclusion in the classroom to access and inclusion in nonclassroom contexts. Rivera et al. believe that:

> ...it is necessary for classroom staff to take the lead when conceptualizing and implementing an intervention to better ensure continued use of the intervention (Coburn, 2003) and to determine what kind of supports and training might be needed in the future... (p. 347).

Research questions and methodologies should strive to include adults with severe disabilities; daily living, financial, work, social, recreational, communicative, and authentic use of the technology with the individual with disabilities; research with persons with multiple disabilities; the use of technology for persons with disabilities by general education; and related service providers, carers, parents, and individuals with disabilities (Bouck & Flanagan, 2016; Hoppestad, 2013; Kagohara et al., 2012;

Okolo & Diedrich, 2014; Penton & Gustafson, 2014). Research focusing on how persons with disabilities or their carers/parents access information, the usability of the information, the accuracy and recency of the information, and the provider's attitude toward persons with disabilities (Chadwick et al., 2013; Tanis et al., 2012) is also needed.

The reviewed research identified the importance of training and collaboration with the educator and/or carer to support access and inclusion in all learning spaces including the classroom environment. The research on adults with disabilities also identified the role of training and professional development for carers and family members.

Training and Professional Development

Given that the teacher will have an impact on student use of digital technologies (Heiman, Fichten, Olenik-Shemesh, Keshet, & Jorgensen, 2017), there is a need for professional development and training of the team of professionals, family, carers, and persons with disabilities to (1) grow knowledge of technologies available; (2) grow understanding of the impact of disability on the learning and functioning of the person; (3) analyze a person with disabilities' talents and limitations and the technology options; (4) develop confidence in the user and supporter of the technology; (5) develop aids for use by carers and persons with disabilities regarding the safety, maintenance, repair, and updating of the technology; (6) modify technology to meet the unique needs and use by the person with a disability; and (7) use the technology across environments, functions, and time.

Hall, Cohen, Vue, and Ganley (2015) and Morningstar, Shogren, Lee, and Born (2015) believe that the role of a teacher, with expertise and intuition in the use of technology with students with disabilities, greatly impacts the effectiveness of technology use, as well as the access and participation of all learners in the classroom. Okolo and Diedrich (2014) found that teachers use technology to instruct learners with disabilities less frequently than they use technologies in their own lives. These teachers indicated a need for professional development, and better access to technology, to support their use of assistive technologies (AT) with their learners.

Researchers (Lenker, Harris, Taugher, & Smith, 2013; Penton & Gustafson, 2014) noted that consumers with disabilities recognized that the use of assistive technologies promoted their independence, subjective well-being, and more equitable access to many aspects of life. However, these same consumers were dissatisfied with the limited knowledge and training of service providers, lack of funding available in existing programs and services, and the length of time to acquire the device.

ICT access, research, and related educator training are important (European Agency for Development in Special Needs Education, 2013). There is a need to further investigate the digital divide between persons with disabilities and those without (Chadwick et al., 2013) and the goodness of fit between the individual and the technology (Leopold, Lourie, Petrasb, & Eliasa, 2015). Access is important for the integration and equity of individuals with disabilities (Roig-Vila, Ferrández, & Ferri-Miralles, 2014).

Persons with disabilities should be taught how to use digital technologies at an early age, along with students who are not labeled as having disabilities (Drigas, Pappas, & Lytras, 2016). Lidström, Granlund, and Hemmingsson (2012) found, for instance, that "...students with a physical disability have restricted participation in some computer-based educational activities in comparison to students from the general population" (p. 21). When compared to students without disabilities, students with disabilities often lack access to ICTs that could be useful (Fisher & Shogren, 2016). Access, interventions conducted online, and the support of family may also support significant improvements for students with learning difficulties (Zhang & Zhou, 2016). Students with disabilities who receive materials in a variety of forms may "be able to connect with these materials after and outside of class to do homework, prepare for tests, complete research projects, and discuss what they are learning with other students, teachers, and their parents" (Vesel & Robillard, 2013, p. 364). Early intervention is not always possible, and accommodations should also be made for adult learners (Terblanché, 2012). In order to best serve the population of persons with disabilities, research questions and methods addressing instructional design, access, and disability should address the life span and life functions of persons with disabilities. The inclusion of instructional designers in all stages of intervention, from research to teaching and assessment to life skills, benefits all stakeholders involved with persons with disabilities.

It is important that learners and educators understand the technology and content before engaging in research studies of effectiveness. However, Kumar and Owston (2016) note a lack of knowledge, training, and professional development for teachers in this area. To strengthen the rigor of design and research and maximize effectiveness, educational technologists and educators/carers of persons with disabilities should collaborate during the research process (de Anna et al., 2014) and/or during the instructional design process.

Collaboration

When conducting research that informs instructional design for learners with disabilities, techniques such as situated learning (de Anna et al., 2014), scaffolding (Zhang et al., 2015), and iteration (Starcic et al., 2013) should be used. Collaborative and situated research designs are likely to improve learning and support transfer of learning to authentic contexts. Researchers should pre-group participants by cognitive or intellectual level rather than by disability; allow for iteration and adjustments that best support learners with disabilities as the study continues; involve the educator, related service providers, family members, and carers in the design and training of the technology to be used with learners (Cano & Sanchez-Iborra, 2015); and involve the learners in technology training before expecting its use.

Ratliffe, Rao, Skouge, and Peter (2012) discovered the importance of collaborating with cultural guides while conducting a study in the Pacific Islands region where the issue of technology access and use for individuals with disabilities is "...complicated by the lack of resources, cultural values that differ from those presenting the mandates, and complexities of hierarchy, relationships, and position in the islands" (p. 209). For example, cultural mores "...value protection and safeguarding for persons with disabilities over helping them become independent" (p. 213). Findings of this multiple case study revealed the importance of collaboration at all levels, barriers to procurement, and the iterative process of supporting learners with disabilities.

Using Instructional Design to Facilitate Access to, and through, Technology

As noted in previous sections of this summary, instructional designers, as a collaborative partner, have a role in facilitating access to and through technology. The instructional design process generally includes the phases of analysis, design, development, implementation, and evaluation. However, while "learner analysis is a cornerstone of instructional design theory and practice, the consideration of characteristics of people with disabilities is rarely done" (Rieber & Estes, 2017, p. 9). An analysis of the talents and challenges of learners with disabilities must include, at minimum, a nuanced review of prior experiences, skills, and motivation for successful learning or functioning with technology. This type of analysis requires collaboration among the learner with disabilities, the teacher, other carers, the family, and the instructional designer. Outcomes should offer insights into why the learner is unable to transfer classroom content and skills into their multiple, everyday contexts. Further, such collaboration allows the instructional designer to see how to maximize what the learner can do rather than focusing solely on the disability.

A critical analysis of context and tasks is necessary. Carver, Ganus, Ivey, Plummer, and Eubank (2016) call for researchers to focus on the factors influencing interactions between a person with a disability and his/her environment(s). Research focusing on access to learning environment(s) needs to address learners with and without disabilities (Starcic & Bagon, 2014). It is important to understand that although a classroom may be considered inclusive, one should question whether students with disabilities do have full access to the educational experience (Edyburn & Edyburn, 2012). Although inclusion is not mandated by US federal legislation, public education is mandated to ensure students with disabilities learn, to the extent appropriate, with their nondisabled peers. US public education is also mandated to "use technology, consistent with the principles of universal design for learning, to support the learning needs of all students, including children with disabilities and English learners" (US Congress, 2016, p. 220).

Universal design principles call for educators to design curriculum and leverage the features of digital tools to support a very wide range of individual learner needs. Digital technologies and related intervention strategies hold promise for learners who are, and are not, diagnosed as having one or more disabilities (Heiman et al., 2017; Kumar & Owston, 2016; Starcic et al., 2013). In order to meet these mandates, collaborative partners will need access to, and training for, the use of technologies.

Strategies and Challenges

Findings in the recent reviewed research literature can inform instructional design in a number of ways. When addressing learners on the autism spectrum and/or with developmental disabilities, Hill and Flores (2014) cautioned that educators should begin by teaching with low-tech strategies before introducing technology. For example, a student who does not understand cause and effect will not understand how to use switches to access a toy or to turn on or off a light, to select a word on a computer, or to otherwise interact with the environment. This mirrors Rodriguez, Strnadova, and Cumming (2013) recognition of the need for educators to plan the introduction and use of devices prior to introducing them.

Hollins and Foley (2013) noted that cognitive and behavioral strategies also impact learner performance online. The idea that instructional designs should address academic, social, behavioral, communication, and motivation challenges is inferred, if not explicit, in the current literature. Foley and Ferri (2012) write that designers should:

> ...consider the needs of those with cognitive, sensory and physical disabilities as important sources of diversity and complexity necessary to inform the design of technology to increase accessibility and usability for all users...[and] enhance the "cool" factor. Accessible technology would also be grounded in the understanding that technology cannot be isolated from the social context, and the knowledge that if technology is to reduce social isolation, it must be designed with social inclusion in mind (p. 199).

As one example, a 19-year-old male with a significant specific learning disability should have technology that looks and performs appropriately for his developmental level and age. His text-to-voice app would have a male adult voice and vocabulary, and his devices would not be covered with childish pictures or images.

Design and technology best practices in the area of disabilities tend to address a specific disability and often a specific learner within that category of disability. Many studies occur in a clinical setting for one-on-one evaluation and matchmaking of learner and technology. The complex nature of disability makes it challenging, if not impossible in some cases, to generalize research findings and design solutions that solve access problems for many different students. While research that occurs in an authentic setting may yield practical results, these studies often lack a large enough sample size, or empirical research design, to yield generalizable results. As Rivera et al. (2017) noted, the use of higher student-teacher ratios can allow for more efficient instructional situations and additional knowledge gain for students with developmental disabilities. A challenge for collaborative partners is to be aware of the complexities and implications of the person's disability, learning environments, activities, resources, and instructional pedagogies encountered.

Implications for instructional designers include the need to expand awareness and demonstrate matchmaking skills during the analysis phase of the ADDIE process. To do this, instructional designers might refer to frameworks used to help map course elements and universal design principles (Rao, Edelen-Smith, & Wailehua, 2015) or to help match needs and preferences to technology features (Loitsch, Weber, Kaklanis, Votis, & Tzovaras, 2017):

> The goal is to allow educators to quickly and easily develop digital instructional materials that are simultaneously accessible, flexible, and engaging for diverse learners such that supports are embedded into the curriculum for all students to use as needed (Edyburn & Edyburn, 2012, p. 199).

Learners with a specific learning disability may need less technology support over time as they master learning strategies or may need more sophisticated technology support as they become a more sophisticated and complex learner. Alternatively, a learner may have a regressive disability such as cystic fibrosis. As the disease progresses, it impacts developmental levels and, therefore, the technologies used successfully in the past become outdated and less effective. For these reasons, instructional designers must be flexible and iterative in their thinking about the nature of design and technology use, over time, and in authentic contexts.

Instructional designers should develop expertise in the legal requirements for accessibility and the tools used to test for web accessibility, when designing eLearning. When considering physical and legal forms of accessibility, such as following set guidelines, policies, and regulations, it is important to not only use automated tools but also include a qualitative check of accessibility (Kumar & Owston, 2016). It is also important to move beyond the letter of the law, to understand the intent of the law for learners with disabilities.

Meeting the intent of federal civil rights and education legislations may consist of instructional designers making designs accessible and usable at the onset of the design process and being flexible and iterative in the design process to account for significant differences. In addition, instructional designers should develop an appreciation for responsive teaching (Foley & Ferri, 2012; Griful-Freixenet, Struyven, Verstichele, & Andries, 2017), technologies (Loitsch et al., 2017), and tiered learning experiences (Edyburn & Edyburn, 2012). It is also important to consider the significant impact that effectively designed digital technologies may have on learners with a range of disabilities. In the United States, the Individuals with Disabilities Education Improvement Act (IDEA) identifies thirteen disabilities, while the Americans with Disabilities Act (ADA) applies to everyone who qualifies as disabled within a broader definition. IDEA serves persons who meet a set of eligibility criteria from birth to graduation of 12th grade, or age 21, while the ADA serves individuals across the life span.

By partnering with disability experts, persons with disabilities, their carers, and instructional designers may increase awareness of, and sensitivity to, the nature of varying abilities and the dynamics of power and culture associated with disability. For example, Haualand (2014) wrote this about video interpreting services:

> ...organisation of the technology and service within an existing sociotechnical system places the users in a more equal position relative to others...the greater the integration of systems of heterogeneous actors, the greater the flow of agency and the less disabled – or different – the actors become (p. 287).

Further, the designer should be aware of implementation issues such as those shifting responsibility more heavily to learners with disabilities than to other learners, requiring, for example, that the learner with disability manages additional resources, processes, and self-advocacy efforts, while also attempting to learn the material. This may require additional time and training—of the person with the disability, the carer(s), and the educator—to implement effectively.

Sustainability

Through Policy

There are a number of policies and standards around the world intended to inform, guide, and sustain movements toward more accessible education, technology, research, and practice. Web Content Accessibility Guidelines (WCAG 1.0 and WCAG 2.0), for example, are international standards for accessible web design (see https://www.w3.org/standards/). The *United Nations Convention on the Rights of Persons with Disabilities* (UNCRPD) has been ratified by member states in the Africas, the Americas, Asia, Europe, and Oceania (see https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html). Regional United Nations policies including but not limited to the *Biwako Millennium Framework (BMF)* (see https://www.unescap.org/search/node/biwako) of the United Nations Economic and Social Commission for Asia and the Pacific were mentioned in the disability and ICT literature (Ratliffe et al., 2012). The *European and International Policy Supporting ICT for Inclusion* (search for "ICT" at https://www.european-agency.org/) addresses equity in educational opportunities, technology access, professional development, research and development, and data collection and monitoring of progress in the European and international communities. The United States has various civil rights and education policies that address access, such as those shown in Table 2. Knowledge of the policies and their operational regulations, as well as the skills to implement them, assess outcomes, and advocate for resources and time, can ensure sustained efforts for access to and through technology for persons with disabilities.

Table 2 Key federal laws in the United States relating to persons with disabilities

Americans with Disabilities Act	The Americans with Disabilities Act (ADA) became law in 1990. "The Americans with Disabilities Act (ADA) prohibits discrimination against people with disabilities in several areas, including employment, transportation, public accommodations, communications and access to state and local government' programs and services" (U. S. Department of Labor, n.d.-b, Americans with Disabilities Act section, para. 1). The ADA was amended in 2008, regulations were revised in 2010, and revisions of ADA Title II and III regulations were made in 2016
Every Student Succeeds Act (ESSA)	ESEA was reauthorized in 2015, replacing the 2002 reauthorization (NCLB), as the ESSA. ESSA ensures success of all students by emphasizing critical protections for students who are disadvantaged or have high needs, as well as requiring that all students be prepared to succeed in college and careers (U. S. Department of Education, n.d.-c)
The Individuals with Disabilities Education Act (IDEA)	"The Individuals with Disabilities Education Act (IDEA) is a law that makes available a free appropriate public education to eligible children with disabilities throughout the nation and ensures special education and related services to those children...Congress reauthorized the IDEA in 2004 retitling it as the Individuals with Disabilities Education Improvement Act...Congress most recently amended the IDEA through Public Law 114–95, the Every Student Succeeds Act, in December 2015" (U. S. Department of Education, n.d.-a, About IDEA section)
Section 504 of the 1973 Rehabilitation Act	"Section 504 of the Rehabilitation Act of 1973 prohibits discrimination against an otherwise qualified individual with a disability solely by reason of disability in any program or activity receiving federal financial assistance or under any program or activity conducted by an executive agency or the US Postal Service. Section 504 was the first federal civil rights law generally prohibiting discrimination against individuals with disabilities. The concepts of Section 504 and its implementing regulations were used in crafting the Americans with Disabilities Act (ADA) in 1990. The ADA and Section 504 are, therefore, very similar and have some overlapping coverage but also have several important distinctions" (Brougher, 2010, p. 1)
Workforce Innovation and Opportunity Act (WIOA)	"The Workforce Innovation and Opportunity Act (WIOA) became law on July 22, 2014. WIOA is designed to help job seekers access employment, education, training, and support services to succeed in the labor market and to match employers with the skilled workers they need to compete in the global economy...Section 188 of the WIOA prohibits discrimination against all individuals in the United States on the basis of race, color, religion, sex, national origin, age, disability, political affiliation or belief, and against beneficiaries on the basis of either citizenship/status as a lawfully admitted immigrant authorized to work in the United States or participation in any WIOA title I-financially assisted program or activity" (U. S. Department of Labor, n.d.-a, Employment and Training Administration, Disability and Employment Online, para. 1 and 2)

Through ID Practice

In addition to broad policies and practices, educational technology researchers have proposed frameworks, models, and practical tools for planning, developing, implementing, monitoring, and evaluating access of, or with, technology for educating persons with disabilities. The article by Edyburn and Edyburn (2012) *Tools for Creating Accessible, Tiered, and Multilingual Web-Based Curricula* seems particularly relevant and practical. The authors propose connecting instructional design and learner characteristics to create “diversity blueprints” (p. 201). As another example, Rao, Edelen-Smith, and Wailehua (2015) offer a detailed framework for applying principles of various forms of universal design to effective pedagogical practice. They encourage instructional designers to expand thinking about learner characteristics during the analysis phase.

Analysis of learners, content, environments, activities, transferability, and transportability is key to sustainable access and success. Rapid prototyping is necessary to ensure the technology is accommodating learners rather than learners adjusting to the technology. The number and nature of nuances are significant. These are often not immediately recognized by readers outside the discipline, in publications that document needs of persons with disabilities and/or technology affordances that provide access. To design a successful experience, we must focus on learner abilities, at least as much as their disabilities. Learner analysis should be expanded to include each developmental domain, in a variety of authentic environments, activities, and developmental ages, thus facilitating sustainability of instructional design for access to/through technology.

Through Enhanced Awareness and Collaboration

A detriment to sustaining ID for access and, indeed, efforts for access to/through technology is the lack of reference to *instructional design* in the reviewed disability literature. This suggests that many educators and other carers either are unaware of instructional design as an area of study or lack understanding and use of it in their research and instruction/interventions. Hoppestad (2013) noted a lack of research regarding methods to help persons with disabilities, especially adults with severe disabilities, to access technology in a useful way. Access to the technology in a timely and efficient way, as well as access to comprehensible information on how to introduce and train the use of technology in a variety of authentic contexts and monitor effectiveness of use, is needed. Problem-solving to reduce the costs in terms of time, funds, frustrations, and wariness of technology should be a collaborative effort among instructional designers and disability specialists, at a minimum. In order to conduct collaborative disability and access research involving the design of instruction, partners should first agree to common definitions, such as those for access, UDL, inclusive classrooms, and differentiation within disabilities.

Through Research

Researchers and findings in the literature, both explicitly and implicitly, call for improved collaboration among professionals to ensure continued services and aids (Bouck & Flanagan, 2016), direct outreach and instruction to parents and carers of persons with disabilities (Okolo & Diedrich, 2014), and offer comprehensive, systemic, and inclusive support for technology and its use (Tanis et al., 2012). Relevant and sustainable research and outcomes depend upon the sharing of resources. Resources include but are not limited to knowledge, access to persons with disabilities, access to educators, related service providers, carers and parents, access to the curriculum and pedagogies in use, and access to the various learning environments and technologies for persons with disabilities.

When research is focused on small samples, or is limited to specific hardware and software with a single population of disability, or for a particular academic purpose, we must address issues of relevance and sustainability. To be sustainable, we need to integrate our knowledge, skills, and resources across disciplines to develop research that is replicable and generalizable in authentic contexts and/or that leads to further study of the access, equity, learning, and design questions that drive this research.

In educational technology literature, the focus is typically on strategies rather than hardware; however, in the persons with disabilities literature, the focus is often on the hardware or app as a tool to an outcome. Too often, in that literature, the description of strategy used with the technology is missing or precise in a one-to-one, isolated setting. Ideally, these bodies of literature would blend, and the experts would partner to design interventions to include hardware, apps, and strategies with the focus always on the desired outcome, in the desired context, with a specific learner with a disability. As noted earlier in this chapter, understanding issues of instructional design and accessibility for persons with disabilities requires recognition and comfort with the complicated and complex. For the authors of this chapter, along with understanding came critical reflection of our disciplines and more questions.

Reflective Questions

Perhaps the disciplines of instructional design and disability should be asking whether evidence-based practices that integrate the variety of knowledge and skills of each other's disciplines are being identified. Are we creating authentic, generalizable, transferable, and transportable research outcomes that benefit all learners, and are we doing that by collaborating with others who have expertise other than our own? Are we aware and sensitive to the different definitions of shared terminologies and how that may impact our understanding of research and practice? Are we narrowly defining our discipline's focus, thereby limiting the efficiency and effectiveness of our professional practices and outcomes?

Are we designing useful interventions that account for the value of the task, the expectation of success or failure, and the cost to the learner? If a designer generates material, activities, or environments in which a learner's initial efforts are not successful, learners with disabilities—particularly those who do not value the knowledge or skill—will not persist. The expectation of failure and the emotional cost are greater than the value of the knowledge or skill to the learner.

Are we sensitive to, and able to leverage, existing policies, research methods, practices, frameworks, and models to make our instructional designs more accessible? Are we using instructional design and technologies to remove barriers to access on multiple levels for persons with disabilities? Are we comfortable enough with disequilibrium to risk collaboration with others engaged in the research and practice of instructional design, educational technology, access, and persons with disabilities? And perhaps most importantly, what barriers have been created to impede such collaboration and why have they not been minimized?

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Intellectual Development and Aging of Adults in Educational Technology

Eunjung Grace Oh and Yi-Chun Hong

Introduction

We live in an interesting era demanding continuous learning throughout our lives. With the advancement of technology and short life cycle of knowledge, we are challenged to adapt ourselves by learning new things and methods in rapidly changing personal and professional situations. At the same time, we are experiencing a rapid demographic shift, particularly in the size of the aging population. With developments in medical science and technology as well as improved healthcare, we live longer than ever before. In the case of the United States, the average life expectancy in 2011 was 78.7 years (OECD, 2013). This greater longevity contributes to the demand for learning and career development throughout the life span, as more adults need employment for longer periods of their lives.

The traditional boundaries and focus of education have been those of K–12 and higher education settings. Educational technology as a field is not an exception. Scholars and practitioners in the discipline pay considerable attention to supporting student learning and studying age-appropriate developmental milestones from birth to adolescence. We live and learn as children approximately one-quarter of our adult lives; moreover, as of July 2016, persons over 18 years of age made up approximately 77% of the population (US Census Bureau, 2017). However, in general, our efforts to understand and fulfill the learning needs of adults, considering their age

E. G. Oh (✉)
Department of Education Policy, Organization and Leadership, College of Education, University of Illinois at Urbana-Champaign, Champaign, IL, USA
e-mail: egraceoh@illinois.edu; https://education.illinois.edu/faculty/egraceoh

Y.-C. Hong
Division of Educational Leadership & Innovation, Mary Lou Fulton Teachers College, Arizona State University, Tempe, AZ, USA
e-mail: shelly.hong@asu.edu

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and intellectual development, have been relatively limited at personal as well as organizational levels. Rather, such efforts have often been made by related disciplines such as human resource development, adult education, and gerontology. Nevertheless, understanding and supporting adult learners are also our responsibility because technology is often inseparable from the learning, performance, and career development of many adults. In fact, understanding learner characteristics and designing instruction and learning environments are at the heart of our field.

The purpose of this literature review is to address the question of how educational technology has served the needs of adult learning from the perspective of intellectual development and aging. The remaining chapter will discuss (1) lifelong learning and characteristics of adult learners, (2) intellectual development in adulthood, (3) a critical review and summary of trends in related literature, and (4) a discussion of the findings.

Lifelong Learning and Adult Learners

There has been an increased discussion and emphasis on engagement in lifelong learning. Lifelong learning is "all purposeful learning activity, from the cradle to the grave that aims to improve knowledge and competencies for all individuals who wish to participate in learning activities" (OECD, 2001, p. 2). The essence is that learning happens and needs to happen throughout one's life span. Regardless of our age, what we learn from school merely helps us create foundations. New essential knowledge and skills are continuously expanded for us in order to effectively and efficiently solve problems encountered in this fast-changing knowledge society. Therefore, from our childhood, the important role of a formal educational system should be training learners to acquire the skills to become lifelong learners in addition to the learning contents themselves. Formal education in schools (e.g., a college degree) would prepare us to get a job. However, in many occupations, those initially acquired skills and knowledge become obsolete soon. In order to remain competitive in the job market, continuous learning and development efforts are required, particularly when our career spans have been extended (Economist, 2017, January 12). While employers provide some trainings for their employees, in reality, organizations are not capable of identifying and fulfilling all the diverse learning and development needs of their employees. Individuals should seek various additional learning opportunities to stay competitive in the labor market. In addition, scholars discuss that as age progresses, older adults have various learning needs and motivations including coping, expression, contribution, influence, and transcendence and that emphasize the importance of ample learning opportunities for older adults (Hiemstra, 1976; McClusky, 1974; Tam, 2013, 2014). Overall, lifelong learning is important for adults to maintain or increase the well-being (e.g., career development, socialization, self-fulfillment, remediation, spiritual advancement) of their lives by updating essential life skills and knowledge.

As every adult's life and experiences differ from those of others, there are various adult education opportunities available, including general education development, continuing professional education, workplace training and development, English as second language programs, and degrees and certificate programs offered at the post-secondary level. In the history of educational technology, the greatest effort expended to study educational technology in an adult learning context has probably been in online education (e.g., massive open online courses (MOOCs) and online degree programs) and a smaller portion in workplace training (e.g., corporate e-learning and blended learning). Although adult education scholars argue that adults are motivated to learn, studies report that the level of motivation and personal barriers influence their participation (Chang & Lin, 2011; Merriam, Caffarella, & Baumgartner, 2007; Narushima, Liu, & Diestelkamp, 2013). In the United States, overall participation in adult education activities has been increasing, yet in 2005, only approximately 44% of adults participated in formal adult education (US Department of Education, NCES, 2007). In addition to the formal learning organized and offered by educational institutions, adults may participate in nonformal learning opportunities provided by agencies whose primary mission is not in education (e.g., museums). Lastly, the advancement of technology and abundant digital resources have expanded the boundaries of adult learning beyond the traditional sense of predetermined and structured learning events offered in formal and nonformal learning settings (Bonk, 2009; Huang & Oh, 2016; Song & Lee, 2014). Adults may have a strong motivation and intentional goals to engage in learning in a self-directed manner. Their learning can also take place spontaneously in social contexts as well as a result of individual exploration (Damnik, Proske, Narciss, & Körndle, 2013; Livingstone, 2001).

Adults are distinct from younger learners in many ways (e.g., Knowles, 1984; Merriam & Bierema, 2013). However, defining adults is not a simple task because each person's life situation is different. For example, some may not consider college students to be adults because they often do not have the social roles and responsibilities of adults, yet some may have full-time jobs with the financial and social responsibilities of a family as caregiver and breadwinner. Although independence is an important factor in being a grown-up, some adults may not be able to live independently due to mental or physical disabilities requiring other people's support. In the United States, at the age of 18, everyone is legally an adult, but high school dropouts younger than 18 may still engage in adult learning programs (Merriam & Bierema, 2013). In fact, the National Center for Education Statistics (NCES) includes 16–17-year-old participants in the career-related adult education demographic. In addition to age and roles as family members and citizens, personal experiences accumulated over the years are an important aspect in distinguishing adults from youth (Knowles, 1984) and tend to increase in significance with aging. Such experiences can be rich resources and a central part of their own learning.

Intellectual Development in Adulthood

Intelligence is understood as smartness or the ability to learn (Merriam et al., 2007). It is a broad term indicating and encompassing many different cognitive abilities. Traditionally, scholars have studied intelligence from a psychometric perspective describing intelligence as an individually distinguishable characteristic. By using instruments such as IQ tests at different developmental stages, they measure an individual's intelligence. However, diverse perspectives for approaching intellectual development exist (Sternberg & Berg, 1992). Some popular perceptions include psychometric (e.g., Horn & Hofer, 1992), Piagetian (e.g., Blackburn & Papalia, 1992), neo-Piagetian (Labouvie-Vief, 1992), information-processing (Salthouse, 1992), learning (Charness & Bieman-Copland, 1992), contextual (Dixon, 1992), and a lifespan developmental perspective (Baltes, 1993; Erikson, 1982; Schaie, 2008a, 2012).

For adults, one broad misperception with aging is that intelligence declines as well as personality traits (e.g., openness, extraversion, and agreeableness) change in a negative direction (Schaie, 2008a; Schaie, Willis, & Caskie, 2004). However, this statement is oversimplified. Intellectual development does not stop at the end of adolescence. Further, a decline does not universally happen to all. The cognitive aging of adults can be categorized into four major groups: normal aging group, successful aging group, aging with mild cognitive impairment, and aging with dementia (Schaie, 2008b; Schaie & Hofer, 2001). Individuals in different groups show different development and decline patterns.

With regard to the influence of aging on the intellectual development and learning of adults, scholars have used empirical efforts to challenge stereotypical ageism and the notion of the universal decline of cognitive abilities with aging with empirical efforts (Merriam et al., 2007). The following section describes some important developments regarding adults and their intellectual development.

First, intelligence is an individual characteristic. And such individual differences in intellectual abilities continue to exist into adulthood (Horn & Hofer, 1992; Schaie et al., 2004). Piagetians argue that there are universal aspects of intellectual development across individuals by characterizing the essence and change in cognitive functioning in each stage (Blackburn & Papalia, 1992). However, a formal operational level, the last developmental stage reached in adolescence according to Piagetian, may not be universally obtained before or during adulthood. Also, Piaget's theory does not capture uses of adults' intellect in different stages (e.g., applications of knowledge) in adulthood as the theory mainly describes the "acquisition of new information" in different developmental stages (Schaie, 2008a, p. 6).

In the Seattle Longitudinal Study, Schaie (2012) has investigated adult development for seven cycles from 1956 to 2005 and found that there were substantial cohort differences in terms of detectable decrement in abilities. He argued that individuals' contextual circumstances, personalities, and health-related factors lead to individual differences in cognitive and intellectual change during adulthood. His co-constructionist model describes how an interplay between neurobiological and sociocultural factors contributes to normative changes and cohort differences in individuals' cognitive abilities (Schaie, 2008a, 2008b). That is, reaching a higher level of intellectual capabilities and cognitive functioning in adulthood also has to do with an accumulation of cultural resources and knowledge across time in addition to individuals' neurobiology. Blackburn and Papalia (1992) also claimed that environmental experiences such as educational, social, and economical factors influence the performances of adults, including the elderly. For example, later-born cohorts with higher educational attainment (e.g., graduate school) and occupational status (e.g., professional) show a higher level of crystallized ability (e.g., verbal meaning) as well as fluid ability (e.g., inductive reasoning) compared to earlier-born cohorts and groups with lower status in education and occupation (Schaie, 2008b).

Therefore, intelligence should be understood more broadly, particularly in the context of adult development, as the growth of adults is a process as well as an outcome of interactions of complex reality of their lives. Neo-Piagetian scholars expanded the notion of cognition, moving beyond "traditional forms of thinking" to domains that are more "transcendent and permanent dimensions of life" such as "self, values, emotions, and coping processes" (Labouvie-Vief, 1992, p. 222). Scholars from the contextual perspectives also pay more attention to adults' dealing with not only changing intellectual abilities (e.g., decline in certain cognitive skills) but also changing contextual social demands (e.g., retirement, health issues), as well as the relationship between those intellectual abilities and environmental contexts (Dixon, 1992). Accordingly, isolation and a lack of stimulation from educational, social, and occupational environments during adulthood can possibly contribute to a decline in intelligence.

Second, intelligence is multidimensional and consists of multiple complex constructs (Dixon, 1992; Horn & Hofer, 1992; Schaie, 1996). Cattell (1963) distinguished fluid and crystallized intelligence in his theory. Fluid intelligence, influenced more by neurobiology, entails abilities such as logical reasoning and problem-solving abilities in new situations. On the other hand, crystallized intelligence involves abilities such as using accumulated knowledge and skills and is influenced by one's acculturation, experience, and information maintenance. Fluid intelligence tends to show a peak in young adulthood and begins to decline progressively around 30–40s, whereas crystallized intelligence tends to reach at a peak in midlife and is relatively well-maintained until near to death (Schaie, 2008a).

Investigating the course of adult intellectual development within individuals, Schaie (2012) measures primary abilities such as verbal meaning, perceptual speed, spatial orientation, inductive reasoning, numeric ability, and word fluency. In terms of these factors, longitudinal decline was observed at mid-50s for perceptual speed and numeric ability, at late 60s for inductive reasoning and spatial orientation, and at late 70s for verbal meaning and word fluency. Yet, individuals may show a modest decline of one ability at 60s, perhaps because such an ability tends to be less used and experienced in their lives; however, there was no evidence of universal decline of all abilities by any individual even at 80s (Schaie, 1996, 2012).

That being said, older adults may or may not struggle with learning. Although with better sociocultural condition, later-born cohorts show higher performance in all cognitive abilities studied in the Seattle Longitudinal Study (Schaie, 2012), older adults may still struggle with age-related declines in their "cognitive architecture supporting information processing" (Charness & Bieman-Copland, 1992, p. 302). However, at the same time, an older adult is likely to have a larger knowledge base (e.g., crystallized ability) with more years of experience as an expert in a field. Moreover, such a large task-specific knowledge base often compensates for their age-related challenges of task performance because their experiences involve learning about efficient and effective procedures, important concepts, critical resources for problem-solving, and so forth. When a new task demands learning and coordinating a new set of skills and knowledge, older adults may be slower in their learning and performance than younger adults; that said, allowing practice and multiple trials can help them overcome age-related difficulties such as speed of organizing and processing new information (Charness, 1989; Charness & Bieman-Copland, 1992). Using external cognitive aids (e.g., memory aids) and social aids (e.g., same-age collaborators) can help older adults' learning and enhance their performance (Dixon, 1992).

In addition to intellectual development, another useful insight into adult learners comes from Levinson's (1978) work on Eras in the Male Life Cycle. He conducted a qualitative study of middle-aged men to understand the overall picture of adult development throughout their lifespan. He categorized it in four major stages, with four transitional periods between the major stages: early childhood transition (0–3), pre-adulthood stage (ends around 22), early adulthood transition (17–22), early adulthood stage (17–45), midlife transition (40–45), middle adulthood stage (40–60), late adulthood transition (60–65), and late adulthood stage (60 and beyond). Although Levinson (1978) only studied males, the framework illuminates how a man progresses through a relatively consistent evolution of the life structure and identifies associated developments and changes. He argues that (1) a man's life is surrounded and modified by his sociocultural world, (2) the self of a man constructed during the pre-adulthood stage, whether consciously or unconsciously, continues to influence a man's life as an "intrinsic element" (p. 42), and (3) a man's participation in his world through various roles and in relationships is another important part of his life and development. In particular, occupation and family are two major common "sources within the self and importance consequences for the self" (p. 45). Additionally, these two conditions may change during the adult life span and result in a different developments and life issues about the self and world.

Accordingly, different periods generate a need for learning and performing a new set of tasks. For example, a man between 22 and 28 entering the adult world for the first time is a novice. His major tasks for this period are establishing his life as adult in terms of occupation, mentor, love relationship, and so forth. Accordingly, he tests a number of choices he has made and makes necessary adjustments. However, a man in the midlife transition (40–45) has different learning and development needs. This tends to be a crisis period when a man critically reviews and reappraises his life, success, and failures and ends his early adulthood. At the same time, he assesses his self and expectations and begins to modify his life structure (e.g., new job position or a career path) to prepare for his future (Levinson, 1978). In summary, an adult life span encompasses various life expectations demanding adjustment and growth in each stage. To support adult learners, it is important to understand a diversity of development needs and provide learning opportunities to help them achieve the necessary development at various stages.

Review of Recent Literature on Educational Technology and the Adult Learners

We have conducted this literature review to examine the research at the intersection of educational technology and learning in adulthood. A number of keywords were used to identify the literature in related areas, including educational technology, technology integration, online learning, distance education, e-learning, adult learning, older adults, aging, lifelong learning, workplace learning, human resources, workforce development, and informal learning. The search was conducted using the Library One Search function via one of the author's institution's library website. Other databases that were utilized include Google Scholar, EBSCOhost, Education Full Text, ERIC, and PsycINFO. The search was limited to journal articles. Additionally, to ensure that the review of the literature was current, only journal articles published in the past 10 years were included in the review with an emphasis on those published between the years 2012 and 2017. The search concluded with 61 references.

Informed by the discussions about intellectual development in adulthood and aging and the features of adult learners in the previous sections, we organized the retrieved references into four categories which respectively investigate (1) the current development of online learning addressing adult learners' characteristics, (2) factors influencing adults' adoptions of new technologies, (3) external agents supporting older adults' learning, and (4) technologies selected to connect older adults with society and communities.

Current Development of Online Learning for Adult Learners

Numerous studies were identified in examining different aspects of adult learners' experiences in Internet-based and computer-mediated learning environments. Five predominant themes emerged from the review: self-directed learning, challenges encountered, adult learners' satisfaction, applications of emerging technologies, and older adults' online learning experiences. The first four collections of literature reflect the young and middle-age adult learners' online learning experience, whereas the last theme includes the literature that specifically describes the features of older adult learners.

First, self-directed learning has been consistently highlighted as one of the important principles in adult education (Knowles, 1984). Several scholars explored the aspect of self-directedness in the context of online learning. Christidou and colleagues (2012) evaluated the level of learner control based on the instructional materials provided in the two lifelong learning and continuing education programs. They revealed that the design of the instructional materials provided adult learners limited control over their own learning. Such design is contradictory to the concept promoted in the field of adult education. That is, adult learners should be given choices to determine their own learning pace, the sequence of the learning events, and the criteria used for evaluating their learning (Christidou et al., 2012). Another study related to adults' self-directedness in the context of open distance learning in higher education examines how adult learner's biographic features (i.e., gender, race, and age) vary in their self-directedness (Botha & Coetzee, 2016). For instance, they found that male adult learners are more self-directed than female adult learners. The results suggest that because the levels of self-directedness differ among adult learners with different biographic factors, when designing online courses for adult learners, these factors should be taken into account so that their unique abilities and preferences can be addressed. The other study recruited the experts in interface design and self-directed learning to look into how the interface designs of various e-learning tools (e.g., file sharing platforms, Web 2.0 presentation software, and learning management systems) support adults' self-directed learning (Firat, Sakar, & Yurdakul, 2016). The study concludes that options should be provided to adult learners to facilitate their capacities in self-directed learning. Taken together, giving learners control, understanding individuals' differing levels of self-directedness, and providing options are ways to accommodate adult learners' demand for self-directed learning in an online learning context.

The second theme centers on the challenges encountered in online education. Online education has been recognized as a viable alternative solution for adults seeking continuing education as well as higher education (Ke & Xie, 2009). However, some adults (e.g., reentry/nontraditional students and first-year undergraduate adult learners) have a lack of confidence in learning online or remotely (Kaur & Sihu, 2010; Ross-Gordon, 2011). Also, adult learners often face other issues, such as financial obstacles, lack of support from family or employers, a sense of hopelessness, concerns about the irrelevance of their education, and the fear of low academic performance (Pozdnyakova & Pozdnyakov, 2016). These studies recommend a number of guidelines to support adult online learning experience. First, adult learners should be guided to develop metacognitive skills (i.e., planning, organizing, monitoring, and evaluating learning processes) in order to boost their confidence in their ability to learn successfully and become autonomous lifelong learners (Kaur & Sihu, 2010). Further, it is critical to equip adult learners with the text-based communication skills and the ability to work independently (Criu & Ceobanu, 2013; Kaur & Sihu, 2010). Another suggestion made is to ensure that the design of the course considers both the flexibility that adult learners desire and the necessary learning trajectories that guide less confident adult learners to succeed in the course (Ross-Gordon, 2011). Lastly, Kahu and colleagues (2014), considering that most adult learners access online courses from their home, offer tips to prepare the home environments that are conducive to learning.

The third theme identified is related to adult learners' satisfaction with online learning. Adults learning online can be influenced by a myriad of factors. For example, in a series of studies using mixed-method and case study approaches, Ke and colleagues (2009, 2010, 2013) discovered that age does not predict adults' satisfaction with online learning experience. Instead, the strong instructor's presence online, the integration of discussion, and collaborative learning activities around the course topics are key to adult students' satisfaction. They argue that extra care should be given to course design and facilitation of students' learning as these two elements are integral to a positive online learning experience. Other than the above factors, Rivera-Nivar and Pomales-Garcia (2010) argue that adult learners have relatively high levels of satisfaction with online courses whose interface design considers the characteristics of adult learners, such as large video display, large font size, and a topic that involves a narrative rather than numerical content.

The fourth group of literature is concerned with promoting the applications of emerging technologies, such as massive open online courses, Second Life, and Web 2.0 tools, in the lifelong learning and adult learning programs (Fini, 2009; Goksel-Canbek, Mavrommati, & Demiray, 2011; LeNoue, Hall, & Elghmy, 2011; Watson, Watson, Yu, Alamri, & Mueller, 2017). These studies examine the adult learning principles and use these principles to inform the integration of technologies to enrich adult students' online learning experience. However, studies that fall under this theme are conceptual discussions rather than empirical work.

The last category of literature is dedicated to examining older adults' online learning experiences. Among the collected literature, there are fewer studies that specifically investigate older adults' learning conditions. Ke and Kwak (2013) discovered that older adults spent more time participating in online discussion activities than their younger counterparts; however, their greater time commitment does not necessarily lead to more meaningful contributions. Another study of Ke's (2010) reported that older adults have a concern about the use of Web-conferencing tools for synchronous communication because using such learning platforms requires them to invest some cognitive effort into learning the tool. Their lack of efficiency in participating in online discussions and handling of their cognitive overload to learn unfamiliar technological tools can be accounted for by the decline of their cognitive capacities. Similarly, Githens (2007) summarizes older adults' decline in some capacities, such as reduced visual acuity, hearing difficulties, deteriorating working memory, and slow learning. He further argues that these areas should be taken into account when designing e-learning opportunities for older learners by using tactics such as presenting content with larger fonts, slowing speech rate in audios and videos, and offering written transcripts for learning materials presented in audios and videos. As illustrated by the retrieved literature, the design of an online learning experience for adult learners involves a wide array of considerations in relation to nuanced differences among individual adults with varying intellectual developments, contextual circumstances, social demands, and so forth. Beyond the identification of the content knowledge for an online program, it is imperative that educators and scholars also take into account the characteristics of adult learners and the possible challenges that adult learners face due to declining cognitive abilities and environmental factors.

Factors Influencing Adults' Adoptions of Technologies

Much of the existing research investigates adults' perceptions toward and acceptance of different technologies. Among the literature, the investigations of hardware equipment targeted mobile devices, tablets, computers, PDAs, camcorders, DVD players, etc. (e.g., Huber & Watson, 2014). The software technologies that were the focus of selected studies include social networking tools, Web 2.0 tools, productivity tools, and basic programming (e.g., Xie, 2007). Some studies investigated adult perceptions of certain technologies using survey or interview methods, while others focused on examining the change in adult learners' adoptions and perceptions of technologies as a result of training or workshops using case study or mixed-method approaches. Across many of the identified studies, models of technology acceptance such as the technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT) served as theoretical frameworks to guide development of the questionnaires, interview protocols, and training sessions. A number of elements were recognized for determining adults' uses of new technologies, including perceived usefulness, perceived needed efforts, social influences, trust, frequency of Internet use, and educational attainments. Among these determinants, perceived usefulness (Barnard, Bradley, Hodgson, & Lloyd, 2013; Braun, 2013; Chiu et al., 2016; Seals, Clanton, Agarwal, Doswell, & Thomas, 2008; Wang, Wu, & Wang, 2009; Xie, Watkins, Golbeck, & Huang, 2012) and the frequent use of the Internet or similar technologies (Braun, 2013; Chiu et al., 2016; Huber & Watson, 2014; Seals et al., 2008) were the two factors that particularly mattered in adult users' perceptions toward and adoptions of new technologies. Further, Seals and colleagues (2008) noted that adults are generally not averse to new technologies. Technical and emotional support is central to their willingness to learn to use new technologies (Barnard et al., 2013; Xie et al., 2012). Also, an interesting finding from one of the identified studies observed that participants' educational attainment positively correlates with their willingness to use new technologies (Chiu et al., 2016), while another study found that participants who had a higher educational background felt less comfortable shopping for new electronic devices (Huber & Watson, 2014). All in all, the literature included in this category collectively identifies a myriad of factors that could possibly influence adults' adoptions of emerging technologies. Among them, the adults' perception toward the practicality of new technological tools seems to dominate adults' decisions to use them.

External Agents to Support Older Adults' Learning of New Technologies

As we learned from the previous section, offering support to older adult learners is critical in assisting in their learning of new technological skills. Three studies were identified; the support systems used in these studies were peer instructor/tutor/assistant support (Woodward et al., 2013; Xie, 2007) and intergenerational support (Hewson, Danbrook, & Sieppert, 2015). In the past, younger adults or experts with a wealth of knowledge were the ones who primarily led the trainings and workshops because of their expertise and familiarity with technological tools. However, their awareness and understandings of the aging-related challenges that older adults could face such as reduced visual, perceptual, psychomotor, and cognitive abilities have been lacking (Xie, 2007). Consequently, younger experts fail to accommodate the needs and characteristics of older adult learners, leading to older adults' decreasing interests in learning technological skills. Recent studies identified such a challenge and implemented a peer support model to teach or tutor peers of similar ages in learning technology skills. Since they experience the effects of aging themselves, they can be more cognizant of the needs of other older adult learners (Woodward et al., 2013; Xie, 2007). Another study implemented a unique approach, arranging learners from different generations to help each other learn digital storytelling. The study reported that both older adults and postsecondary students mutually benefited from each other in their acquiring knowledge of digital storytelling and in their understandings of the difficulties and thoughts shared by each generation (Hewson et al., 2015). On the whole, older adults are not resistant to adopting and learning new technologies. With adequate support and training that consider older adults' traits and their rich life experiences, it increases the chance to equip them with necessary knowledge and skills in technological tool to stay connected with family, friends, and communities.

Technologies Collecting Older Adults with the Societies and Communities

Other prominent issues adults face in their middle and late adulthood stages are social isolation and loneliness, which could negatively impact their health and wellbeing. The existing literature has discussed the great potential of technologies (e.g., the Internet) to connect older adults with their communities and society. For example, Black (2012) reviews the features of different technologies (e.g., blogs, online chats, and tweets) for engaging older adults in civic-related activities. Khosravi and colleagues examine varied electronic devices such as information and communication technologies, video games, social network sites, and asynchronous online chat rooms to alleviate older adults' feelings of isolation (Khosravi, Rezvani, & Wiewiora, 2016). Both studies have shed some light on exciting ways to support older adults' connections with the outside world. Nonetheless, neither of these studies is an empirical one; thus, there is a need to further our knowledge in this particular area by investigating the effectiveness of the identified methods.

Discussions

The examination of the existing literature in the previous section has shed light on our understandings of areas we can contribute in the future as a field to support adults' learning and intellectual development as they confront challenges distinct from those faced by other groups of learners (e.g., K–12 students) whom we have extensively investigated in the past. As we move forward, the literature review offers three directions to guide the educational technology community in addressing the needs of a significant and growing population of adult learners, particularly older adult learners.

First, we have learned from previous research about the determinants affecting adults' perceptions toward and use of new technologies as well as the approaches to support their acquisition of technological skills. The purposes and outcomes of such existing studies emphasized supporting adults' learning of new technologies or computer skills (e.g., Barnard et al., 2013; Xie et al., 2012), and they were mostly published in the scholarly communities of gerontology, adult education, and human-computer interaction. Moving beyond imparting knowledge and skills about technological tools, adult learners should be provided with the same opportunities as other group of learners to use technologies and the Internet to assist their learning of other subject matters for their continuing education, workplace learning, and lifelong learning. However, only a few studies delved into the understanding of the design of learning environments (e.g., Ke & Kwak, 2013), learning technologies (e.g., Woodward et al., 2013), and learning experiences (e.g., Kaur & Sihu, 2010) to cater to the particular needs and characteristics of adult learners. For example, Ke and Kwak (2013) reported that instructional design and teaching presence are central to increasing adult learners' satisfactions with online learning. However, what factors should be considered for the design of learning environments is under researched. How can the design of learning environments address older adult learners' declines in cognitive abilities? How can the design of online learning experiences provide both the flexibility and structure that adult learners desire? How can the design of learning experiences speak to the change of contextual social demands adult learners face? How can the selection of technologies address adult learners' visual and psychomotor abilities? These questions demand further explorations and investigations in our field.

The second direction is concerned with the methodology for conducting research in the related areas. Many identified studies were exploratory in nature and employed self-reported surveys with Likert scale type of questions to uncover learners' perceptions toward new technologies or learning a particular technological skill (e.g., Huber & Watson, 2014). Some other scholars developed new supporting models to teach adults using technologies. For such research, a case study approach (e.g., Barnard et al., 2013) or a mixed-method approach (e.g., Chiu et al., 2016) was used to investigate participants' reactions to the newly developed programs. While these research approaches provided us with initial insights on understanding adults' feelings toward these programs, it is equally necessary to probe into adults' learning gains as a result of these programs. That way, researchers could examine the effectiveness of the employed instructional model and instructional strategies for supporting adults' learning in online or computer-mediated environments. Additionally, as developing adult learners' abilities with the support of educational technology is relatively early in its development, to expand the contributions from educational technology communities, design-based research (McKenney & Reeves, 2012) can help improve both the practice and the theoretical development of learning environments for supporting adult learners.

Third, the review of literature indicates two major findings regarding older adult learners. First, designing successful learning experiences with technology for older adults requires somewhat greater consideration as they experience difficulties due to aging (Xie, 2007). However, second, our efforts regarding how to support and accommodate older adults' learning technology and learning with technology are still at an early development stage with relatively preliminary knowledge, despite a growing demand for information and support for this particular group of learners. Adult learning literature emphasizes how learning in older adulthood enhances the well-being of individuals and the social community to which they belong (Merriam & Kee, 2014). Much adult learning traditionally happens in informal and nonformal venues (Merriam & Bierema, 2013). Also, regardless of the type of erudition, learning with technology is now clearly prevalent in and increasingly accepted by younger generations. The rapid advancement in digital affordances such as Web 2.0 tools and smart technology has changed the way we work, learn, socialize, and entertain ourselves, along with enriching our lives. Therefore, a lack of exposure to technology and a deficiency of knowledge of how to appropriately use technology can compromise the well-being of older generations and generate unavoidable stress for them (Seals et al., 2008). In a 2015 report on American adults' social media use, only 51% of individuals 50–64 years old and 35% of adults over 65 use social media. Although there has been a significant increase in social media use in these groups since 2005 (5% and 2%, respectively) (Perrin, 2015, October 8), these are still small numbers of users compared to young adults. In addition, the essence of Web 2.0 technology is the generation of content and a sharing of knowledge. Baby boomers have the greatest involvement with a broad range of valuable experiences, knowledge, skills, and wisdom in their professional fields and life in general; however, in this digital world, they seem to have limited opportunities to engage in activities and share their ideas and expertise.

Today, organizations employ the most diverse generational workforce ever (Oh & Reeves, 2014; Reeves & Oh, 2007). Due to the experiences older workers have accumulated, they are expected to be more independent in performance without receiving the relevant training and coaching that can help them improve their performance and adapt to any change at work (Lim, Oh, Ju, & Kim, 2019). However, efforts for lifelong learning and career development are important for all generations of workers in a knowledge society in which the cycle of viable knowledge is very brief. Despite existing perceptions, many older people are still actively engaged in the workforce, have a desire to learn and develop their competencies, and are concerned with re-employment and career advancement (Kampfe, Harley, Wadsworth, & Smith, 2007; Lim et al., 2019). With appropriate support, older-generation workers can continue to be successful in workplace performance and contribute their expertise in a fast-paced digital age. Assisting older adults with the kinds of expertise that the educational technology field has developed for many decades is critical at both individual and organizational levels. Our future efforts should focus on accommodating the needs of older adults with instructional strategies and learning designs relevant to their age-related development and sociocultural characteristics as well as expanding our boundaries of research and practice to different types (e.g., formal, informal, and nonformal learning) and content of learning (e.g., health, retirement, and leadership) that are more approachable by and attractive to older adults.

Conclusions

We live in an era in which our lives have become more diversified and dynamic than ever before with changing demographics, globalization, and advancement in technologies. We not only face a strong societal demand for lifelong learning but also actually have more abundant access to learning opportunities than ever before because of ubiquitous emerging technologies. Through a critical literature review, the authors of this chapter believe that although our effort thus far has generated useful knowledge and insight to support adult learning, such an endeavor has been limited to understanding the needs of adult learners and effectively supporting them in inclusive ways. Although much effort regarding adult learning for the past few decades has been focused on distance education, particularly on online learning including MOOCs, continuous effort should be made to consider adult learners' changing characteristics throughout their life span and their needs beyond such learning environments. How does the field of educational technology address intellectual development and aging to effectively support the learning and development needs of adults? How can adults successfully use technology for their learning, development, and performance improvement throughout their life span? We argue that our effort for responding to these important research questions is still in early development.

Technology has transformed our personal and professional lives in numerous ways (Oh & Reeves, 2014). For learners in K–12, although there is always room for improvement, we actively teach and support how to use digital and emerging technologies for their learning and lives. For example, the International Society for Technology in Education (ISTE) offers standards to be used in school environments to educate students to become well-rounded and competent citizens of a digital era. However, many adults still have limited access to and opportunities for education and learning with technology. The authors of this chapter urge that educational technologists should undertake substantial action for supporting this important population by leading interdisciplinary teams of scholars and practitioners. With our keen learning design expertise and comprehensive perspective on technology, we could contribute to promoting the well-being and equity of adult members of this society through meaningful lifelong learning.

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Equity-Centered Approaches to Educational Technology

Antero Garcia and Clifford H. Lee

This chapter reviews the perspectives and scholarship that address educational equity through the application of technology and digital tools. We first explore how equity is framed in global discourse and the role that educational technology has played in both addressing and perpetuating disparities in achievement. Policymakers, designers, and researchers have routinely attempted to use digital technologies to address the learning needs of historically marginalized populations. Before we examine these technological interventions in context, we must first explore the root causes of what "counts" as an achievement gap as well as what "counts" as technology.

Following this overview, this chapter then offers a sociocultural rationale for what equity-centered approaches to educational technology could look like. These guidelines are offered to ground design, research, and pedagogy and build on a foundation that strengthening the relationships fostered in formal learning environments is essential to improving learning outcomes sustainably.

Much of the literature on educational technology centers on its innovations, effectiveness, efficiencies, and the promise of quick fixes to systemic and entrenched educational problems. Scant research has examined its role in addressing inequity (Tawfik, Reeves, & Stich, 2016). Specifically, we question what educational technology can do for students who contend with intergenerational forms of institutional racism, classism, and sexism. How can educational technology be used to liberate students instead of perpetuate inequalities in the schooling system? What does it look like to utilize an equity-centered approach to educational technology in school and out-of-school contexts?

A. Garcia
Stanford University, Stanford, CA, USA

C. H. Lee (✉)
Mills College, Oakland, CA, USA

M. J. Bishop et al. (eds.), *Handbook of Research in Educational Communications and Technology*, https://doi.org/10.1007/978-3-030-36119-8_10

We ground this chapter's analysis of achievement, equity, and technology around a central perspective based on a review of global literature. Myopically focusing on educational and instructional technology tools, curriculum, and pedagogy as a panacea for achievement gaps fails to achieve the goal of equality. Such approaches do not accurately historicize the macro-sociopolitical root conditions that produce these inequalities. By prioritizing an equity-centered approach to educational technology, educators and researchers can leverage the technology in order to demystify, explain, and analyze the unequal societal conditions of historically marginalized youths' realities. This in turn provides youth with an explanatory framework and model for their struggles, as well as instruments and skills to transform the conditions of their reality. Further, a by-product of this may include the technical know-how to build the tools to create the future they want to see.

For this chapter, we build on a definition of educational technology as "any tool, equipment, or device—electronic or mechanical—that can help students accomplish specified learning goals" (Davies, Sprague, & New, 2008, p. 233). Much of educational technology is designed for a general (e.g., early readers) or highly targeted audience (e.g., students who have failed algebra). Yet decades of Learning Sciences literature has taught us that an ideal learning ecology is designed and customized to address the unique learning styles and cultural backgrounds and experiences of each learner, based on the situated context of their environment (Lee, 2003; Rogoff, 1994; Vygotsky, 1986). And in many cases, that learning environment, whether it is situated within the classroom, school, or community, is filled with material inequities that shape the way individual learners make sense of educational material. By ignoring these institutional constraints and structured forms of marginalization, young learners are again forced to adapt to the tools, rather than the tools adapting to their needs. In this way, educational technology simply perpetuates and reifies the same inequitable conditions found in dominant schooling practices that ignore, invisibilize, and discount the experiences/backgrounds and epistemological traditions of marginalized communities. Rather than see value in who they are and the communities they are from, they are forced to erase their identities to acquiescence to the dominant culture and its practices. To genuinely move toward an equity-centered approach to educational technology, policymakers, district administrators, educators must prioritize and historicize the inequitable conditions of these youths while using technologies that embrace the multiliterate environments they are immersed in (Subramony, 2004).

Contemporary educational research consistently echoes the narrative of an achievement gap between high- and low-resourced students (Darling-Hammond, 2015; Lee, 2002; Reardon, 2011). For historically marginalized populations, policymakers and district officials have routinely attempted to use digital technologies and tools to address this gap (Cakir, Delialioglu, Dennis, & Duffy, 2009; Darling-Hammond, Zielezinski, & Goldman, 2014; Edyburn, 2006). Before we examine these technological interventions and their effectiveness in context, we first explore the root causes of educational inequality and the assumptions underlying the role of technology in addressing these causes. This review, then, focuses on the lasting legacies that have caused purported achievement gaps as well as the sociocultural construction of what technology means in the twenty-first century. Though this analysis of issues of educational equity is driven by our expertise within primarily US-focused contexts, we recognize that the disparities of achievement that cleave students in the United States by race, class, and gender are consistent with similar differences globally.

Understanding Contexts of Equity and Contesting "Gaps" in Student Achievement

Across eras of schooling and policy, technology has been seen in schools as a means of quickly improving learning outcomes and leveling the playing field for students of various socioeconomic backgrounds. Implicit in these efforts is the need for students to be prepared for the sociotechnical developments within a globally competitive, capitalist society (New London Group, 1996). Preparation for postsecondary education and the ability to navigate new systems and tools are key guidelines for how educational technology falls hand-in-hand with the educational policies shaping public schooling systems today. Reviewing the names of historical policies that have guided educational reform within the United States in the past few decades as an example, the narratives of competitiveness and measuring inadequacy at the student, teacher, school, district, and statewide levels are clear. From fear of leaving children behind (No Child Left Behind) to sustaining state-by-state "races" to achievement metrics (Race to the Top), these policies highlight how educational decisions—and the use of educational technology as part of these decisions—are shaped by market forces and competition across nations.

Within this context of competition, socioeconomic divides in traditional measures of academic achievement are largely understood as dividing student success. This achievement gap highlights educational disparities but also belies the lasting legacies of inequality that have led to its formation. Instead, we propose building an understanding of the role of educational technology by first acknowledging Ladson-Billings' (2006) explanation of an educational "debt" *instead* of an achievement gap. In her explanation of educational inequality within the United States, legacies of economic, racial, and political oppression have fomented the differences in educational outcomes across socioeconomic, gendered, and racial lines. By shifting from a focus of how some students are behind others academically toward understanding the legacies that have created unasked for educational differences within a population (namely, state-sanctioned disparities in equitable schooling, government policies to advantage one group over another, and blatant institutional racist structures), Ladson-Billings' framework allows educators, policymakers, and researchers to shift toward an emphasis on answerability (Patel, 2016) in our responses to equity-driven educational approaches.

This shift acknowledges the cultural aspects of teaching and learning that are often unrecognized in high-stakes testing contexts and builds from the understanding that "learning is actively mediated through learners participation in their culture"

(Young, 2014, p. 350). As Gutiérrez and Rogoff (2003) remind researchers, “people live culture in a mutually constitutive manner in which it is not fruitful to tote up their characteristics as if they occur independently of culture, and of culture as if it occurs independently of people” (p. 21). Further, this is not to say that academic rigor is disregarded from this lens; instead, we recognize that rigor is more than test scores and is tied to equipping students with opportunities for meaningful and dignity-driven educational experiences (Gutiérrez & Penuel, 2014). This cultural historical lens of educational equity broadens the perspectives for studying the possibilities of educational technology by emphasizing the daily lives of individuals in complex learning environments (Gutiérrez, 2008). Further, this perspective recognizes that students do not interact with tools within an isolated bubble but that, instead, meaning making in classrooms is jointly constructed by both teachers and students (Gallego, Cole, & Laboratory of Comparative Human Cognition, 2001; Pacheco & Gutiérrez, 2009). Examining the sociohistorical nature of schooling inequities becomes a broader opportunity to consider the *purpose* of educational technology and to explore the possibilities for improvement and capacity for change through technological innovation. Recognizing that “culture influences and is influenced by human learning and development,” we now more specifically explore the role of technology across various educational contexts (Young, 2014, p. 350).

The Allure of Technology as an Educational Panacea

Detailing examples of technology use in classrooms across more than a century, Larry Cuban (1986) highlighted the rigid consistency of schooling systems in his review of technology in classrooms across a century of schooling. And not much has changed in the years since this scholarship. Despite decades of investment and focus on the allure of tools for addressing achievement gaps, Cuban and other researchers have highlighted how myriad schools and districts invest in the latest digital tools—desktop computers, interactive whiteboards, and handheld tablets—in the hopes of improving learning outcomes (e.g., Cuban, 2012; Darling-Hammond et al., 2014). These are “unsubstantiated assurances” from districts about the role that technology can play in transforming young people’s learning experiences (Philip & Garcia, 2013).

One danger of the investment—financial, social, and professional—in the value of technology as a means of addressing equity is that it places further expectations on a teaching force rather than distributing this responsibility across multiple actors in educational and social systems that have shaped the tools placed within classrooms. For example, although the Technology, Pedagogy, And Content Knowledge (TPACK) framework attempts to address these concerns with an explicit focus on the relationships and interactions between Technology, Pedagogy, And Content Knowledge (Koehler & Mishra, 2009), it does not take into consideration larger sociopolitical factors that created these “gaps” in the first place. Likewise, while the affordances of educational technology change from year to year, how teachers in schools globally are prepared and expected to teach has largely remained the same. As Cuban (1986) notes, "Those who have tried to convince teachers to adopt technological innovations over the last century have discovered the durability of classroom pedagogy" (p. 109).

And yet, despite the ruggedness of traditional classroom practices and pedagogy, digital, participatory culture and youth engagement with mobile devices has transformed the landscape of informal learning practices (e.g., Garcia, 2017; Ito et al., 2013). Though we highlight the possibilities of these new cultural practices below, we note here that these evolutions in youth interactions have led to contestations of power and technology use in classrooms. Reflecting on the ways that iPads were implemented in a district-wide rollout in Los Angeles Unified School District (LAUSD)—the second largest district in the United States—*LA Times* reporter Howard Blume (2013a) writes:

> It took exactly one week for nearly 300 students at Roosevelt High School to hack through security so they could surf the Web on their new school-issued iPads, raising new concerns about a plan to distribute the devices to all students in the district.

The more than $1 billion iPad initiative in LAUSD is a notable highlight of the failure of buying tools in an attempt to boost flat lining or declining measures of student growth. However, it is not notable because of the large price tag that came with the initiative's failure nor due to the fact that this failure led to the ousting of the LAUSD superintendent (Blume, 2013b). Instead, the *regularity* that districts will invest in software, digital tools, and the consultations for implementing these devices over the support of educators in meaningful, digitally mediated instruction is what is most notable. The pattern of tech-focused investment, as Cuban and others continually remind us (e.g., 1986, 2012, 2018), is one that—across global contexts—narrows assumptions of achievement to being merely tied to issues of access.

From the use of 16 mm film in the 1950s to *edutainment* mobile apps and immersive digital simulations today, educational technologists have long touted the value and importance of these tools in enhancing the learning for students, often in contrast to traditional teaching methods. Major technological advances since the late twentieth century have significantly altered the information and communication technology (ICT) landscape, particularly around the use of computers, mobile devices, and the Internet in daily life. This in turn has transformed educational technology. In 2014, the US PreK-12 educational software market exceeded $8.5 billion (The Software & Information Industry Association, 2015). By 2020, projections estimate the global educational technology industry will exceed $252 billion (Global Report Predicts, 2016). For countries like Indonesia, China, and India where their youth population exceeds 60, 260, and 350 million, respectively, the focus on educational technology is even more pronounced (Emmanuel, 2018). These profound changes in how twenty-first-century learners receive and make meaning of information force researchers to inquire about the effectiveness of these tools. The benefits of educational technology have been widely documented: from opening new learning opportunities to connecting over physical and political boundaries to increasing communication speed and access, there is little dispute. However, literature reviews of various global educational technologies and its effectiveness on learning have been mixed (Delgado, Wardlow, McKnight, & O'Malley, 2015; Escueta, Quan, Nickow, & Oreopoulos, 2017).

In addressing issues of technological access, the "one-to-one" model—where every student in every class, school, and district is provided with personal computers—has been widespread (Zheng, Warschauer, Lin, & Chang, 2016). Organizations like One Laptop per Child (OLPC) have provided over 2 million children with a "rugged, low-cost, low-power, connected laptop" in mainly Latin America and Africa. Within the United States, programs such as the Maine Learning Technology Initiative have attempted to provide every secondary student with laptops and tablets. These approaches place solutions of educational equity in enacting widespread distribution of devices; putting a digital device in the hands of youth across the globe—as attempted by OLPC, Maine, and LAUSD—is assumed to "fix" the equity issues that have exacerbated across generations. To address equity around Internet access, former President Barack Obama announced the ConnectED initiative to bring high-speed broadband to 99% of K-12 students by 2018. Despite these efforts, access inequities continue to persist. Bulman and Fairlie found that among US households with incomes in excess of $100,000 per year, 98% of students have a computer at home, as compared to 67% for children in households with incomes less than $25,000 (2016). Globally, there has been mixed results regarding the impact of increased access to hardware on learning outcomes and cognitive results. Several countries, Colombia (Barrera-Osorio & Linden, 2009), Peru (Beuermann, Cristia, Cueto, Malamud, & Cruz-Aguayo, 2015; Cristia, Ibarraran, Cueto, Santiago, & Severin, 2017), and Kenya (Piper, Zuilkowski, Kwayumba, & Strigel, 2016) showed no impact on learning outcomes in experimental studies. However, one of the interventions in Peru showed positive results on cognitive outcomes and a program in China demonstrated significantly improved Math scores (Mo et al., 2015).

Unlike access to hardware, computer-assisted learning (CAL) focuses on the use of software program to complement and supplement traditional classroom learning. CAL may include any of the following: games, research, networking, and/or tutoring. Out of twenty-nine randomized control CAL trails that Escueta, Quan, Nickow, and Oreopoulos reviewed, twenty demonstrated positive results, with fifteen of those twenty focused solely on Math intervention; eight had no effects for a mix of language, Math, and other topics; and one resulted in negative outcomes (2017). An argument made for CAL is its ability to adapt to learners of different ability levels, especially in providing material at the appropriate skill level (Banerjee, Cole, Duflo, & Linden, 2007; Banerjee & Duflo, 2016) and giving real-time feedback for students and teachers to best adapt their curriculum. These twenty-nine studies included a variety of schooling contexts: elementary, secondary, rural, urban, and suburban classrooms from mainly US-based schools.

While these examinations of randomized control trials of various hardware access and CAL programs and interventions shed light on its use and effectiveness in a multitude of schooling contexts around the world, we are wary of making overreaching generalizations over the efficacy for educational technology.

Developing, Sustaining, and Researching Equity-Centered Approaches to Educational Technology

Reviewing the research above, we recognize that there have been substantial transformative, powerful outcomes from some uses of educational technology. At the same time, intentional efforts that ground the needs of educators, students, and communities across various geographic, political, cultural, and socioeconomic contexts require realigning where and how educational technology assists young people's learning experiences. Rather than assuming that technology will inherently address equity issues in classrooms, we describe here what the goals of an equity-centered approach to educational technology would look like and how aspects of design and instruction can build from this stance.

Missing from many of the studies and approaches to utilizing educational technology is the analysis of *how* devices, tools, and investments in new resources will improve learning in particular contexts. In this sense, our field's "fascination with technology and its ostensibly inherent qualities of relevance, motivation, and engagement for youth almost always preclude any possibility of digging deeper" (Philip & Garcia, 2013, p. 302).

Central to an equity-centered approach to educational technology is a focus on teaching, pedagogy, and sustained relationships within classrooms. Tools—and the possibilities that they may bring—come secondary to the core relationships fostered in classrooms (Cummins, 2009; Vakil, 2018). While we recognize the importance of providing access to technological tools and CAL software to support student learning, educational technologists should also consider a deeper and more profound question regarding the need for these tools. Too often these tools are created to address "gaps" or inequalities between groups, whether it is providing broadband access in materially unprivileged communities and low-cost tablets in the global south or using computer tutorial programs to catch struggling readers in an under-resourced urban school in a colonizing nation. But what are the historical antecedents that nurture and uphold structures of inequality? And more importantly, what can be done to dismantle them?

An equity-centered approach to educational technology means addressing these questions head on. The foundation of critical theory is predicated on the fact that technology, particularly as it relates to the industrial revolution, has resulted in a separation between the laborer and the labor and, as a result, exacerbating the dehumanizing effects of management over the working class (Gitlin & Ingerski, 2018 citing Held, 1980). However, technology is a tool designed by people to accomplish certain tasks, often in a more efficient manner. In fact, though we began this chapter with a narrow definition of educational technology (Davies et al., 2008, p. 233), we build on Pea's (1985) recognition that technologies are meant to reshape "who we are by changing what we do" (p. 168). In this way, technology can be redesigned to address various systems that reproduce social inequalities and hierarchies and even serve the interests of those who are most marginalized (Gitlin, 2017).

Though not comprehensive, we offer three design-based and pedagogical directions for equity-centered educational technology. These are built on the previous discussion of Band-Aid approaches that assume that technology alone can heal the wounds of the lasting harms of colonialism, capitalism, and globalization affecting working class youth globally. In doing so, we explore authentic possibilities for technology to extend the natural capabilities of human interaction and to foster powerful relationships within classrooms.

Expanding the Voices and Epistemological Perspectives Undergirding Educational Technology Like the vast majority of education-related research (Smith, 1999), the knowledge that defines educational technology and its school-based implementation comes from particular, western perspectives (Spring, 1994). In this way, expanding the perspectives of this work requires intentionally *repairing* the harms that Ladson-Billings (2006) has noted contribute to educational debt. Such work requires "suspending damage" (Tuck, 2009) in the orientations of research. This perspective of an equity-centered approach to educational technology must take into account that knowledge—in research contexts, in the lives of students, and in the ways that digital tools are developed—can come from myriad perspectives and ontologies (e.g., Bang, Warren, Rosebery, & Medin, 2012; Smith, 1999). Historical perspectives from such framing can ultimately bring in the identities and values of more diverse communities in their design and in their instructional application. An educational technology that stems from often overlooked indigenous roots (de Alvarez & Dickson-Deane, 2018; Moreno Sandoval, 2013), for example, allows researchers to broadly reimagine the nature and values of the field.

This approach recognizes that technologies are not inherently neutral (Bradshaw, 2017; Subramony, 2017). Each line of code, each digital product, each algorithm, each product feature is authored by someone. As Noble (2018) emphasizes in her ethnography of a search engine, each tool we use has implicit, invisible values based on who creates it. Noble's search results of racist and oversexualized pages when she *googles* "black girls" highlight values that may have dehumanized and can shift at the whims of capitalist and social value. Though we do not argue that simply elevating more diverse bodies into existing corporations is the solution to the pressure points of educational technology, researchers should consider who authors the tools within classrooms and from what perspectives.

This expansive approach is one that *can* heal and restore relational trust and empathy between educators and students and between researchers and communities and seek to shift the norms of design-based approaches to technology in schools (Osguthorpe, Osguthorpe, Jacob, & Davies, 2003). As Vakil et al. (2016) explain, "Making visible this relational work will allow the research community to better understand the sets of skills and competencies required to engage in theoretically rich, ethically sound, and hopefully equitable design research" (p. 196).

Constructing Critical Computational Literacy Another example of this can be found in the conceptual and pedagogical framework of Critical Computational Literacy (CCL). Building on diversification efforts at multiple levels of the technology talent pathway, CCL attempts to address the critical lens required to produce technological tools for disrupting and dismantling structures that uphold inequality while inventing new tools that sustain a more equitable and humanizing world. Critical Computational Literacy is the fusing of critical literacy (Luke, 2012) and computational thinking (Grover & Pea, 2013; Wing, 2006) to create technological tools for transformative social action. Critical literacy advocates have long called for an instructional literacy approach focused on "reading the world and reading the word" (Freire & Macedo, 1987) where one analyzes the macro-sociopolitical messaging undergirding various texts[1] and taking action upon it. Wing (2006) states, "computational thinking (CT) involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (p. 33). More specifically, CT is the thought process required to understand a problem and express "its solutions in such a way that a computer can potentially carry out the solution" (Grover, 2018). In this process, one may be required to analyze and "decompose" problems to manageable pieces; create computational artifacts; remix, transfer, and reformulate prior solutions; develop algorithms; and collaborate with experts in different disciplines while utilizing a variety of typical computer science concepts like logic, patterns, abstraction, generalization, automation, and iteration (Grover, 2018; Wing, 2006, 2008).

Blending critical literacy and computational thinking toward a production-centered learning environment is a fluid and iterative process that requires the use and knowledge of highly sophisticated digital tools and a contemporary and historical consciousness around sociopolitical systems, including white supremacy, patriarchy, heteronormativity, and capitalism and its impact on society. YR Media, formerly known as Youth Radio, is a youth-driven, multimedia production organization centered in Oakland, California, that epitomizes CCL in several of their publicly disseminated interactives (Lee & Soep, 2016). West Side Stories, an interactive, multimodal map (see Fig. 1), highlights the impact of gentrification in the community of West Oakland (http://youthradio.github.io/). It demonstrates what happens when youth are offered space and tools to cocreate, cosign, and coproduce within a "pedagogy of collegiality" with adult staff (Chávez & Soep, 2005) on an issue that is dramatically impacting the social, economic, and material realities of their neighborhood. They utilized Mapbox, a "mapping platform for developers," to accomplish their goals of highlighting the rich history and culture of this traditionally Black community through digital drawings, video, and audio for transmedia storytelling (Lee & Soep, 2016).

YR Media has continued to demonstrate how CCL can be employed through design in #LR9Live (https://yri.youthradio.org/littlerock9/), "a live tweet-style reenactment of the 60th anniversary of desegregation" of the previously all-White Central High School in Little Rock, Arkansas (Lee & Soep, 2018). Know Your Queer Rights, a mobile app, allows users to learn about historic LBGTQ+ leaders,

[1] Texts refer to the multiple types of artifacts information is communicated and delivered in the twenty-first century. It may include multimodal texts that incorporate the use of images, video, audio, animation, and semiotics disseminated in digital and socially networked interactive spaces.

Fig. 1 Screenshot of West Side Stories: Gentrification in West Oakland interactive map

laws that protect their community, the reporting of discriminatory acts, and message contacts when they are in trouble (Soep, Lee, Van Wart, & Parikh, 2020).

Most would agree that the digital tools used to create these projects (Mapbox, Twitter, Photoshop) were not necessarily created within the framework of traditional "educational technology" tools in mind, but they were clearly used to "help students accomplish specified learning goals." The learning goals in these instances happen to be relevant to taking social action against inequalities in their lives, whether it is about giving a platform for dispossessed peoples or accurately representing the hues of Black people in the media or providing LBGTQ+ youth a space to learn, report, and connect with others. These projects demonstrate that youth themselves investigated the roots of the problems, and through their critical conscious lens, they create solutions that utilized technology for the very same populations that are impacted.

Reaching a New Civic Imagination Finally, we want to recognize that a fundamental purpose of schooling is one of preparing youth for success in interacting within and transforming society beyond the walls of their schools. In this sense, schooling is an act of civic education, and the digital tools that we develop within educational contexts provide implicit and explicit lessons for how youth are to learn, interact, and participate in civic life (de los Ríos, 2018; Mirra, 2018). From punishing students for using mobile devices during class time (Garcia, 2017) to filtering the websites and content they may view to installing keylogging and surveillance software of their netbooks, implicit lessons of docility and control are often part and parcel of contemporary educational technology deployment. From this perspective, we imagine several other dimensions for sparking powerful civic imagination vis-a-vis educational technology.

Cohen, Kahne, Bowyer, Middaugh, and Rogowski (2012) have described "participatory politics" as a kind of civic practice built on the affordances of digital and participatory culture. In it, young people can engage in "interactive, peer-based acts through which individuals and groups seek to exert both voice and influence on issues of public concern" (p. vi). Such activities are reflective of broader frameworks of "connected learning" (Ito et al., 2013) in which young people collaborate, distribute expertise, and engage in interest-driven and production-centered activities. At the heart of these civic activities are the relationships that are fostered between participants; the tools that facilitate and sustain these relationships come secondary to the foundational role of mentorship, learning, and youth interests (Ito et al., 2015). These largely extracurricular contexts of civic learning and participation exemplify the possibilities of educational technology to augment new kinds of civic practices in classrooms.

Designers, researchers, and educators must consider how the lives of young people are shaped civically by the tools introduced in classrooms—both implicitly and explicitly. An equity-centered approach to educational technology grounds the orientations of tools and the assumptions built into their uses. These include both the proximal uses of technology—such as the moment-by-moment instructional possibilities they possess—as well as the distal uses of technology—such as the long-term shifting of civic identity (Philip & Garcia, 2015).

Conclusion

Throughout this chapter, we have highlighted the generational attempts to "fix" global achievement gaps through well-meaning applications and research of educational technology. Though we note several successes with this approach, we are mindful of two key flaws with this premise. First, the assumption of an achievement gap undermines work toward addressing the historical role that racism, oppression, colonialism, and violence have played in disenfranchising large portions of the global population. Secondly, educational technology that is not developed *alongside* and *in* the interests of historically marginalized communities cannot substantively repair the damage done by dominant educational systems. In light of these flaws, this chapter highlights the necessity to shift from educational technology that is at the center of instructional design to tools that support the relationships in classrooms and the possibilities of individual agency.

Educational technology must be of secondary concern to the people and relationships within classrooms. Our articulation of *some* tenets of equity-centered approaches to educational technology is by no means definitive. Instead, we seek to ground some considerations that individuals must make when considering how their tools will be taken up and for what purposes. Ultimately, we see a need for the field to revisit the initial purpose and meaning of educational technology today. Considering the diverse voices, hopes, dreams, and fears of students in global classrooms today, how do tools supplement the startling power of collective action and solidarity?

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Cultural Implications in Educational Technology: A Survey

Patricia A. Young and Tutaleni I. Asino

Internationally research about culture and educational technology is on the rise. Scholars are researching topics such as web-based learning, digital literacy, technology use, social networks, games, mobile technologies, Web 2.0, MOOCs, and their relations to culture or cultural contexts. The research supports that there is a need to better understand how instructional designers, educators, and innovators perceive culture in relation to the expanding field of educational technology.

There is a broad spectrum of how culture is defined across disciplines. One often cited definition of culture is from UNESCO (2001) which defines culture as *that complex whole which includes knowledge, beliefs, arts, morals, laws, customs, and any other capabilities and habits acquired by [a human] as a member of society*. As can be seen from this definition, culture is very broad and is composed of everything that makes one human and everything that humans make. In educational technology research, conceptualizations of culture are often segmented into subcultures (school culture or organizational culture) and referenced with terms such as cultural conflict and culturally relevant as ways to operationalize the definition of culture within that specific context. Put differently, while we are engaged in research on how culture is influenced by or influences technology, there is currently no agreed upon definition of what culture is in the field of educational technology. However, the importance of culture is embedded in definitions of educational technology. According to the Association for Educational Communications and Technology (AECT),

P. A. Young (✉)
Department of Education, University of Maryland Baltimore County, Baltimore, MD, USA
e-mail: pyoung@umbc.edu

T. I. Asino
School of Educational Studies, Educational Technology, College of Education, Health and Aviation, Oklahoma State University, Stillwater, OK, USA
e-mail: tutaleni.asino@okstate.edu; http://edtech.okstate.edu

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"Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources" (AECT Definition and Terminology Committee, 2008, p. 1). Spector (2015) adds that "Educational technology involves the disciplined application of knowledge for the purpose of improving learning, instruction and/or performance" (p. 10). In examining these definitions of educational technology, we argue that it is implicitly crucial to recognize the importance of culture when engaging research in our field. This is important because it is impossible to improve learning, instruction, or performance if one does not take into account the culture in which learning is embedded or the culture of individuals or groups who use the technology.

Cultural implications in educational technology begin with understanding culture as everything that makes one human and that humans make by engaging with information and communication technologies to learn, use, interact, produce, consume, understand, invent, communicate, socialize, discover, innovate and perform.

Having conceptualized the above definition, we explore the topic through the following two research questions:

- What does the research reveal about culture and educational technology?
- How is culture integral to research in the field of educational technology?

Our goal in this chapter was to conduct a review of the literature that explores how culture is being used and defined (whether explicitly or implicitly) in research on educational technology. Given the several thousand articles in current journals of educational technology, we focused our review on a sample of articles across journals in distance education, distance learning, computer science, and educational technology published between 2011 and 2017. Using EBSCOHost Academic Search Premier, we gathered educational technology articles and reviewed them to determine if culture was a central tenant. The articles that contained some focus on culture and educational technology covered the following topics: web-based learning, digital literacy, technology use, social networks, games, mobile, Web 2.0 and MOOCs. Explanations and integrations of culture, in most of the reviewed articles, did not make culture an explicit aspect of the research. The appearance or mention of culture was only incidental, and when applied, it was not about the culture of the people but often focused on a subculture. A discussion of each topic follows this section.

Web-Based Learning

Instruction is digital. Web-based learning, or learning that is facilitated through the Internet, is exploding in formal and informal learning contexts. This section examined the web-based literature and found that it focused on several areas: e-learning, online learning, distance learning, and cultural considerations (i.e., cultural contexts, Confucian heritage culture, and language and culture).

E-learning

E-learning has been characterized as learning through web-based systems and associated with online training videos, learning management systems, and online courses. The intersections of culture and e-learning, as reported by various research, focused on two strands: 1) the inclusion of culture in designing e-learning systems and 2) resistance to technological changes. The research indicates that the culture of the learner affects their learning performance (Aparicio, Bacao, & Oliveira, 2016). This means that in designing e-learning platforms, these platforms should make cultural considerations for use in international contexts (De Freitas & Bandeira-de-Mello, 2012; Lee, 2010). For example, in the development of e-learning courses, focused on improving airline customer service, there was limited integration of the cultural and language differences in an international flight crew. The airlines designed a culture-neutral e-learning environment based on westernized perspectives. The e-learning platform "served solely as a content repository based on the airlines cultural values. The airline did not emphasize core pedagogical values or recognize the learners' needs during the analysis and design phases of instruction" (de Brito Neto, Smith, & Pedersen, 2014, p. 1067). In this case, the elearning course on airline customer service could have been more effective if it integrated the culture and language of the international flight crew. The inclusion of this culture-specific content might enable better comprehensible input (Krashen, 1985) and improved learner performance.

The second issue of concern is resistance to e-learning technology that lies with both the users (faculty and students) and administrators at institutions of higher education. De Freitas and Bandeira-de-Mello (2012) found resistance by students and faculty against the implementation of a new e-learning technology in Brazilian business schools to be a cultural conflict, because this resistance was not consistent with administrative needs to improve teaching practices. The problems found in Macfadyen & Dawson's (2012) study of the adoption of technological innovations addressed the failure of the institutional culture within higher education, to acknowledge the degree of pushback by individuals and to understand how to motivate social and cultural change throughout the institution. Specifically, in this study, technological innovations were stifled by a culture of resistance and administrator's inability to foster cultural change. This suggests that adopting e-learning will and can meet with much resistance by faculty. Further administrators need to be able to integrate these changes into the structure of the university and prepare faculty for what's to come.

The culture of the target audience who use any e-learning tool should be considered when designing the product. Otherwise, e-learning remains generic, culture-neutral (Young, 2009) and misses the target learner.

Online Learning

The research characterized as online learning focused on learning that is computer supported, computer mediated, collaborative, interactive, distributive, and self-regulated. Culturally appropriate instruction and learning culture emerged as two themes maybe due to their frequency in educational research. Culturally appropriate instruction in online learning and a learning culture. Research about culturally appropriate and culturally sensitive instruction centered on instructors need to develop cultural competency and diverse perspectives in their teaching. Instructors, as suggested by the research, should design instruction that is culturally appropriate to diverse student backgrounds, thereby acknowledging the differences in perspectives from international students. This might better align with the learner's preferences (Alalshaikh, 2015; Cronjé, 2016; Gómez-Rey, Barbera, & Fernandez-Navarro, 2016; Rawls & Hammons, 2016). Similarly, Gómez-Rey, Barbera, and Fernandez-Navarro (2016) identified important stages of the online experiences (e.g., pre-enrollment, in-class, and course completion) as perceived by culturally diverse students (i.e., American, Chinese, Mexican, and Spanish). They agreed that instructors should deliver culturally adaptive instruction that provides flexible activities. The reason for these cultural considerations, according to Barbera and Linder-VanBerschot (2011), is that students from different cultural backgrounds perceive the online experience differently but still satisfactorily. Further, there needs to be "specific cultural adaptations" in the design of online learning to accommodate for these differences (Barbera & Linder-VanBerschot, 2011, p. 176). This indicates that online learning should be culturally appropriate, culturally sensitive and aligned with learner's preferences; this type of learning environment should yield more satisfaction to an online learning experience. It is ultimately up to the instructor to make these culture-based online interactions happen.

Distance Learning

Learning that is synchronous, asynchronous and enabled through web-based software or videoconferencing manifested as distance learning in the research. Further, distance learning presupposes some type of learning culture that is web-based, organized, and criteria-based. Learning cultures evolve from student's engagement with the technological environment and human interactions. Chen, Wang, Kinshuk, and Chen (2014) focused on 'learning cultures' in higher education as identified by one of the four pillars of the FLIP (flexible environment, learning culture, intentional content, and professional educator) schema. In a classroom model of a learning culture, class time was student centered and focused on a flexible learning environment, self-paced versus teacher-directed instruction, and an enriched learning experience. Xie, Miller, and Allison (2013) examined the culture of learning communities in online classes maintaining that these communities have common characteristics such as online etiquette, rules, and disinhibition. Social conflict affected the class culture causing cultural clashes (Kitade, 2012). However, online environments fostered a culture of niceness. This meant that instructors should, thereby, engender a positive culture within these online learning environments (Xie, Miller, & Allison, 2013). Stewart, Harlow, and DeBacco (2011) saw the classroom as a culture of its own whether local, distance, or blended. Looking at the culture of learning from a Chinese context, Zhao, Chen, and Panda (2014) advocated for the use of distance learning "vis a vis the traditional culture of learning in China" (p. 943). Zhao, Chen, and Panda's (2014) findings suggested that males have "higher self-regulated learning" abilities than females (p. 955). Specifically during an online course that required self-regulated learning, females lacked the "capabilities" to self-monitor or self-evaluate and lagged in terms of learning content and using learning resources. This study concluded that this gender difference was consistent with prior research studies and the culture of learning in China. Similarly, Jung, Kudo, and Choi (2012) found that within the context of a Japanese study, instructional design should reflect the "Japanese way of learning" (p. 1026). The Japanese way of learning was supported in this research by Japan's students who preferred structured learning objectives and prepared outcomes in an online collaborative learning environment (p. 1026). This research indicates that distance learning creates a learning culture that is highly sytlized by cultures, regions and international contexts. Distance learning is place specific and involves situated learning experiences mediated by human interaction (Lave, 1991). The cultural nuances of people, places and things become actualized in these situated spaces like they would in borderless spaces or the real world. For example, if a society has gender or race specific matters, these matters replicate themselves in a distance learning environment. For better or worse, learning can be altered based on culture-based situations.

Cultural Considerations

There are many ways in which cultural considerations manifest within web-based research (i.e., cultural contexts, Confucian heritage culture, and language and culture). The use of the term cultural context has been broadly conceived. Cultural contexts have helped researchers to define the location or place in which individuals live such as Spain or Ireland (De Morentin, Cortes, & Medrano Apodaca, 2014). Pseudoscientific beliefs, such as fortune telling, astrology, or alternative therapy, seem dependent on culture and cultural contexts (Tsai, Lin, Shih, & Wu, 2015). For example, Tsai, Lin, Shih, and Wu (2015) proposed that an online argumentation system for instruction can lower pseudoscientific beliefs and further that these beliefs are culturally situated. Cultural contexts have also been conceptualized as sociocultural when the tool of technology (discussion boards, wiki) is seen as integral to the expectations and norms of the "context in which it is used" (p. 118). In these examples, cultural contexts are specific to geography, psychology and sociocultural ideologies; this may mean that cultural contexts serve interdisciplinary roles to explain and define cultures.

Research has found that Asian countries (China, Vietnam, Singapore, Korea, and Japan) who abide by the Confucian heritage culture share the characteristics of collectivist cultures such as belonging to the group, in-group cohesion and approval, and valuing harmony (Chen, Chou, & Cowan, 2014; Xu, Du, & Fan, 2014). These characteristics may influence student's emotional behaviors (e.g., feedback) in online environments (Xu, Du, & Fan, 2014). Jung, Kudo, and Choi (2012) also document that the collaborative process in an online environment can be stressful for Japanese students; in particular, Japanese students may fear a loss of face by team member relationships and the opinion of others. Similarly, Zhu (2012) found significant cultural differences between Chinese students from a Confucian heritage and Flemish student's satisfaction with their online performance, learning environment, and construction of knowledge in group discussions. For example, the Chinese students indicated a greater satisfaction with the collaborative aspects of online learning. The Flemish students expressed greater satisfaction with the results of the online group work. Overall, the findings reveal that the culture of the individual influences how they perceive interactions in an online environment.

Some research explored the connections between language and culture positing that language and culture are inseparable. Therefore, "Culture can be taught as an internal part of language in technology-enhanced intercultural interactions" (Chen & Yang, 2014, p. 264). Chen and Yang (2014) investigated student's language development and intercultural communicative competence (including knowledge, attitudes, intercultural awareness, and skills) with Taiwanese seventh graders and participants from five different countries (Canada, Ghana, Lebanon, the Netherlands, and Taiwan). Through the United Beyond Our Diversity project, students engaged in online exchanges through wikis and Moodle. Participants examined their biases and stereotypes and further developed their language and cross-cultural awareness (Chen & Yang, 2014). This research suggests that students who learn a foreign language online benefit from this experience because it offers authentic examples of language use and cultural experiences (Angelova & Zhao, 2016; Cho, 2016). However contrary to these studies, Wu, Yen, and Marek's (2011) study of Taiwanese students learning English as a Foreign Language in an online setting found more value in learning English through face-to-face interactions with American native language speakers. This may indicate that online environments have the potential to aide in acquiring a foreign language but many more cultural nuances (perspectives, biases) need to be attended to as part of this learning experience.

Web-based learning must advance beyond its present generic walls to a culture-based–eclectic medium that is inclusive of others. The research indicates that e-learning, online learning and distance learning are merging to the point of bluring the lines of them as distinct fields. This means that all online learning will be just web-based learning. Web-based learning within cultural contexts means that learning is more human centered. However, web-based learning is challenged by the resistance of individuals, institutions, and traditions. To move forward, other research has found the benefits of establishing learning cultures and the value of language acquisition in technological contexts. Much more work is needed to provide a truly inclusive web-based learning experience.

Digital Literacy

Digital literacy remains broadly defined as the knowledge acquired through the use of information and communication technologies. In this review of digital literacy, three strands were found to be prevalent: cultural capital, designs for learning, and cross-cultural learning.

A link can be made between the work of capital as articulated by Bourdieu (1986) and digital literacy. In their work, Hatlevik and Christophersen (2013) argued that a Norwegian student's cultural capital is a high predictor of digital competence. They defined cultural capital according to Pierre Bourdieu's interpretation to mean the location of a person within the social space. Digital competence included the skills, attitudes, and knowledge that enable learners to use, participate, and work with digital media. In this case, the study proposed that students who have a large number of books at home had more cultural capital than those who did not (Hatlevik & Christophersen, 2013). Literacy is capital for learners; digital literacy may prove to be more valuable.

Cultural contexts also focused on research related to designs for learning. Designs for learning, as described by Kress and Selander (2012), proposed that teachers have become designers through their planning processes and assessment practices, and students have become designers by taking responsibility for their own learning. This research argued that new conceptualizations of learning are a result of these new virtual spaces, blended media, and communicative patterns. These new signs of learning can be called "cultures of recognition" because learning must now be understood in these e-learning contexts (Kress & Selander, 2012, p. 266). Through media, students learn cultural competencies and social skills (Wasson & Vold, 2012). Wasson and Vold (2012) advocate for a "participatory culture of learning" that requires students to be active versus passive participants in acquiring intellectual and artistic content (p. 255). Students engage in peer assessment while in this participatory culture of learning (Wasson & Vold, 2012). Cultures of recognition are created by new digital spaces (virtual, blended, etc.) and a participatory culture of learning requires active participation of learners. These iterations of culture in the classroom are designs for learning that teach kids multiple skills and abilities (social, cultural, assessment, intellectual and artistic). Culture in these examples are more specific to space and place and the manifestation of literacy through these means.

Shadiev and Huang (2016) designed a set of cross-cultural learning activities supported by a computer-aided translation and speech-to-text recognition system with the goal of determining the effectiveness of these systems in cross-cultural learning. This research sought to enable bicultural information and interaction exchange between ten high school students (six Chinese native speakers from Taiwan and four Russian native speakers from Uzbekistan) who did not share a common language. The findings revealed the potential of these systems to help students communicate independently and provide an authentic context for cross-cultural learning. Cross-cultural learning considers the culture of participants in a learning space and tries to provide a common way to communicate and learn.

This research demonstrates that digital literacy holds the same high level of importance as any other form of literacy. As new technologies permeate this society, we must be responsive in providing learners with the tools they need to become competent users and learners. Part of this process will be enabling learners to understand what they know through their own cultural capital, encouraging learners to be designers of their own learning, preparing teachers to design instruction for diverse learners, preparing learners to adapt to the changing face of technology, and building technologies that consider cross-cultural learning and instruction.

Technology Use

How technology is used across cultures reflects the desires, goals and beliefs of the people using these technologies. Technology use varies from culture to culture and can be articulated as theory, practice, or a societal factor that enhances or impacts people. The research strands most prevalent, in terms of technology use, discussed school culture, cultural models, Confucian heritage culture, and the language of culture.

The organizational culture of educational institutions is referred to as a school culture. A school culture might include the mission, vision, plans, values, or norms shared by school members (Tezci, 2011). School culture can also influence teacher's buy-in to technology integration (Koh, Chai, & Tay, 2014; Perrotta & Evans, 2013; Tezci, 2011). In Blau and Presser's (2013) study, the school culture was changed dramatically by the implementation of a school management system to engage in e-leadership by secondary school principals in Israel. Specifically, principals were able to make decisions based on data; monitoring students and teacher performance; assigning staff tasks via the school management systems; and interacting with parents, teachers, and students. This tool dramatically changed school culture. Every school creates its own school culture. School cultures, in turn, enable or disable people who participate within its doors.

Cultural models, as defined by the research, provide a foundation to broadly interpret technology use in many contexts. Russell, Kinuthia, Lokey-Vega, Tsang-Kosma, and Madathany (2013) argued that culture is an important construct in the field of instructional design and technology and that comprehensive descriptive models, like Young's Culture-Based Model, served as a "lens for exploring cultural dynamics" (Russell et al., 2013, p. 707). Lotz, Law, and Nguyen-Ngoc (2014), similarly, offered a process model to examine learning design patterns within an international scope. In this model, the relationship between artifacts, behaviors, and values revealed a pattern for designers to develop internationalized learning designs; thereby culture is very relevant to design. The educational technology acceptance (ETA) model, adapted from the unified theory of acceptance and use of technology (UTAUT), allowed for correlational verification between the acceptance and the culture. For Nistor, Göğüş, and Lerche, the combination of ETA and culture resulted in significant relationships (Nistor, Göğüş, & Lerche, 2013). These cultural models demonstrate that models can be used as evaluative tools to more accurately define cultures and explain educational technologies.

Culture is rooted in the beliefs and values of societies, and these cultural factors influence a culture's technology adoption (Fong et al., 2014; Iriti, Bickel, Schunn, & Stein, 2016). In a Confucian heritage culture, Fong et al. (2014) concluded that support by Hong Kong and Taiwan teachers was critical to the adoption of digital teaching portfolios. Similarly, Yuen, Park, Chen, and Cheng (2017) found that digital inequity was rooted in its cultural context. Yuen et al. (2017) discovered that the values held by communities who practice Confucian heritage culture may interfere with parents' willingness to adopt, access, and use information and communications technologies (ICTs) as it relates to their children. This practice can create digital inequities for students. Basically, this means that the cultural backgrounds of individuals or groups may inhibit them from accessing new technologies, thereby creating digital inequities. The implications of this could be grave as these groups will be left behind in the technological revolution.

Indigenous communities are losing their elder speakers and thereby their native language. Technology provides a way to expose learners to the language in many domains and contexts (e.g., conferencing, social networks, virtual environments). Indigenous language revitalization has been confronted with many issues that prevent technology and learner connections such as accessibility to computers, economic factors (human resources, finances), environmental conditions (weather, water, electricity) and technological resources (computer equipment, infrastructure, software, support, and training) (Galla, 2016). In the research of Galla (2016), indigenous communities became bound by their cultural challenges to use technology to retain the life blood of their communities—language. Certain technologies may serve as a container or time-capsule for human existence. Indigenous communities are primed to work quickly to capture all that may be lost through cultural change.

Research on technology use is very broad and could well be classified in other sections of this chapter. However, most of this research sought to provide examples of how technology has been used in school cultures (places and spaces), through cultural models (theory), as a blockade to cultural adoption of technology (practice) and through language loss (impact on people). This research indicates that technology use by groups and people varies based on the cultural context and that a symbotic relationship exists between to culture, cultures and the technologies used. This means that people can be defined by how, when and where they use exisiting technologies. As people use technology, they are also making a place and space for its history.

Social Networks

Research on social networks and culture reveals an acknowledgment that cultural shifts are impacted by technologies and that learning is mediated by sociocultural contexts and affordances of new technologies (Turvey, 2012). The research coalesces around language learning, teacher practice, cross-cultural interactions, and participatory culture.

One area where culture and social network research intersect is in supporting language learning cross-culturally. Language and culture are intimately related. Social networking sites can be used to connect learners studying a language to learners in the culture where the language originates. This connection provides language learners opportunities to improve their language skills (Aydin, 2012). As an example, Yen, Hou, and Chang (2015) integrated Facebook and Skype into their English as a Foreign Language Class. The three-phase integration process consisted of an initial classroom lecture, Facebook discussion in subgroups, and Skype negotiations with opposing groups. An analysis supports that Facebook is effective in increasing writing and speaking skills because it gives learners opportunities to improve their speaking and writing skills through peer-to-peer and self-correction behaviors on the platform. The study is representative of research illustrating that social media sites like Facebook can be beneficial language learning environments.

Research on social networks and culture also reveals challenges to acceptance in the existing culture of teacher practice. Manca and Ranieri (2016), in their study of Italian academics, argue that challenges facing social networks as teaching and learning tools include cultural resistance which stems from social factors such as the perceived erosion of teachers' traditional roles, concerns of how to manage relationships with students when engaging on social media, and issues concerning privacy. This culture of resistance was presented itself in contrast to a recognition that social networks can also be a tool for integrating culture in teaching practices. Chuang (2016) argued that social media can facilitate online group collaboration as well as present opportunities and challenges for culturally responsive teaching (CRT). For pre-service teachers who will go out into an increasingly multicultural educational environment, social network environments provide an opportunity to practice incorporating multicultural information, resources, and materials in their practice. Melo-Pfeifer (2015) highlighted how blogs can be used for language teaching by helping learners develop plurilingual and intercultural competences. A blog can be used for pedagogical purposes to promote interaction of language and culture by enabling interactions between users, authors, and the community at large. However, regardless of the advantages and opportunities, the benefits will not be realized if there is resistance to incorporating culture into teaching.

Social network sites provide an opportunity to study and understand cross-cultural interactions which are occurring with more frequency at educational institutions. Cook and Pachler (2012) found that social technologies provide users opportunities to communicate, interact, share, and make meaning. However, the technologies also provided space for conversations about how the affordance of the technological innovations (e.g., ability to tag digital resources such as images) differs cross-culturally (i.e., the distinction between what is acceptable to be posted and tagged from culture to culture). While social networks can increase cross-cultural collaborative interactions, Stepanyan, Mather, and Dalrymple (2014) cautioned that an emerging pattern is that participants from the same culture were more likely to interact with each other than interact with those of a different culture. In other words, more effort should be made to provide students cross-cultural collaborative opportunities globally and not only with cultures that are similar.

Social networks are also seen in the literature as promoting a participatory culture. Research by Song, Williams, Pruitt, and Schallert (2017) demonstrated that social network sites such as Pinterest create a participatory culture, "characterized by distributed cognition, accessibility for creation and participation, and informal learning and support, creating democratic ways of collaborating among participants to share and celebrate multiplicity and heterogeneity of ideas as individuals execute their knowledge and expertise in creative ways" (p. 34). Beyond sharing, social networks can also be seen as a form of participatory technology that impacts scholarship practice. According to Veletsianos and Kimmons (2012), social networks provided for a new form of scholarship, referred to as Networked Participatory

Scholarship, that allows scholars of different cultures to "share, reflect upon, critique, improve, validate, and otherwise develop their scholarship" (p. 768). However, perceptions around the issues of participatory cultures can differ by subject. Issues which inhibit teachers from adopting more participatory approaches were more prevalent in applied sciences than in social sciences and more influential in the social sciences than in mathematics, computer science, and natural sciences (Manca & Ranieri, 2016). This research indicates that the benefits to participatory culture vary depending on the domain of scholarship.

While causality between social network technology and culture is difficult to prove, the research indicates that both are undeniably intertwined in a complicated fashion (Veletsianos & Kimmons, 2012). Social networks and their use in the larger culture are influenced by various subcultures such as university culture, scholarship culture, and the culture of acquiring or valuing knowledge. The research in this area suggests that the focus should not be placed solely on how technologies such as social networks influence or transform the culture of education or educational scholarship, but an emphasis should also be placed on examining what emerging tools (Facebook, Twitter, etc.) reveal about scholars producing the research (Veletsianos & Kimmons, 2012). While it is important to examine the interplay between social media and culture, it is also significant to examine the connection between social media, the subculture, and the larger culture.

Games

Incorporating game-based approaches in learning is a common practice across many domains. Over the last two decades, digital games have become an increasingly popular subject to study in education (Dickey, 2011). The literature reviewed supports an emergence of three strands as they relate to culture: (1) accessibility, (2) theoretical perspectives, and (3) engagement across cultures.

At the intersection of culture and games in education is a recognition that games are an integral part of the human social and cultural environment that attracts people's interest and attention and allows participants access to inaccessible worlds (Kordaki & Gousiou, 2016). Often cultural spaces can be inaccessible especially to people with a wide range of disabilities (Brown et al., 2011). In other words, it can be difficult for someone with a physical disability to travel to many of the popular cultural attractions around the world. When designed and used well, digital educational games are able to promote, support, and engage especially those with learning disabilities (Ke & Abras, 2013) by providing an environment to gain confidence and independence to travel virtually to different cultures. This affordance can be beneficial if designers ensure that the metaphors used in games are appropriate for the targeted groups and the language used especially when translated is appropriate and without mistakes (Brown et al., 2011). What is significant and different about the research with regard to games and culture is the use of the term accessibility. Often the term is used as a reference to making tools usable to people with different abilities; however, the reviewed research adds a different dimension, that of accessibility in terms of transporting individuals virtually to experience different cultures.

Two theoretical perspectives standout in the research on games and culture: cultural-historical activity theory (CHAT) and sociocultural perspective. One theory that is examined with regard to games in education is CHAT. Lazarou (2011) argued that for more than a decade, there has been a debate on whether CHAT could be an appropriate theoretical framework for the design of computer tools such as games. Lazarou (2011) produced a scenario-based educational game focused on “the teaching and learning of ‘Expansion and Contraction of Air’ in primary science, a subject that existing research suggests is conceptually difficult for students” (p. 424). The design team used CHAT “as a methodological and analytical tool to guide the design of a new computer tool and its accompanying pedagogy” (p. 437) and found that the use of CHAT was essential to producing a computer game that was not only usable but also useful. Sociocultural perspectives appear to be prevalent in the research on games as they relate to culture. Research with a sociocultural perspective reveals constructs that play a central role to learning especially in the domain of second language acquisition (Peterson, 2016). Hämäläinen and Oksanen (2012) set out to study knowledge construction through 3D learning games from a sociocultural perspective. The sociocultural perspective recognizes that collaboration, learning, and shared knowledge constructions emerge from a social context. Sociocultural perspectives are important when looking at research on games because the very nature of games is such that regardless of what computer game is being played, learners, especially children, will transform it to suit their purpose. This purpose forms children’s culture where they construct their own forms of play, expression, and understanding (Vangsnes, Økland, & Krumsvik, 2012). In their work with preschool teachers in Norway, Vangsnes, Økland, and Krumsvik (2012) found that being unaware of the sociocultural perspectives manifested in children’s cultures leads to difficulty by teachers in realizing didactical implications on how games impact student’s learning process. Beserra, Nussbaum, Zeni, Rodriguez, and Wurman (2014) concur that culture is a factor that influences learning and student interest when interacting with game-based activities. The involvement in a digital game is greater for the student when the narrative of the game is closer to the sociocultural context of the learner (Beserra et al., 2014).

A third research strand emerging around games and culture is the suitability of digital games to engage learners across multiple cultures. Clark, Nelson, Chang, Martinez-Garza, Slack, and D’Angelo (2011) investigated the potential of a digital game to support student exploration of core science concepts in Taiwan and the United States. The researchers argued that the high level of motivation seen by students when playing the games supports the notion that games can engage a large spectrum of learners from multiple cultural backgrounds. Digital games such as massively multiplayer online role-playing game (MMORPG) present opportunities for addressing culturally bound stereotypes such as those of males as dominant leaders and females as obedient followers (Jang & Ryu, 2011). MMORPGs provide a space for acquiring leadership in digital spaces which can be transferred to the real world. In their study with Briton and Spaniard participants, Guillén-Nieto and

Aleson-Carbonell (2012) demonstrated how a game can teach intercultural communication and positively impact intercultural communicative competence. Games in education provide interactive relationships with local sites and heritage (Chen, Shih, & Ma, 2014). They facilitate experiential contact with digital representations of cultural content, objects, or places, enabling acquisition of procedural knowledge relative to the cultural domain such as the possibility to understand roles in past societies as that of an athlete in ancient Olympic games through a walk-through game of ancient Olympia (Malegiannaki & Daradoumis, 2017). The benefits of interactive relationships through games are also fraught with challenges because game-based approaches that fully integrate culture in training and learning are still scarce. Malegiannaki and Daradoumis' (2017) research analyzed 34 digital games that allow learners to have physical or virtual interaction with a cultural place and its objects. The authors argued that some of what exists instead serve as games for cultural tourism, giving a cursory view of cultural elements.

The research on the intersection of culture and games in education acknowledges culture as an integral part of the learning process. While there is valuing of the capability of games as an educational technology, there is also a realization that to truly harness the power, more research is needed in how to move games from the research arena into everyday formal educational experiences (Ketelhut & Schifter, 2011). Such research is important considering that games and gameplay have their own culture. Just like the broader culture, game culture is also made up of rules where violating them can upset the system (Dickey, 2011). In other words, while there is a robust body of research on the benefits from the use of games in education, it is also necessary to increase the research on the subcultures (i.e., school culture and organization culture) and their role in the adoption process and utility of games for learning.

Mobile

Mobile technologies are part of global everyday life. The focus of mobile technologies in relation to culture can be divided into three research strands: (1) providing organizational culture support, (2) authentic learning and assessment, and (3) supportive technologies for L2 learners. The first strand views mobile devices as able to provide an organizational culture of support. Lea and Callaghan (2011) reported on the process of developing and delivering m-learning to placement students in the healthcare industry who often feel isolated when in service. The researchers argued that the success of m-learning initiatives for students in placements was contingent upon understanding the overall context of where the initiative would take place, and such contexts include departmental and university culture. In their study of workday practices of school heads and principals in Chilean schools, López, Ahumada, Galdames, and Madrid (2012) refer to culture in the sense of how mobile devices can help in developing a culture of learning and support school leaders with issues that emerge from everyday school culture.

The second strand of research focuses on the utility of mobile devices as essential to authentic learning and assessment, enabling students to learn in situ about local cultures and ecosystems (Huang, Liao, Huang, & Chen, 2014; Santos, Cook, & Hernández-Leo, 2015). Hwang and Chang (2011) combined the formative assessment-based mobile learning (FAML) approach using mobile devices as the technology and the Chin-An temple in southern Taiwan as a learning environment to bring local culture and the ancient customs of Taiwan to learners. The utility of mobile devices in Hwang and Chang's is an example of how mobile devices can be used to evaluate cultural experiences in context. Similarly, Chu (2014) used mobile devices in an 18-week course that introduced learners to the indigenous languages, culture, and history of Taiwan where it was found that students who learned in the physical world with mobile devices experienced a higher cognitive load which then led to a negative effect on their learning achievements. The above case illustrates works designed to bring learners closer to the local culture and recognition that learning is embedded in cultural contexts that give rise to the need to use mobile devices (Chan, Walker, & Gleaves, 2015).

The third strand is using mobile devices as a supportive technology for second language learners (L2). Mobile devices enable seamless support in language learning from the classroom to executing language-related tasks outside of the classroom (Lan & Lin, 2016). This support is indispensable especially for learners in immersive language learning experiences (Ma, 2017) and can take various forms such as providing mobile-assisted oral feedback for learners through voice-messaging functions of texting apps such as WeChat (Xu & Peng, 2017). However, while the research supports the use of mobile devices to support L2 learners in different cultural contexts, it is also important to emphasize that mobile-assisted language learning (MALL) is not perceived equally cross-culturally. Viberg and Grönlund (2013) used Hofstede classifications of cultures to investigate whether cultural factors affected university student attitudes toward the use of mobile technologies in second and foreign language learning in Sweden and China. The researchers concluded that in their study, "the hypothesis that cultural differences impact the perceptions of, and attitudes toward, mobile technology for language learning among students must be rejected," (p. 178) because no significant evidence could be found to support it. Rather gender had a slightly more impact on attitude toward mobile devices for learning than the cultural environment of participants. Hsu (2013), alternatively, illustrated that a student's culture does influence their perception of whether the mobile device should be an educational tool. Overall, the research on MALL is significantly tilted toward the technological development rather than learners (Hsu, 2013).

Web 2.0

The term Web 2.0 in the research is used to reference the evolution of the web from its early days when only a few could contribute to the current state where technologies allow for greater contribution, collaboration, and interaction. The availability and ease of use of Web 2.0 tools enable contributions from users from around the world, including communities that are often ignored (Huang, Chen, & Mo, 2015) and further cementing the impact of the Internet cross-culturally. The research around this topic can be characterized as both explanatory and exploratory. From an explanatory perspective, the research is focused on explaining that technology should be understood to be embedded in the cultural values of people (Pereira, Baranauskas, & da Silva, 2013). From an exploratory vantage point, it is an interest in comparative studies that explore the effect of Web 2.0 applications cross-culturally (Bohemia & Ghassan, 2012; Yoo & Huang, 2011). What is consistent, in explanatory and exploratory research about Web 2.0 and culture, is that culture pervades every aspect of life (Pereira et al., 2013).

MOOCs

The initial chorus of researchers espousing the benefits of massive open online courses (MOOCs) globally was based on the notion that MOOCs open up new venues to access education from institutions around the world without the sticker price. Some argued that the platform would "soon become the de facto way to remediate and educate a broad swath of students in a wide variety of content areas" (Cook & Santos, 2016, p. 318). Pangeni (2016) suggested that in small countries such as Nepal, the addition of open and distance learning options such as MOOCs will change the education culture by enabling Nepali higher education institutions to reach students across the country and around the world. MOOCs provide a "new learning culture" or online community for Nepali learners. Such examples have led to MOOCs being referred to as an equalizing force (Rolfe, 2015).

Their massiveness and ability to reach a global audience have also necessitated the need to examine how culture manifests itself or influences this still emerging platform (Loizzo & Ertmer, 2016). MOOCs naturally create learning cultures that could potentially impact learners' beliefs and attitudes. However, investigating culture in MOOCs proves to be a challenge because of the diverse makeup of its users (i.e., culture, geographic, language, ethic, social, backgrounds; Rolfe, 2015). The benefit of the platform being available for free globally ensures that thousands to even hundreds of thousands can enroll in one course. From a research standpoint, however, this mass enrollment can sometimes be problematic in studying culture in depth, hence leading to studies that look at nationality and research that looks at subcultures. Zhang et al. (2016) set out to explore how learners in a MOOC "from various cultures prefer to communicate with each other" (p. 809). What emerged from the result was that the majority of participants preferred synchronous means and female learners were more likely to indicate interest in studying within groups. What could not be easily accomplished here however, especially given the quantitative nature of the study, is an explanation of how these preferences manifest cross-culturally. Examining MOOCs through a subculture lens has been shown as possible. Grünewald and Meinel (2015) examined how to encourage and develop a culture of participation. The researchers argued that in MOOCs, like online learning, there is often a dilemma where people are hesitant to contribute since they feel like the only ones contributing. They receive nothing, but if no one contributes, then the group does not perform well and course engagement becomes affected. Similarly, Loizzo and Ertmer (2016) examined a subculture using virtual ethnography, an Internet-based research methodology developed by Bianco and Carr-Chellman (2002), which they reference as a learning culture in MOOCs. The authors contend that the research, models, and theories that promote meaningful learning can be viewed as coming together to form a MOOC learning culture. Loizzo and Ertmer (2016) coined the term MOOCocracy to explain adult learners' perceptions of their experiences within an "MOOC learning culture." The term "encapsulate the construct of a democratic global social learning culture that is developing in social science MOOCs with predominantly adult learner participants" (p. 1026). MOOCs represent a platform where cross-cultural learning has infinite possibilities.

Discussion

This chapter examined the treatment of culture in current educational technology research. What is evident from the research is that an interest in culture as a variable in education in general and educational technology specifically continues to increase. The reasons for this are wide and varied, but undoubtedly the two that stand out are the influence of sociocultural approaches that emphasize the recognition of social and cultural experiences as formative to learning. The other factor is opening the global educational complex by various technologies that enable individuals from different corners of the planet to contribute to educational technology on their own behest. As research from various cultures contributes to the body of knowledge and as more research is done comparatively across nations, examinations of culture will only grow. Consequently, there is a need for more cultural considerations of how the design of curriculums, experiences, and technologies for education influence and affect learning. Without these cultural considerations, we continue to dance in the dark about how to best educate people.

Global literacy is a theme across all media. There is an emphasis on how to use technologies to support literacy and improve access to learning materials across populations. Educational technology research often does not acknowledge that these media are for the privileged few. Only those who have the financial means can gain access. Therefore, research focuses on the privileged few and maybe conducted from a privileged perspective. Examinations of culture in educational technology must be cognizant that despite best efforts, some folks will be left behind. How can researchers examine culture if its only for the select few? The cultural lens provides a more inclusive perspective. It is important that this movement be enacted by all stakeholders—universities, colleges, technology providers, and distributors of accessible content. If people can't access learning technologies at home, work, or school, then global literacy is doomed to fail.

Often we talk about and research around culture. We use proxies that are easier to quantify and categorize such as gender but ignore issues around ethnicity and the role it plays. “Culture as a construct is a contested space in terms of how it is defined, whom it references and how, and who can legitimately write or research about it” (Dickson-Deane, Bradshaw, & Asino, 2018, p. 1). Hence, this leaves many questions that need to be explored with regard to culture and educational technology. Culture-based studies in educational technologies need to be inclusive of examining not just the technologies but also the context that provides a need for the use of the technology. For example, with MOOCS, one does not only need to have Internet access but sustained Internet access, as such the issue of culture around MOOCs must also include issues of access and the digital divide. Moreover, given that most educational technology is Western based and relies on the knowledge of the English language, examining culture in educational technology must also explore issues of cultural disconnects that prevent people from engaging. Researchers must begin asking and seeking to answer what happens when one has access to the technology but does not possess the required literacy or knowledge of the language (lingua franca). We must explore ways to get people who don’t participate in these groups’ access. Access without opportunity leaves out many valuable voices that stifle global technological and educational progress.

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Using Technology to Facilitate Second Language Learning

Yanghee Kim, Sherry Marx, and Joshua Thoms

Introduction

While the acquisition of one's first language and additional languages share some similarities, such as the order in which aspects of language are developed, the processes are very different. Every child with normal cognitive resources acquires a first language. Babies and toddlers make sense of and begin to use their native language without explicit teaching, acquiring fluency naturally in a few years. In contrast, not everyone is successful in learning a second language, and most second languages are learned in purposeful educational settings.

In this chapter, we present the challenges that second language learning (SLL) students currently face in schools worldwide and the increased demand this has incurred for inclusive educational contexts. We overview effective pedagogical approaches to second language learning and how the computer-assisted language learning (CALL) community has attempted to address various aspects of second language learning. Also, a trend in SLL research and pedagogy pays great attention to the social and cultural context of language learning. Reflecting this trend, new tools like advanced communications tools and embodied technologies (e.g., virtual agents and humanoid robots) have been used to add social and emotional richness to conventional CALL. Next, we discuss appropriate research questions and methodologies to examine the efficacy of advanced technology-based environments for SLL that have become increasingly sophisticated in functionality and features. Finally, we conclude with recommendations for designing technology-based SLL environments to increase sustainability and scalability in public education.

Y. Kim (✉)
Northern Illinois University, DeKalb, IL, USA

S. Marx · J. Thoms
Utah State University, Logan, UT, USA

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The Educational Need of Second Language Learners

The ease of global travel and communication enables many families to voluntarily move abroad to pursue enhanced career opportunities. At the same time, political and economic challenges worldwide have contributed to an increasing number of people involuntarily displaced from their homeland (Canagarajah, 2017). This number has been as high as 65.3 million people in recent years, and more than half of all refugees and immigrants globally in 2014 and 2015 were children (United Nations High Commissioner for Refugees, 2015). In many countries, second language fluency – often in English – is a requirement for economic opportunity and prosperity in life. Many children study English as a second or foreign language as early as kindergarten and throughout their formal education to enhance these opportunities.

Although second language acquisition may occur in natural settings, formal schooling is an important resource for learners to develop essential skills in the target language and culture. Schooling in a second language, however, can be a challenging and even alienating experience for some learners. Children who are not fluent in the target language and local culture commonly enter school already behind academically and socially. Around the world, evidence shows that learners not fluent in the target language consistently fall behind in scholastic achievement, from English language learners in the United States (e.g., Kena et al., 2015; Saunders & Marcelletti, 2013) to Chinese native-speaking learners acquiring Korean in university settings (Yan & Cheng, 2015) to immigrant students learning German in Germany (Kigel, McElvany, & Becker, 2015).

Gaining target language fluency sufficient to succeed can be challenging for many second language learning (SLL) students (Sayahi, 2015). Technology has the potential to mitigate some of these challenges and has been used in varying ways around the world to this end. In particular, technology has greatly expanded the opportunities many second language learners learn and practice discrete aspects of the target language. At the same time, ample opportunity still remains for improving applications, so they can better address a variety of learner needs. In the following section, we examine recent literature on SLL pedagogies and how technologies have been used in line with these pedagogies.

Recent SLL Research and Contributions of Technologies

Many SLL students lag behind native-speaking peers in achievement throughout their education since SLL students have difficulties in understanding instruction when their target language skills are not yet proficient (Garbadi & Mady, 2015; Umansky, Valentino, & Reardon, 2016). A variety of accommodations have been provided in the classroom, ranging from none at all to ad hoc solutions to institutionalized programs of varying quality (Garbadi & Mady, 2015; Marx & Saavedra, 2014). Nonetheless, substantial constraints prevent SLL learners from having opportunities to participate in and engage with core and advanced curriculum in their schooling (Umansky et al., 2016). In examining the research on effective pedagogy for second language learners, the authors have identified five pedagogical approaches: (i) *providing systematic instruction and collaborative activities*, (ii) *addressing SLL learners' unique needs*, (iii) *developing balanced second language skills*, (iv) *creating supportive language learning contexts*, and (v) *using learners' first language and native culture*. As we explain these approaches below, we also present how instructional technologies are being used to address each of these approaches to some degree.

Providing Systematic Instruction and Collaborative Activities

What we know about good instruction and curriculum holds true for second language learning. Well-planned instruction with clear goals and strong organization, in general, benefits all learners. Especially, a volume of research attests to the effectiveness of systematic and explicit instruction on SLL outcomes (Ardasheva, Wang, Adesope, & Valentine, 2017; August, McCardle, & Shanahan, 2014). Collaborative learning is acknowledged as another effective strategy for second language learners (Baker et al., 2014; Garbadi & Mady, 2015). Collaboration in homogenous and heterogeneous groups (Bowman-Perrott, deMarín, & Mahadevan, 2016) can provide many opportunities to practice the target language formally and informally with peers.

A volume of work in computer-assisted language learning (CALL) has provided systematic and explicit instruction on learning grammar, vocabulary, and pronunciations with ample opportunity for repeated practice. In particular, mobile learning (i.e., mobile apps and games) has been increasingly used in both first and second language learning contexts with learners of all age groups (Shadiev, Hwang, & Huang, 2017). Meta-analytic studies report that SLL is one of the most studied domains with mobile devices (Liu et al., 2014; Shadiev et al., 2017). Language learning mobile applications (e.g., *Duolingo*, *Memrise*) provide systematic instruction in which second language learners practice developing vocabulary and grammar. The portability of mobile devices allows seamless transfer from home to classroom and also provides flexible interfaces like touch screens and speech recognition features (Judge, Floyd, & Jeffs, 2015). Yet, researchers have yet to fully explore the short- and long-term effects of these applications on SLL. In addition, instructors often have difficulty in making the applications part of their instruction since integrating mobile app activities into course learning objectives is often challenging.

Collaborative reading and writing are popular areas in recent CALL research and practice, using advanced online technologies like wikis, blogs, or web-based word processing tools (Bikowski & Vithanage, 2016; Kessler, 2017). For example, digital annotation tools (DATs) (e.g., *eComma*, *HyLighter*, *Classroom Salon*) allow instructors to upload texts so that students can read, highlight, and have virtual threaded discussions with one another. When they write an essay collaboratively using wikis, students give the peers feedback on their writing. Recent research in this area investigates SLL student perceptions of collaborative reading (Nor, Azman, & Hamat, 2013), the effectiveness of DATs on reading comprehension (Yeh, Hung, & Chiang, 2017), and other linguistic, literary, and social affordances for language learners and teachers (Blyth, 2014; Thoms & Poole, 2017). While such technologically mediated collaboration offers much potential for authentic, collaborative experiences in SLL, the majority of the research to date has almost exclusively been carried out with adult SLL students. Much more empirical work is needed, which deals with young learners in public schools and at home.

Addressing SLL Learners' Unique Needs

SLL students often face the simultaneous challenges of learning academic content and skills while learning the target language and culture. It is a demanding, multifaceted process. Traditional classroom practices alone are insufficient to assist SLLs in meeting these demands, which is, perhaps, a major cause for the widening achievement gap with native-speaking peers as the students advance through school (Goldenberg, 2015). Students with limited second language fluency are simply unable to fully engage with information they cannot understand. Effective instruction for SLL students should be adaptive to the needs of these students.

Blended language learning and teaching involve the use of classroom instruction and online learning to support personalized learning experiences without sacrificing the quality of classroom instruction and in-person interactions (Rubio & Thoms, 2013). Through this personalization, learners can often adjust the content, pace, and location of their learning according to their preferences (Powell et al., 2015). When implemented properly with the necessary resources, technologies, and training for both instructors and students, the overall effectiveness of blended learning for SLL is equal to or better than face-to-face instruction (Gruba, Cárdenas-Claros, Suvorov, & Rick, 2016).

Although blended learning in SLL has some benefits for learners due to its potential for personalized instruction, it still can be challenging for some students. The autonomous nature of blended learning requires learners to be highly motivated to work on their own (Blake & Arispe, 2012). Noteworthy, there are some accessibility concerns. Network bandwidth varies place to place, and the digital divide still exists among learners throughout the world (Hilbert, 2016; Ortega, 2017). Finally, blended language learning and teaching is almost exclusively used in higher education. A few recent studies have started exploring blended learning with primary and secondary students (O'Callaghan, McIvor, McVeigh, & Rushe, 2016).

Developing Balanced Second Language Skills

All four aspects of language – speaking, reading, writing, and listening – must be purposefully addressed in SLL instruction. Oral language development is necessary for SLLs to be able to interact with the environment and integrate into the classroom (Snyder, Witmer, & Schmitt, 2017) and the second language community. Although listening skills are not often directly addressed in second language teaching, there is a predictive relationship between early listening comprehension and later reading comprehension performance (Richards-Tutor, Baker, Gersten, Baker, & Smith, 2016). Reading and writing skills are also key areas of academic language development. Oral and written language development activities should be integrated into the content area classroom, so that language learners can have consistent, structured writing opportunities while learning academic content (Baker et al., 2014). Teachers should plan explicit time for speaking, reading, writing, and listening practice each week to ensure that all areas are regularly addressed in the process of language development, as well as providing plenty of authentic opportunities for SLL learners to use the target language (Gilakjami & Sabouri, 2016).

Providing opportunities for the development of discrete language skills has been prolific in CALL research. As previously mentioned, much work on second language writing has focused on collaborative writing in digital environments (Grosbois, 2016; Strobl, 2014), as well as collaborative and social reading (Blyth, 2014; Thoms & Poole, 2017; Thoms, Sung, & Poole, 2017). Multimedia presentations have been found to facilitate the acquisition of vocabulary for young learners (Silverman & Hines, 2009). Also, the incorporation of multimedia glosses (e.g., pictures and/or videos alongside translations of words) in digital reading texts facilitates vocabulary acquisition and results in better overall reading comprehension (Yanguas, 2009).

For oral proficiency, videoconferencing tools (e.g., *Skype's The Mixxer*, *Talk Abroad*) allow learners to engage in online discussions synchronously with others and practice second language speaking outside of the physical classroom (Blake, 2016; Bryant, 2013). Other asynchronous tools, like *VoiceThread*, allow oral-based, threaded discussions, where learners first view and listen to a video of another student's response to a prompt, formulate their own oral response, and upload this to a virtual thread for others to view. This recorded-video-based activity offers second language learners planning time, as well as improved oral language skills (Gorjian, Hayati, & Pourkhoni, 2013; Guillén & Blake, 2017).

Creating Supportive Language Learning Contexts

The social context of learning is recognized as a critical factor in the educational success of all learners. Especially in public school settings, inclusive and supportive contexts are a necessity, in which SLL students feel respected and encouraged to participate (Gonzalez, Eades, & Supple, 2014). Such contexts help students develop positive learner identities that lead to their investment in the learning process (Kayi-Aydar, 2015) and facilitate their motivation to learn the target language (Dörnyei & Al-Hoorie, 2017; Ushioda, 2016). When students identify themselves with the language community, they can see the language as a crucial vehicle for developing cross-language and cross-cultural friendships and academic and economic opportunities (Darvin & Norton, 2015; Lee, 2016; Takeuchi, 2016). These benefits make their efforts to learn the language worth the challenges.

Technological applications that facilitate social and emotional aspects of second language learning have not been common in SLL research. Recently, embodied technologies such as virtual pedagogical agents (animated on-screen characters) and humanoid robots are used occasionally to promote social and relational experiences in second language learning. In a study (Carlotto & Jaques, 2016), a pedagogical agent tutored Brazilian college students learning English grammar. Students liked to learn with the agent and performed better in a posttest than those students who did not have an agent. Robot-assisted language learning (RALL) is emerging as a way to add a social and interactive context to language and literacy instruction for second language learners. Some examples include RALL-E, an embodied robot who tutors teen students learning Chinese as a second language (www.alelo.com/rall-e-project/), and a stuffed-animal robot that acts as a storytelling partner for young ESL children as they develop oral language skills (www.media.mit.edu/projects/storytelling-companion/overview). Also, the robot *Skusie* acts as a playmate for preschool- to kindergarten-aged ESL children and assists in the development of early literacy skills (Kim & Smith, 2017). These robots are presently in the early stages of development and have only been tested in a few classrooms or lab settings. Much more work is needed to fully understand how RALL can complement and advance conventional CALL research, facilitating all aspects of SLL.

Using Learners' Native Language and Culture

Several studies have established that, when the first language is enhanced and used as a mediating tool when acquiring the second language, learners improve their progress in learning (Ellis, 2015; Ghobadi & Ghasemi, 2015). The first languages of SLL students therefore are important assets that can help learners make sense of the target language in the learning process. Similarly, much research in multicultural education emphasizes the value of accessing and building on second language learners' native cultures in the classroom (Ladson-Billings, 2014; Moll, 2015; Paris & Alim, 2014). They acknowledge the multilingual and multicultural realities in which SLL students live (Ortega, 2017). To be effective, second language instruction should support learners using their first language as a linguistic resource while engaging in the language learning activities.

Tele collaboration is a way to connect classes of geographically dispersed learners via online for the development of language and/or intercultural competence (Helm, 2015). It allows students to use their first language when they reflect on first and second language cultural issues. For example, in a Skype-based tool called *The Mixxer* (https://www.language-exchanges.org/), SLL students use their first language when interacting with native target language speakers in an informal, synchronous tutoring environment (Bryant, 2013). Yet, CALL approaches that highlight and make use of learners' native languages and cultures have not been common.

Most recently, Kim and colleagues (Kim, 2016; Kim, Marx, & Nguyen, 2017) have been exploring the design of a bilingual robot that encourages young children (English-speaking and Spanish-speaking) to use their first language in their collaborative interactions. This work is part of a larger collection of research on culturally responsive computing (CRC) that seeks to connect classroom learning to students' indigenous cultural and linguistic heritage. CRC fosters the transfer of culturally and linguistically diverse knowledge and skills to learning school topics, as well as to developing students' positive identities (Lachney, 2017). This is a new body of research; much research is needed to better understand its potential.

In examining key work in technology-based SLL, it is clear that the current technologies have potential to address challenges in SLL, although there are limitations to overcome. The greatest strength might be the opportunities that they provide for language learners to repeatedly practice the target language skills inside and outside the classroom. Some growing opportunities for collaboration using network technology are also promising for adult learners. Given the vulnerability of young children, open network-based technologies should be used on a limited basis and with great caution. Alternatively, humanoid robots seem to have much potential in supporting social and collaborative contexts for young learners as a robot acts as a communicative partner. As mentioned previously, however, humanoid robot technology is in the very early stage of development. There is a long way to go before it is proved as a viable SLL tool, particularly to be used on a broad scale. In the following section, we discuss how technology applications for SLL can be improved through new approaches to research and development.

Critical Research Questions and Methodologies

As implied in the five pedagogical approaches, language learning is a socio-cognitive process where learners' cognitive, social, and cultural experiences synergistically work together to bring about successful language acquisition (Ellis, 2015; Vygotsky, 1978). Nevertheless, meta-analytic studies find that much of the CALL research to date is heavily focused on the cognitive aspects of second language learning (Ellis, 2016; Sung, Chang, & Liu, 2016) and usually limited to linguistic forms and rules (e.g., grammar, phonetic symbols, and vocabulary). Similarly, much research in CALL, perhaps due to its emphasis on achieving discrete skills, has been conducted in controlled instructional settings. CALL research relies heavily on quantitative measures (e.g., pre- and posttests and other self-report surveys) to assess learners' second language performance and to evaluate the effectiveness of technology programs. In general, such proficiency measures present an incomplete picture of the second language learning process.

Research in technology-based SLL could be expanded to holistically examine learners' target language uses in natural settings. Both quantitative and qualitative data can inform researchers about language learning not only as a product but can also examine the processes of SLL. Thanks to technological advances, it is possible to capture visual and auditory information of learners while they engage in the learning process. For example, in a study on a robot assistant for children's language development (Westlund et al., 2017), children's facial expressions were captured by a camera on a tablet and analyzed to assess children's emotional engagement in the task. In another study (Bassiou et al., 2016), secondary-school students' conversations were recorded over time while students engaged in collaborative group work. Using advanced speech software, the pitch and intensity of their speech were analyzed to help researchers assess learners' participation patterns during collaboration.

Also, designing technologies to support both cognitive and sociocultural aspects of SLL might be a complex and demanding process that involves a variety of advanced features, multidisciplinary design expertise, and iterative testing and refinement. Meaningful research in technology-based SLL therefore could pay as much attention to the design processes of effective programs (and also ineffective programs) as the end products, so the research can inform future designers about what works and what does not. Findings from this kind of research will foster the instructional design and technology communities that evolve productively and constantly.

To summarize, the robust investigation of technology-based SLL environments may give equal attention to the language learning processes and the technology design processes, starting with two sets of holistic questions: (1) *How do learners' intellectual and social experiences evolve as they engage with the program* and (2) *what does it take to design a technological tool that supports the intellectual and social development of SLLs?* These questions may be complemented with specific granular questions that reflect the particulars of the research context and the needs of target learners and teachers at hand. Obviously, both numerical and descriptive data will inform researchers complementarily, helping to find genuine answers that present the whole picture of SLL as both outcome and process.

Designing Sustainable and Scalable Technologies for SLL

From our discussion thus far, several implications can be drawn for designing and adopting sustainable and scalable SLL programs. First, SLL research highlights the integral relationship between language development and social contexts, as well as the importance of valuing and building on native languages and cultures. Approaches to designing technologies for SLL will likely be sustainable when they afford spaces for learners to use the language and culture of their everyday lives (Ladson-Billings, 2014; Paris & Alim, 2014). These everyday skills and sources of knowledge can orient learners to the target language and culture.

Although the application of interactive technologies for SLL has been prolific commercially and educationally, meta-analytic research reports that theoretical grounds for learning activity designs in many applications are often lacking (Liu et al., 2014). Too often designers seem to immediately start experimenting with new technologies. The educational potential of technological devices should be leveraged and confirmed through robust designs that are grounded in established learning theories (Sung et al., 2016). Design projects that are carefully founded on theory and practice are more likely to lead to sustainable and scalable products.

In addition, the design of SLL technology requires adroit orchestration of all factors involved in learning and teaching (Dillenbourg, Nussbaum, Dimitriadis, & Roschelle, 2013). Having a clear understanding of learners, contexts, and educational missions is crucial for designers to succeed. A designer's prior assumptions about learners and content may be rooted in his or her own experiences and biases associated with his or her own cultural contexts rather than the contexts of the learners at hand. Ideally, the goals and perspectives of teachers, administrators, and parents along with learners' expectations should be taken into consideration from the early stages of technology design for SLL. Through this comprehensive understanding, researchers and designers will be able to understand the unique challenges of the target learners and the particular demands of the learning context(s). This, in turn, can lead to solutions that are both effective and feasible. Resulting products should be user-friendly and affordable so all stakeholders can have easy access.

Finally, although CALL researchers have taken advantage of advanced technologies for enhanced SLL over the decades, young SLL students in public schools are still in great need of quality resources and exemplary pedagogies, as discussed previously in this chapter. On one hand, CALL research should be communicated to practitioners more effectively to benefit SLL practices. On the other hand, technology applications must make room for teacher involvement, embedding teacher materials as a core component of the package (Kessler, 2016). Since encouragement from a teacher has a significant influence on students' language use inside and outside the classroom (Lai, Li, & Wang, 2017), the teachers' role in facilitating broad use of technology-based SLL should not be overlooked. To increase scalability of SLL tools, teachers need to develop proficiency in using technology-enhanced programs and, at the same time, technology programs should allow SLL teachers to customize the content to suit their unique needs. To this end, researcher/teacher partnership is crucial. Working closely with teachers in a dialogic process, researchers and designers should be willing to not only share their expertise but also adjust their design goals flexibly to meet classroom needs.

To conclude, technology-enhanced SLL environments that (i) provide systematic instruction and collaborative activities, (ii) address SLL learners' unique needs, (iii) develop balanced second language skills, (iv) create supportive language learning contexts, and (v) use learners' first language and native culture have a great deal to offer SLL students, enabling rich and successful language learning experiences. A genuine understanding of second language learners – their needs, the resources they bring to the learning scene, and the social contexts in which they are placed– should guide sustainable research and design efforts.

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Section III
Understanding the Role Instructional Design/Technology Plays in Achieving Broader Learning Outcomes

Insights and Development of Non-cognitive Skills

Jeffrey Pedersen

Introduction

A substantial body of research indicates that non-cognitive skills predict a wide range of life outcomes, including academic and educational achievement, labor market outcomes, health, and criminality (Kautz, Heckman, Diris, Ter Weel, & Borghans, 2014). For several outcomes, the predictive significance of non-cognitive skills on the quality of peoples' lives rivals that of the measures of their cognitive ability. The intent of this chapter is to establish a foundation and purpose for consideration in investigating and applying non-cognitive skills in all aspects of learning, teaching, and instructional design.

Non-cognitive Skills

Defining non-cognitive skills is complicated and is often disputed. Gutman and Schoon (2013) suggest there is little agreement even on whether non-cognitive skills is the appropriate term to describe the behaviors such as character skills, personality traits, twenty-first-century skills, and social skills. Within any given concept of a particular non-cognitive skill, such as work ethic, there is a historical recount of theory and measurement and competing definitions of what is being discussed and measured. As a means to define non-cognitive skills, the terms cognitive, non-cognitive, and skills will be distinguished.

J. Pedersen (✉)
C.L.A.S.S. Education, Carmel, IN, USA
e-mail: jeff@joyofclass.org

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Distinguishing the Terms Cognitive, Non-cognitive, and Skills

Although a distinction between cognitive skills and non-cognitive skills is being made in this chapter, it is not implied that these skills work in isolation from each other. All non-cognitive skills involve cognition, and some portion of performance on cognitive tasks is attributed to the use of non-cognitive skills (Schanzenbach, Nunn, Bauer, Mumford, & Breitwieser, 2016).

In economics literature, non-cognitive skills are often described as soft skills and elsewhere as social and emotional learning, social skills, or behavioral skills, including specific qualities associated with leadership ability (Duckworth & Yeager, 2015; Jones et al., 2017). In attempt to account for all educational and industry sectors, the term "non-cognitive" will be defined in this chapter as patterns of thoughts, feelings, and behaviors (Borghans, Duckworth, Heckman, & Ter Weel, 2008) such as personality traits, attitudes, and motivations. In contrast, the term "cognitive" will be defined as the ability to understand complex ideas, adapt effectively to the environment, and overcome obstacles by taking thought (Pierre, Sanchez, Maria, Valerio, & Rajadel, 2014).

The term "skill" is often considered a key variable that contributes toward the sustainable development of nations and an individual's well-being (Zhou, 2016). From an economic perspective, "skill" is a form of human capital that produces value and has a significant impact on income distribution. In sociology, "skill" is assessed by the extent of complexity of the task that requires that particular skill (Attewell, 1990). In this chapter, we will define "skill" as a personal quality that meets three criteria: (1) socially determined, (2) capable of producing value, and (3) improvable by training and development (Green, 2011).

Non-cognitive Skills Defined

For the purposes of this chapter, the term "non-cognitive skills" will be broadly defined as patterns of thoughts, feelings, and behaviors such as personality traits, attitudes, and motivations that are socially determined, capable of producing value, and improvable through training and development throughout one's life.

Non-cognitive Skills in the Workforce

In a survey conducted on behalf of the Association of American Colleges and Universities (Hart Research Associates, 2015), employers agreed that students entering the workforce should be able to solve problems with people who have varying points of view different than their own (96%), orally communicate effectively (85%), communicate effectively through proficient writing skills (82%), work effectively with others as a team member (83%), possess critical thinking and analytical reasoning skills (81%), and apply knowledge and skills to real-world settings (80%). Furthermore, Bronstein and Fitzpatrick (2015) indicated the need for students to learn non-cognitive skills such as critical thinking, collaboration, and communicating with others to be successful in their careers. For those entering the workforce, being effective at these non-cognitive skills can lead to promotion and provide a long-term competitive advantage (Hopkins, Raymond, & Carlson, 2011; Windels, Mallia, & Broyles, 2013).

Studies suggest that increased profits in the labor market correlated to non-cognitive skills have been producing a positive trend over time (Deming, 2015; Weinberger, 2014). In particular, the non-cognitive skills of leadership, teamwork, personality factors, relationship management, and the ability to assimilate information are shown to be highly predictive of success in the labor market (Bassi, Nansamba, & Liberia, 2017; Borghans et al., 2008; Deming, 2015; Groh, McKenzie, & Vishwanath, 2015; Guerra, Modecki, & Cunningham, 2014; Heckman & Kautz, 2012; Montalvao, Frese, Goldstein, & Kilic, 2017). Survey data from employers around the world suggest that non-cognitive skills are in great demand and that there are increasing difficulties finding employees that possess these skills at a higher level (Cunningham & Villasenor, 2016). The foregoing information provides insight into the economic impact of non-cognitive skills in the workforce.

Economic Impact

Historically, we are continuing to see the impact of non-cognitive skills on economic growth and development. A study of non-cognitive skills provided by Heckman and Rubinstein (2001) investigated the General Educational Development (GED) program in the United States. Results indicated that, once controlling for the impact of cognitive skills, job training, and the number of years attended school, GED recipients have lower wages than high school dropouts without a GED degree. They find that the former group is much more likely to exhibit delinquent behavior during adolescence such as skipping school, getting into fights, or engaging in crime and less likely to hold a job when adults than either high school graduates or high school dropouts without a GED. Brunello and Schlotter (2011) suggest these results indicate that recipients of GEDs are relatively intelligent individuals but that these individuals lack non-cognitive skills such as discipline or motivation and, as a result, are penalized in the workforce.

Further, data from the National Longitudinal Survey of Youth suggest there is a significant increase of wages associated with non-cognitive skills. Results indicate that if a person excels from the 25% lowest performer category in non-cognitive skill development to the 25% highest performer category, wages at age 30 improve by approximately 10% for males and by more than 30% for females. Moreover, for those at age 30, employment probabilities increase substantially. Increases in non-cognitive skills for a male raise the probability of employment by close to 15 percentage points and close to 40 percentage points for females (Heckman, Stixrud, & Urzua, 2006).

This trend of positive effects on non-cognitive skills and economics continues today. In the past 30 years, job tasks in the United States have moved sharply toward tasks requiring non-cognitive skills. Job actions and responsibilities associated with working collaboratively with others are substantially more important and needed today than they were in prior decades (Schanzenbach et al., 2016). Deming (2015) suggests that the reason for this need is based on the fact that computer technologies are still poor at simulating human interactions. Human interactions in the workplace involve employees working and playing off each other's ideas and strengths while adapting to changing circumstances. It is these nonroutine human interactions that provide an advantage in the workplace over current technologies.

The correlation between the use of both cognitive and non-cognitive skills among employees has become increasingly profitable. Raised earnings from possessing high levels of both non-cognitive and cognitive skills have increased by approximately 6 percentage points per decade (Weinberger, 2014). In addition, the increased probability of full-time employment associated with a one standard deviation increase in non-cognitive skills has risen from 0.5 percentage points in the 1980s and 1990s to 2.6 percentage points in the late 2000s and the early 2010s (Deming, 2015; Weinberger, 2014).

For those in the workforce or just entering the workforce, employers are communicating strongly on the need for both cognitive and non-cognitive skills, ranking many of the non-cognitive skills as a higher priority. Results from a survey of over 400 employers in the United States indicated that the four most important skills are oral communication, teamwork/collaboration, professionalism/work ethic, and critical thinking/problem-solving juxtaposed to writing, mathematics, science, and history ranked 6th, 15th, 16th, and 19th, respectively, out of 20 skills. More than 90% of employers surveyed declared these skills to be "very important" (Garcia, 2014).

Heckman and Kautz (2012) suggest that non-cognitive skills predict success during one's lifetime and that programs that teach and instill these skills have an important role in public policies. Increased emphasis on the need for non-cognitive skills in the workforce and the value it provides for economic growth brings to the forefront the need of inclusion and emphasis on these skills when considering educational design and deliveries. In the foregoing section, implications for inclusion of non-cognitive skills in educational settings are discussed.

Educational Implications

Empirical evidence indicates that non-cognitive skills can be developed with proper instruction and experiences and that those in occupational positions including, not limited to, educators, instructional designers, and training experts can play a pivotal role in this development by improving learning environments, designs, and deliveries to enhance these skills (Almlund, Duckworth, Heckman, & Kautz, 2011). The succeeding sections describe human development of non-cognitive skills and the impact of formal educational environments on this development.

Nature and Nurture

To some degree, the ability to acquire non-cognitive skills is inheritable. Researchers suggest that inherently, it is easier for some people to develop non-cognitive skills, such as getting along with others, than it is for others, just as it is easier for some to acquire cognitive skills more so than others (Knudsen, Heckman, Cameron, & Shonkoff, 2006).

Added to the complexity of acquiring these types of skills are the learner's environmental surroundings and conditions. Segal (2008) suggests that through several correlational studies, we understand that students' personality and incentives provided by their environment are important in explaining disruptive, inattentive, and tardy behaviors. Research in parental nurturing and education is indicating a significant impact on children's development of non-cognitive and cognitive skills. Children of parents who did not complete high school score almost 20 percentiles lower on a measure of non-cognitive skills and nearly 40 percentiles lower on a measure of cognitive skills when compared with children of at least one parent with some postsecondary education (Schanzenbach et al., 2016).

Researchers have debated whether non-cognitive traits formed earlier in life become more difficult to change and adapt to needed non-cognitive skills later in life. While evidence suggests that heredity, parental nurturing, and environmental factors can play a role in the development or lack of development of non-cognitive skills, additional research in understanding brain development has indicated that like cognitive skills, non-cognitive skills can be developed, nurtured, and taught (Heckman & Kautz, 2013). Moreover, social psychologists argue that these skills are malleable and can be developed at any age (Boyatzis, 2008; Goleman, 2000).

A range of literature supports the belief that some of the most cost-effective interventions for instilling these skills begin at an early point in the lifecycle (Kautz et al., 2014). Evidence from longitudinal studies suggests that interventions in non-cognitive skill development at an early age are successful in changing the economics and life outcomes of people including a decrease in arrests and an increase in employment, in particularly with males (Heckman et al., 2013). Formal educational environments are becoming acutely aware of the need to intentionally include these skills within their instructional designs and deliveries. The succeeding section investigates these types of environments.

Formal Educational Environments

Studies suggest that those with fewer non-cognitive skills struggle more to complete degrees than do those with more non-cognitive skills. People who have weaker non-cognitive skills are less likely to complete high school and less likely to complete a postsecondary degree of any kind. Juxtaposed are those who are in the top 25% of possessing non-cognitive skills. The majority of these students complete high school, and more than half complete a postsecondary degree (Heckman & Rubinstein, 2001).

Increased pressures on formal educational systems and institutions are being made to increase the inclusion of non-cognitive skills into the curriculum and for good reason. Results from meta-analyses of evaluations of social and emotional learning programs (Schanzenbach et al., 2016) indicated that non-cognitive skills can be taught, leading to improved student outcomes. The analyses summarized the findings of hundreds of studies of school-based non-cognitive skill development interventions. “Although the effect sizes differed in magnitude across the types of intervention, the impact on students’ development of non-cognitive skills was considerable. Each non-cognitive skill intervention resulted in improved academic achievement and positive social behaviors as well as reductions in conduct problems and emotional distress” (Schanzenbach et al., 2016, p. 5).

These studies indicate that several facets of non-cognitive skills are malleable and teachable. Celio, Durlak, and Dymnicki (2011) found that service-learning interventions that integrated community service into the school’s academic programs showed improvement in student achievement and social skills. Zenner, Herrnleben-Kurz, and Walach (2014) determined that mindfulness interventions increased students’ awareness, causing increased improvements in student achievement and lower cases of emotional distress. Losel and Beelmann (2003) found social skill development programs contributed toward the growth in social skills and reductions in conduct problems. Garcia (2014) suggests that these results indicate the significance of non-cognitive skills in K–12 academics and how non-cognitive skills support cognitive development and demonstrate that these skills are interdependent and cannot be isolated from one another.

Not only are early childhood development systems and elementary and secondary schools being pressured to integrate these skills, but higher educational institutions are also finding greater need and pressure to build non-cognitive skills into the curriculum. Colleges and universities are implicitly being held responsible for student development of non-cognitive skills aligned with workforce needs (Cleary, Kerrigan, & Van Noy, 2017). This view on higher education’s role in the workforce and in society has become one of the most influential discussions currently shaping global postsecondary policy and practices (Clarke, 2018; Tomlinson, 2017).

Educators and Non-cognitive Skills

Much of this responsibility is assumed by the educators themselves and their ability to improve non-cognitive skills. Typically, social science research has estimated a teacher’s value toward a student’s growth and progress in academics by using standardized test scores (Schanzenbach et al., 2016). Chetty, Friedman, and Rockoff (2014) suggest that students having access to teachers who add value by this metric have important positive effects on later-life outcomes, raising their annual earnings by 1.3%, increasing college attendance, and increasing retirement savings.

However, this metric excludes non-cognitive skills and its effects on student growth. As Jackson (2016) indicates, teachers who improve their students' non-cognitive skills make large gains and benefits on their students' development and outcomes. Jackson (2016) investigates both cognitive skills, measured in terms of test scores, and non-cognitive skills, defined as a student's grade point average, absences, suspensions, and on-time grade progression. When considering only the effect of a teacher on students' test scores, Jackson finds that higher-quality teachers provide an increased value of 0.14 percentage points to high school graduation rates. When Jackson considers the effect of teachers on both test scores and non-cognitive skill factors, the increased value is higher, raising high school graduation rates by 0.74 percentage points (Schanzenbach et al., 2016).

Interestingly, Schanzenbach et al. (2016) suggest that teachers who are proficient at increasing test scores and teachers who are exemplary in teaching non-cognitive skills are often not the same people. A recent study (Jackson, 2016) comparing the fraction of teachers who excel in instilling both non-cognitive and cognitive skills with the fraction of teachers who would be expected to excel along only a single dimension indicated that the correlation between the two abilities is low. "Because the correlation between the two abilities is quite low, there are relatively few teachers who are adept at both cognitive and non-cognitive skill development. Under some accountability policies, teachers are judged based on their impacts on test scores. These results suggest that there are many teachers who are adept at developing students' non-cognitive skills who are not also skilled at raising student achievement; these teachers will be identified as low-impact teachers under such policies, despite the value they provide to students" (Schanzenbach et al., 2016, p. 7). These findings suggest the need for support in helping educational instructors infuse non-cognitive skills into their curriculum and deliveries, providing them with the tools and know-how to effectively create an environment and learning experience needed for learner development and growth.

Implications for Instructional Design

The integration of non-cognitive skills in any curriculum requires thoughtful analysis and critical processes that assure the instruction is meeting the needs of the learner. The identification of the non-cognitive skills within the context of the intended learning environment whether in K–12, higher education, or workforce training should be taken into consideration in the broader constructs of curriculum development and design.

The succeeding sections provide an instructional foundation and considerations to support the intended designs and instructional processes for development in non-cognitive and cognitive skills. It is important to note that there are several aspects concerning the design and deliveries of instruction in supporting the development of non-cognitive skills, far more than what is described in this section. For the purposes of this chapter, a focus of four primary key areas is discussed based upon neuroscientific research on how humans think, learn, remember, control, and develop their thoughts and actions (Wolfe, 2010; Medina, 2008; Goleman, 1995; Hart, 1998). The intent of these succeeding sections is to communicate a basic foundation of instructional practice that maximizes the opportunities in supporting the development of non-cognitive skills and cognitive skills. It is worthy to state that the use and integration of these four key areas, as a whole, provide a platform where non-cognitive and cognitive skills can be nurtured for successful development. It is suggested here that a specific non-cognitive or cognitive skill is not correlated to only one key area of this foundation. Rather, it is the design and use of all of these key areas that provide a learning experience to foster any of the desired skills to be obtained. These key areas include meaningful and active experiences, collaboration, emotion, and feedback.

Meaningful and Active Experiences

When planning learning opportunities for others with the intent to incorporate non-cognitive skills as a developmental objective, designers and instructors must take into consideration the need to provide meaningful and active experiences. Wolfe (2006) suggests that learning is the positive change in what the learner knows, does, or feels because of experience. When the learner is actively involved in the learning process, three areas of learning (cognitive: thinking/knowledge; psychomotor: doing; and affective: feeling (Bloom, 1956)) are more likely influenced.

Wolfe (2006, p. 24) states that "when an experience enters the brain, it is deconstructed and distributed throughout the cortex. The affect is stored in the amygdala, visual images in the occipital lobes, source memory in the frontal lobes and where you were during the experience is stored in the parietal lobes. When you recall information, your brain reconstructs the learning paths or connections. Because memories are reconstructed, the more ways students have the information represented in the brain through experiences and use of the senses, the more pathways they have for reconstructing and the richer the memory."

Designing these types of experiences for the learner requires the integration of active engagement where students participate in meaningful learning activities that include non-cognitive skills. This engagement involves providing opportunities for students to meaningfully talk and listen, write, read, experience, and reflect on the content, ideas, issues, and concerns of a particular subject that is relevant and meaningful to the learner (Meyers & Jones, 1993). Providing experience such as service-learning projects within the community or situational experiences using problem-based learning gives these types of learning experiences where students can practice, relay, and reflect on their non-cognitive skill development. These experiences lead to a deeper understanding of concepts, enhanced critical thinking and problem-solving skills, and higher levels of intellectual development and metacognition all associated with non-cognitive skill development (Bush, Haygood, & Vincent, 2017). Additionally, engaging in meaningful content and exercises helps students acquire real-life experience, improves their attitudes toward learning and the academic discipline, and improves general satisfaction with the learning experience (Johnson, Johnson, & Smith, 1998; Springer, Stanne, & Donovan, 1999).

From a design and implementation perspective, instructional challenges are emanating. Instructors must engage with risk, primarily encountered through the loss of control in a more student-centered classroom (Wurdinger & Carlson, 2010). Furthermore, experiential learning opportunities designed for the learner rely on the ability of the instructor to facilitate a challenging learning environment where participants feel a sense of control over their education, work collaboratively with others, and receive quality feedback. In short, educators are part of the community of learners and not limited solely to planning and assessment activities; they are consciously part of the experiential activity (Fenwick, 2007).

Other considerations when creating meaningful and active experiences include attention to quality support systems. Previous research has shown the importance and requirement of implementing learning activities with quality supports in authentic contexts. Doing so allows the learners the opportunity to identify and solve problems in a more concrete manner, simulating how to effectively problem-solve in real-world contexts (Burden & Kearney, 2016). In creating this type of learning environment, educators begin the process of leadership distribution whereby students are given further autonomy to incorporate their own supports, such as new technologies that associate and combine real and virtual learning resources to enhancing their learning engagement and interactions during the learning process.

The value of engaging learners in meaningful and active learning experiences cannot be understated. Harvard psychologist Daniel Schacter writes, "For better or for worse, our recollections are largely at the mercy of our elaborations; only those aspects of experience that are targets of elaborative encoding processes have a high likelihood of being remembered subsequently" (Wolfe, 2006, p. 5).

Collaboration

Northey et al. (2017) suggest that collaborative learning may exceed higher benefits than what an individual might achieve on their own. Because of this, collaborative learning has been described as a "social imperative" (DuFour & Marzano, 2016) that produces a positive effect on one's learning behaviors and academic outcomes. According to social constructivist learning theory, social interaction is a key principle in active learning (Vygotsky, 1978). Non-cognitive development in areas of managing conflicts, making timely decisions, effective communication, and trust building are among the social/interpersonal skills promoted by actively engaged learning (Nealy, 2005).

The need for collaborative learning has become an important factor in instructional design (Northey et al., 2017). This is increasingly so given the advancements in technologies and the increase of educational needs in the global market. Learning is no longer held to time and physical space. Instead, limitless boundaries that allow "here and now" learning (Martin & Ertzberger, 2013) are shifting the focus of control to a student-centered environment and are redefining a new type of active learner.

Group work, when structured properly, leads to improved interpersonal relationships, social support systems, and increased self-esteem (Johnson & Johnson, 1994; Panitz, 1999). When students work together interdependently toward a common goal, they tend to work harder and develop more social competencies. During this type of engaged learning, students build trust and effectively resolve conflicts in addition to becoming more psychologically healthy (Johnson & Johnson, 1994).

Pedagogically, key concerns of collaborative learning and design are to facilitate students' development of cognitive and social skills (Seitamaa-Hakkarainen, Lahti, & Hakkarainen, 2004) and to support and manage their cooperation and communication (Cumming & Akar, 2005). When learners are deeply involved and actively participating to resolve problems, it is anticipated that sociocultural skills and values, such as trust building, integrity, competence, empathy, and openness, are developed (Mitchell & Zigurs, 2009). These types of collaborative structures can be as simple as group circles where learners and facilitators share information with each other while respecting each other's points of view, learning clubs where learners are grouped into small groups of four to six people to process information, or processing structures where the learners go through a set of procedures to communicate with other learners in different ways.

However, developing a collaborative environment can be difficult. Simoff and Maher (2000) suggest that creating a sense of place and community among students is a great challenge for instructors. This is so especially in the design of online collaborative environments. For these types of interactions to be successful, the facilitator must be deliberate in setting the behavioral expectations and goals of the structures. In infusing non-cognitive skills in the curriculum through the use of collaborative learning, considerations must be made directly and indirectly on building inclusion, values, and sociocultural skills among students to foster an environment that is safe, inviting, and conducive for learning.

Emotion

Hart (1998, p. 196) states, "Emotion cannot be separated from cognitive thinking and development. One feels fear because a situation has been recognized as calling for fear. To be angry at an insult, we must first recognize that we have been insulted."

Over the last decade, research has focused on the effects of emotions on a number of educational outcomes, including non-cognitive skills, motivation, self-regulation, and academic achievement, indicating that emotions are significantly important during the learning process (Frenzel, Goetz, Lüdtke, Pekrun, & Sutton, 2009; Scrimin, Altoe, Moscardino, Pastore, & Mason, 2016; Valiente, Swanson, & Eisenberg, 2012).

In both social and biological sciences, the roles of emotion in learning have a long historical significance in human development (Immordino-Yang & Gotlieb, 2017). Early educators and instructional developers intuitively recognized the power of emotion in learning. Emphasis of the use of emotion in the learning process has increased, in large part, due to the expansion of neuroscientific research and new discoveries about the brain (Farah, 2010).

These advancements in neuroscience suggest that attention and memory, two important cognitive components of learning, are profoundly affected by emotion (Immordino-Yang & Damasio, 2007), and considerable research supports how different levels of arousal and valence affect attention and memory (Staus & Falk, 2017).

In creating memory, information must be encoded. This information is selected, in part, by an orienting response that is triggered by emotion through an unexpected stimulus (Ohman, 1997). Emotionally arousing stimuli may also be linked directly to the processing and storage of information into long-term memory (Bradley, Greenwald, Petry, & Lang, 1992). Molecular biologist John Medina (2008) suggests that the more attention the brain pays to a given stimulus, the more elaborately the information will be encoded and retained. This has significant implications for instructional design and deliveries. The use of emotion to gain and maintain attention can greatly affect how the information will be stored into memory.

In academic settings, research indicates a negative relationship between low-valence emotions, such as anxiety or shame and academic outcomes, juxtaposed to positive relationship outcomes between high-valence emotions, such as enjoyment and pride and creative thinking and engagement (Pekrun, Elliot, & Maier, 2009; Staus & Falk, 2017; Valiente et al., 2012).

Medina (2008) indicates that the amygdala, the part of our brain that helps create and maintain emotions, releases dopamine into the system when the brain detects an emotionally charged event. This dopamine greatly aids memory and information processing by connecting the piece of information with the dopamine causing a more robust processing neural wiring connection in our brains. These robust connections provide a higher probability that the information being learned is retained for further retrieval and use.

To engage learners, Medina (2008) suggests to engage the amygdala in a positive way. One way to accomplish this is to trigger an emotion using a specific “hook” such as laughter or happiness and to be sure the hook used is relevant to the learner and meaningful. A learner’s brain is good at detecting disorganization and can become upset if they felt they were treated in a condescending or disdained manner. Providing a hook that is emotional and intentionally connected to the instructional topic moves the learner from feeling entertained to feeling engaged.

Assessment and Feedback

Feedback can be one of the most powerful instructional strategies for improving a learner’s performance (Hattie, 2012). The use of assessment and feedback, from a design perspective, is based, in large part, upon the intent of what the learner is to gain through the learning process and its long-term effects. How we teach and assess the learner has important implications for whether the learner will retain content or skills for the short- or long-term (Hardiman & Whitman, 2014).

Tokuhama-Esinosa (2010) suggests that while some students manage to keep enough dates, facts, and formulas in their head to pass the test, this knowledge never makes it to long-term declarative memory. Furthermore, it is never truly learned at all, only memorized for a limited period of time, enough time for short-term recall. From a perspective of instructional design and delivery, this has significant implications in how to approach non-cognitive skills in terms of positive long-term effects.

Assessment and feedback, when viewed as an integral part of the instructional process, become a vital component to the success of the learner's development in non-cognitive skills. Hattie (2012) indicates that feedback should help the learner answer three questions during this process: Where am I going? What progress am I making toward those goals? And where do I need to go next? By keeping these questions in mind and providing different kinds of feedback depending on what the learner needs at the time, instructors can ensure that their feedback is meaningful. To help facilitate this process, there are several areas of design presented here, not limited to, for consideration.

Building Trust

Brookfield (1990) suggests that underlying all significant learning is the element of trust and that the trust between teachers and students is the glue binding educational relationships together. Effective feedback is greatly dependent upon the relationship and trust that is built between the teacher and learner. It is trust that brings out the best in people and literally changes the dynamics of interactions.

Although there are several opinions on how to build trust, Brookfield (1990) suggests there are two characteristics that make teachers more trustworthy through student's eyes: teacher credibility and teacher authenticity.

Teacher credibility is described as the ability of teachers to present themselves as a person who has something to offer students. This is a valued perception where students see their teachers as knowledgeable and skillful based upon their life experiences. Students strive to be in the presence of teachers who possess these qualities to help them understand the complexities and dilemmas they are experiencing during the learning process.

Teacher authenticity represents how a student sees the teacher as a person. Students are more apt to trust their teacher if they appear more human with emotions, feelings, and passion rather than creating an emotionless barrier.

Brookfield (1990) states, "students see four behaviors as evidence of authenticity: (1) teachers' words and actions are congruent; (2) teachers admit to error, acknowledge fallibility, and make mistakes in full public view of learners; (3) teachers allow aspects of their personhood outside their role as teachers to be revealed to students; and (4) teachers respect learners by listening carefully to students' expressions of concern, by taking care to create opportunities for students' voices to be heard, and by being open to changing their practice as a result of students' suggestions."

Learning Intentions and Success Criteria

When learners are aware of what they're expected to learn, they are more likely to learn it (Hattie, 2012). When they do not fully understand the expectations of what they are supposed to learn, they disengage and/or agreeably complete the performance tasks, only to forget the information upon completion (Fisher & Frey, 2016). Fisher and Frey (2016) provide three questions pertaining to the learning intention to help support the mindset of both the instructional facilitator and learner: What am I learning today? Why am I learning this? And how will I know that I learned it? "When only some learners infer what they were supposed to learn, understand why they were supposed to learn it, and know whether or not they learned it, inequity begins to take root" (Fisher & Frey, 2016, p. 529).

Guiding this process of learning intention is the creation of success criteria defined here as determining what will be accepted as evidence of learning from your learners. These are the artifacts of the learning processes. Fisher and Frey (2016, p. 529) state that "the success criteria changes as the unit progresses and that the assessment results are derived from your learner's performance toward daily success criteria. As such, this allows the instructor to provide actionable feedback to the learner, identify learners who need additional or differentiated instruction, and determine the continued pacing of the learning process."

To make the most of feedback, instructors must know how to effectively communicate the expectations, and learners must clearly understand these expectations, when developing for both non-cognitive and cognitive skills. When the learner is able to evaluate their task with a clear understanding of what is expected, they are more likely to accept and value an instructor's feedback (Hattie, Fisher, & Frey, 2016).

The Intent of the Feedback

The intent of the feedback has a significant impact on the effect of the outcomes. Frey, Fisher, and Hattie (2018) suggest that if the feedback provided is only corrective (John, stop talking in the hallway), but doesn't provide an opportunity to consider the processes used or the task itself (Let's revisit our hallway procedures that we created together. What did we decide would be the most appropriate behaviors when walking in our school hallways? And what were our reasons for this?), then the effects are muted. How the feedback is presented in terms of depth and breadth of what is expected from the learner has a significant impact on the learners' outcomes. Attention and time used to foster the learners' critical thinking skills toward self-regulation and metacognitive understanding lead to a more effective feedback that supports the learners' development.

With effective feedback, learners become more accepting of the instructors' comments and are more apt to monitor their own progress. As the learners begin to develop these habits of self-regulation and deepen their knowledge or skills, such as in developing non-cognitive skills, they become more open to feedback that challenges them to reflect on their metacognitive processes used to learn the intended knowledge or skills (Hattie & Timperley, 2007).

The Learner's Willingness to Receive Feedback

Feedback is effective if it supports the learners in improving their cognitive and non-cognitive development. Whether or not feedback is effective also depends on what the learners need to hear. Learning is active. In order for students to improve and achieve, they must be able to internalize the concepts through effective feedback processes (Brookhart, 2011).

However, for some, the ability to receive feedback can be complicated. Hattie et al. (2016) suggest that one problem is bias. Some students seek feedback that increases their self-image. If feedback is vague and personal, the learner may selectively accept only positive comments and reject negative comments that were made with constructive intent but lacked clarity.

Indeed, it is the responsibility of the instructor to provide clear and constructive feedback that is actionable. Feedback that is left for interpretation, especially for those types of learners who struggle to receive feedback, can have a negative impact in supporting the learner in their growth and development.

Timeliness

Effective feedback is timely. Timely feedback has been shown to deepen one's memory of the learned materials (Pashler, Cepeda, Wixted, & Rohrer, 2005). In a study comparing immediate versus delayed feedback, students who knew that they would get immediate feedback performed better on a task than those who were told that feedback would be delayed (Kettle & Haubl, 2010). Researchers have found a complex relationship of three factors that influence the effectiveness of feedback: the length of post-feedback intervals, the frequency of feedback itself, and the nature of the intervening activity between the behaviors and the feedback (Iigen, Fisher, & Taylor, 1979). Brookhart (2011) suggests that for recall tasks like learning facts, immediate feedback is best. For more complex work, feedback should also be timely. The longer the delay in providing feedback to the learner, the less likely the feedback provided will have a significant impact on the learner's task and performance.

Conclusion

Messaging from workforce development indicates a significant need in equipping our current and future employees in the application of non-cognitive skills. Research has indicated that these skills, such as problem-solving, communication, cooperation, critical thinking, and the ability to get along with others, have a significant impact upon society. This chapter has outlined the economic impacts and educational implications of non-cognitive skill development, although they are subject to change and expand as the workforce and educational demands continue to change. This chapter also has provided a foundation of instructional design principles aligned with non-cognitive and cognitive development to be taken into consideration when tasked with the inclusion and integration of non-cognitive skills into educational curriculum and practices.

Non-cognitive skills are no longer an educational subset that can be overlooked in importance when attributed toward success in the workplace. The need for these skills to be developed starts at an early age and continues throughout adulthood based upon the needs, changing climates, and environments in which societies operate.

Those responsible for instilling these skills in formal educational settings as part of human development are tasked with significant challenges. It is the effectiveness of the design and instructional deliveries, the learning environments, and curriculum created that, in large part, will determine the outcomes of success. Although this chapter outlined four key components of design consideration, active and engaging experiences, collaboration, emotion, and feedback, there is considerable room for expansion in both depth and breadth in how one approaches instructional design for non-cognitive skill development.

Indeed, it is worthy to reiterate that the term “non-cognitive skills” continues to be debated in both scholarly contexts and global workforce environments. In this chapter, non-cognitive skills were broadly defined; however, it is imperative in meeting the needs of human development and workforce demands to look upon non-cognitive skills within the contexts in which it is being served including, not limited to, workforce sectors, educational environments, global communities, and ethnic/cultural contexts.

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Understanding Learners' Challenges and Scaffolding their Ill-structured Problem Solving in a Technology-Supported Self-Regulated Learning Environment

Victor Law, Xun Ge, and Kun Huang

Introduction

It has been nearly three decades since Sinnott (1989) published her influential book *Everyday Problem Solving*. Everyday problems are also known as ill-structured problems that we encounter every day in our life, which are situated, complicated, and intertwined. Ill-structured problems may involve multiple paths to multiple solutions, or they may not have solutions at all (Jonassen, 2004). Ill-structured problems are distinguished from well-structured problems that have clearly defined goals and can be solved by following step-by-step procedures, as often found in school textbooks (Jonassen, 1997). Whether we recognize it or not, ill-structured problems permeate every aspect of our life.

As a key twenty-first-century skill, problem solving is gaining increasing attention in education and workforce development (e.g., Bulu & Pedersen, 2010; Casner-Lotto & Barrington, 2006; Chen, 2010; Milbourne & Wiebe, 2017). Arguably, if we fail to prepare learners to become effective problem solvers today, we would fail to cultivate a generation of creative thinkers and innovative problem solvers that could contribute significantly and dynamically to tomorrow's world. Today's educators generally agree that it is insufficient to focus on rule-based, well-structured problems

V. Law (✉)
Program of Organization, Information, and Learning Sciences, University of New Mexico, Albuquerque, NM, USA
e-mail: vlaw@unm.edu

X. Ge
Department of Educational Psychology, University of Oklahoma, Norman, OK, USA
e-mail: xge@ou.edu

K. Huang
Department of Curriculum and Instruction, University of Kentucky, Lexington, KY, USA
e-mail: K.Huang@uky.edu

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only; we need to invest more effort on providing learners with rich and authentic learning experiences that help to cultivate their everyday problem-solving skills (Kim & Hannafin, 2011). Yet, conventional school curricula and instructional approaches often do not adequately prepare learners to solve ill-structured problems. As a result, learners are often unable to transfer their knowledge, that is, they often cannot apply what they have learned from school to solve problems in real-world situations (Feltovich, Spiro, Coulson, & Feltovich, 1996).

Although the disconnection between the school and the outside world was noticed decades ago, this situation has not been significantly improved. While today's school curricula have incorporated key problem-solving skills (e.g., reasoning, reflection, decision making) and adopted more student-centered learning approaches (e.g., problem-based learning, project-based learning, guided inquires), there are still discrepancies between the ideal of instructional design and the reality of actual instructional practices. Numerous factors can affect the execution of student-centered learning focusing on ill-structured problem-solving, including both teacher factors and learner factors (e.g., learners' internal processes and external factors, Ge & Hardre, 2010). Most literature on ill-structured problem solving anchored on an understanding of the expert model (i.e., the knowledge schema of an expert), with the hope of providing scaffolding to learners (Jonassen, 1997), while little research has attempted to understand learners' difficulties in the process of solving ill-structured problems. In order to effectively scaffold ill-structured problem solving, it is important that we understand both the expert model and the learner model. Apart from understanding learner challenges in cognition and metacognition, it is also essential to understand those issues concerning learners' other internal processes (e.g., motivation and beliefs) involved in solving ill-structured problems (Ge & Chua, In Press; Ge & Hardre, 2010).

Purpose

The purpose of this chapter is to understand learners' challenges in ill-structured problem solving and identify effective strategies and tools to scaffold their problem-solving processes. The following goals serve to organize the chapter: (1) presenting an updated expert model of ill-structured problem solving by critically synthesizing the literature on self-regulation and problem-solving models (e.g., Ge, Law, & Huang, 2016; Robertson, 2017), (2) identifying learner challenges in the ill-structured problem-solving processes by comparing their performance with the expert model, (3) proposing a scaffolding framework with strategies and tools to address learner challenges. In achieving the third goal, we present the scaffolding framework in two separate parts. Part 1 focuses on the *design* of scaffolding that addresses key stages of problem solving, the iterative self-regulation processes within the stages, and learners' motivation and beliefs. Part 2 focuses on *facilitation*, that is, the dynamic scaffolding provided by the teacher, facilitator, or peer learners. In other words, Part 1 focuses on *hard* scaffolding (Saye & Brush, 2002) such as pre-defined, pre-designed, or pre-planned scaffolding (e.g., prompts, templates, canned feedback), while Part 2 focuses on *soft* scaffolding (adaptive, just-in-time scaffolding afforded by the teacher, facilitator, or peers). Finally, an example is provided to illustrate how to incorporate both hard and soft scaffolding tools in an ill-structured problem-solving task.

Expert Model of Self-Regulated, Ill-Structured Problem Solving

Research on how experts solve problems provides insights into the nature of cognitive processes in problem solving (Bransford, Brown, Cocking, 2003). There is a wealth of literature on how experts solve problems (i.e., expert model) (e.g., Lajoie, 1993; Shute & Psotka, 1996). The expert problem solving is compared with a novice's problem solving (i.e., student model) in order to identify gaps and effective strategies to bridge the gaps (Lajoie, 1993; Shute & Psotka, 1996). In this section, we begin by reviewing and comparing a few prominent expert models in ill-structured problem solving, which then lead into the updated expert model, with a particular focus on self-regulated, iterative nature of problem solving while taking into consideration the roles of learners' epistemic beliefs and motivation (see Ge, Law, & Huang, 2016).

Ill-structured problems often have a vague initial state or unclear goals, and the means and paths to solve the problems are not clearly defined, which require problem solvers to identify and determine unstated goals and constraints in the problem-solving process (Jonassen, 1997). Since the 1980s, researchers proposed various models to capture how experts solve ill-structured problems (Ge & Land, 2003; Jonassen, 1997; Sinnott, 1989; Voss & Post, 1988). Table 1 summarizes the key problem-solving processes described in some ill-structured problem-solving models:

Although the key processes vary in different models, all the models include two main processes: problem representation and solution generation, with essential components such as monitoring and evaluation. In the problem representation stage, solvers explore the problem space and connect their prior knowledge in an attempt to develop an understanding of the problem. In the solution generation stage, learners develop, implement, and justify plausible solutions. All of the models suggest that problem solvers have to engage in both cognitive and metacognitive processes, but only one model (Sinnott, 1989) pointed out motivation and emotion as important non-cognitive processes in ill-structured problem solving.

Recently, Ge, Law, and Huang (2016) proposed an updated ill-structured problem-solving model by highlighting the iterative nature of ill-structured problem solving. The model depicts ill-structured problem solving as a series of self-regulation processes that feed from one stage to another (see Fig. 1). Problem solvers are required to self-regulate themselves throughout the problem representation and solution generation stages. Moreover, the evaluation and judgment of their

Table 1 Key expert models on ill-structured problem solving

Author(s)/year	Problem-solving processes
Voss & Post (1988)	Problem representation Problem solution
Sinnott (1989)	Construction of problem space Generation of solution Monitors Memories Non-cognitive elements
Jonassen (1997)	Articulate problem space and contextual constraints Identify and clarify alternative opinions, positions, and perspectives of stakeholders Generate possible problem solutions Assess the viability of alternative solutions by constructing arguments and articulating personal beliefs Monitor the problem space and solution options Implement and monitor the solution Adapt the solution
Ge & Land (2003)	Problem representation Problem solution Making justification Monitoring and evaluation

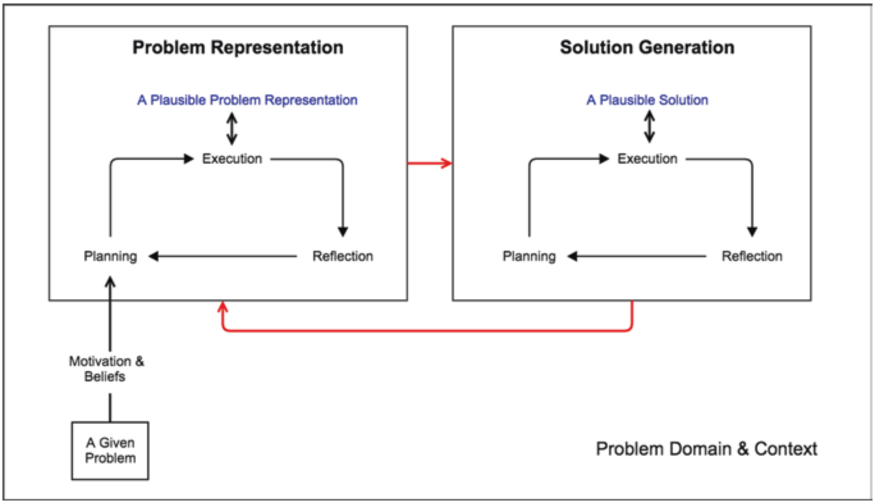

Fig. 1 An updated self-regulated ill-structured problem-solving model

problem representation or solution generation will trigger problem solvers to move between stages. For instance, when problem solvers find a solution unsatisfactory upon evaluation, they may revisit and further redefine the problem representation. Expert problem solvers frequently regulate and refine their problem representations and solutions throughout the problem-solving process.

In addition to highlighting the iterative nature of ill-structured problem solving, motivation and beliefs have been integrated as essential components in the Ge, Law, and Huang (2016) model (Fig. 1). Motivation and beliefs in learning have gained increasing recognition in recent educational research (Boekaerts, 1997; Muis, 2007; Pintrich, Marx, & Boyle, 1993). Accumulating evidence suggests that motivation and beliefs play essential roles in learning, which we address in the next section as we analyze and discuss learners' challenges in ill-structured problem solving.

Learners' Challenges in Solving Ill-Structured Problems

Following the discussion on the expert model of ill-structured problem solving, we now direct our attention to the student model (Lajoie, 1993; Shute & Pskota, 1996), which is grounded in learners' difficulties or challenges in solving ill-structured problems. Based on a review of the literature, we first present five challenges learners commonly experience *within* the two problem-solving stages: problem representation and the solution generation; next, we identify learners' challenges in their navigation *between* the two stages.

Learners' Challenges Within Problem Representation and Solution Generation Stages

Challenges in Applying Prior Knowledge

When faced with an ill-structured problem, learners draw on prior knowledge as a frame of reference to help with problem representation, and later, solution generation (Ertmer et al., 2008). A part of prior knowledge is the existing schema in the problem domain, which learners are often lacking (Rumelhart & Norman, 1978). For example, if learners need to design a training plan while having little prior knowledge about teaching and learning, they may have difficulties identifying key aspects of the problem. Similarly, in the solution generation stage, due to a lack of procedural knowledge in instructional design, learners may not execute the instructional design task effectively. Furthermore, they may not be able to identify appropriate resources and strategies to facilitate the process, which may eventually impact the solution, that is, the training plan.

When domain knowledge is lacking, learners often fill in with another part of their prior knowledge—personal experience that may bear certain resemblance with the problem, in an effort to make sense of the problem and generate solutions. In some cases, the personal experience may help steer toward an initial problem representation that acts as a springboard for further development. For instance, teachers who are new to instructional design often use their past lesson-planning experience to interpret and perform an instructional design task (Ge, Chen, & Davis, 2005).

In other cases, prior experience may lock learners in fixed problem representations or solutions without necessary updates to a more appropriate version. For example, when faced with the problem, "How to handle expired food?" A learner who always throws away expired food may interpret the problem as a need to find evidence to support his personal experience, and thus directs his solution generation effort accordingly (Huang, Law, Ge, & Yu, 2017).

Challenges in Cognitive Processing

To develop a precise representation of a problem, problem solvers need to engage in articulating problem space and constraints, synthesizing information, and identifying the relationships among issues in the problem (Jonassen, 1997). However, learners often do not engage in all or some of the cognitive processes (Ertmer & Stepich, 2005). As a result, they often cannot identify all the relevant constraints nor understand the relationships among different variables of a problem (Dörner, 1987). Due to problems' complexity and ill-structuredness, learners often have difficulties predicting the development of complex problems which may grow exponentially (Dörner, 1987), which, in turn, can lead to high cognitive loads (Marcus, Cooper, & Sweller, 1996). To cope with the cognitive loads, some learners may choose to focus on salient surface features of a problem while filtering out less salient but more important and relevant information, which may subsequently affect the solution generation stage (Ertmer et al., 2009; Jonassen, 2007). For example, when designing instructions, some learners may focus only on the content of the training, while disregarding other important information such as learners and the context of learning, even though they are required to analyze learners and context of the instruction. As a result, they are not able to synthesize all the relevant information when designing instructions.

Challenges in Regulative Thinking

Regulative thinking is critical in ill-structured problem solving. Shin, Jonassen, and McGee (2003) found that regulation of cognition predicted ill-structured problem solving in astronomy simulations. At the problem representation stage, regulative thinking focuses on the monitoring, justification, and adoption of a plausible problem representation. However, many learners go through the stage rather quickly, without taking time to consciously monitor the coordination among several interrelated components at this stage: the information about the problem, the recall of prior knowledge, and the emerging problem representations. For example, upon reading task materials, it is common that problem solvers do not activate all the relevant prior knowledge at once. Yet, some learners do not consciously revisit the task information to determine whether they have missed recalling any relevant information. Furthermore, upon formulating an understanding of the problem, learners often do not consciously examine their understanding against the task information and their prior knowledge. As such, they miss the opportunity to identify and fill any gaps, which could otherwise lead to an enriched problem representation. Similar challenges exist in the solution generation stage, where regulative thinking can help learners to monitor the solution progress iteratively and evaluate, select, and justify solutions. Learners often approach the solution stage in a linear manner and settle on a solution without evaluating its effectiveness or considering alternative solutions (Quintana et al., 2004).

Challenges of Unproductive Epistemic Beliefs

In addition to cognitive factors, learners' epistemic beliefs have an important bearing in how they conceptualize a learning task (Muis, 2007). As an important antecedent of learning, epistemic beliefs refer to our beliefs about the nature of knowledge and knowing (Hofer & Pintrich, 1997). Schraw, Dunkle, and Bendixen (1995) found that learners' epistemic beliefs are related to their performance in ill-structured problem solving. Epistemic beliefs can be a reason underlying the aforementioned learners' challenges in solving ill-structured problems. For example, over-reliance on personal experience to interpret a problem while discounting or rejecting new information is likely due to unproductive epistemic beliefs about the construction of knowledge (Huang, Law et al., 2017). Furthermore, the lack of regulative monitoring and coordination among one's prior knowledge, task information, and problem representation is also likely due to epistemological standards originated from immature epistemic beliefs (Muis, 2007). As such, learners do not see potential misalignment among the three, which can lead to an inaccurate judgment of the plausibility of a problem representation. Epistemic beliefs can also influence the solution generation stage. For example, learners of immature epistemic beliefs may seek information and resources to support their planned solution, while not willing to seek or to ignore the information that may challenge their original solution plan (Chinn & Brewer, 1993; Huang, Ge, & Law, 2017).

Challenges in Learners' Motivation

In addition to learners' fundamental beliefs, their motivation also plays a role in problem representation and solution generation. For example, in solving an information problem, those learners whose goal was to avoid showing incompetence may represent the problem as the search for a perfect website that contains the answer to the problem (Wallace, Kupperman, Krajcik, & Soloway, 2000). At the solution generation stage, these learners tend to use ineffective search strategies (Zhou, 2013b). In addition to achievement goals, learners' adopted identity in a problem situation can affect how they approach a problem. For example, in working on the same software design project, some learners positioned themselves as software developers working for a client, while others took on the role of learners who were trying to earn a course grade; the identities, in turn, affected how they represented and approached the problem-solving task (Ge, Huang, & Dong, 2010).

Learners' Challenges Navigating Between Problem Representation and Solution Generation

A critical process in ill-structured problem solving is the navigation between two stages: problem representation and solution generation (Ge, Law, & Huang, 2016). The navigations between the processes are precisely where learners experience great challenges. The challenges are centered on three key areas. First, learners often do not judge or misjudge the plausibility of a problem representation and move hastily to the solution stage (Ertmer & Stepich, 2005). This is likely due to the lack of domain knowledge (e.g., applicable domain standards), lack of elaboration of thoughts, lack of regulative monitoring (between problem representation, prior knowledge, and problem information), as well as immature epistemic beliefs, which can lead to the lack of monitoring of one's problem representation.

The second challenge lies in the alignment between problem representation and solution generation. In a study that examined ill-structured problem solving in learners' handling of instructor's qualitative feedback, Huang, Ge et al. (2017) found that some students' solutions were not aligned with their problem representation, that is, their understanding of instructor's feedback. While this case shows a clear lack of regulative monitoring, Huang, Ge et al.'s (2017) findings suggested that immature epistemic beliefs might be the root cause.

The third challenge for learners is the multiple iterations between problem representation and solution. Ill-structured problems can rarely be solved with a single iteration from problem representation to solution generation. Often, challenges and new information surfaced in the solution stage may prompt problem solvers to question their existing problem representation. Consequently, they may revisit the problem representation stage and develop an updated problem representation in light of the new information. However, many learners do not go through the iterative processes. For example, in Huang, Ge et al.'s (2017) study on information problem solving, a learner had only one iteration and one updated problem representation before reaching his final solution. The underlying factors behind the lack of iterations may include immature epistemic beliefs (Huang, Law et al., 2017) or negative emotion (Zhou, 2013a).

Designing Technology-Supported Learning Environments to Support Ill-Structured Problem Solving

Understanding learners' challenges in solving ill-structured problems provides us with a concrete starting point to create a conducive learning environment that leads to productive problem solving. Such learning environments need to be open-ended in supporting learners' goals and means to achieve their goals in problem solving (Hannafin, Land, & Oliver, 1999; Jonassen, 1999). We start by discussing the design of problem scenarios as the first step in building such an environment. We then move on to discuss the design of *hard* scaffolding strategies and tools that can help learners to overcome challenges in ill-structured problem solving.

The Design of Problem Scenarios

Problem scenarios can orient learners to a need or problem and situate them in an interpretive perspective (Hannafin, Land, & Oliver, 1999; Jonassen & Hung, 2008). The scenarios act as the driving force to motivate and engage learners in solving problems. Several dimensions need to be considered in the design of problem scenarios: the complexity of problems, the size of the problem space, level of ill-structuredness or authenticity, and student autonomy. Problems can vary in levels of complexity and student autonomy, providing contexts that range from externally imposed, externally induced, to internally generated, which afford different levels of autonomy to learners (Hannafin et al., 1999). The 3C3R model by Hung (2006) provides guidelines for developing problem scenarios to assure learners' autonomy and cognitive flexibility and to immerse them in scenarios. Problem scenarios should include (1) well aligned and appropriately scoped *content*, (2) valid *context* for the instructional goal and appropriate degree of contextualization, (3) explicit *connections* between the concepts of the domain (Hung, 2006).

A well-designed problem scenario can help to activate learners' schema, which will guide them to identify what is known and unknown, what information is needed, and what skills they need to learn, all of which can prepare learners for problem solving by addressing their challenges in applying prior knowledge and experience. Furthermore, well-designed problem scenarios can afford needed problem space and level of complexity, which can engage learners to self-regulate their cognition and metacognition as they work on problem representation, solution generation, and the navigation between the two stages. Meanwhile, authentic and complex problems can situate learners in appropriate social and cultural contexts, which prompt them to reflect on their epistemological perspectives or stances through constructing arguments and making justifications in the problem-solving processes.

Scaffolding and Tools

Besides providing problem scenarios that orient and engage learners in problem-solving activities, it is also important to design scaffolds and tools to support learners' move from the novice to the expert model. In this section, we use learner challenges as lenses to explore how scaffolds and tools can effectively support ill-structured problem solving.

Scaffold Activation of Prior Knowledge

For learners who do not have sufficient prior knowledge, the 4CID model advocates the provision of just-in-time information (van Merriënboer, Clark, & de Crook, 2002). As learners acquire necessary knowledge in the process, the just-in-time information should be faded away. For students who have difficulty activating prior knowledge pertaining to the current problem, Land (2000) suggested multiple ways to prompt and guide them to see the connection with prior knowledge, including the use of learners' familiar experience, diagrams, or analogies. Technology can provide learners with necessary background information of a problem. For instance, in inquiry-based learning, Reid, Zhang, and Chen (2003) presented learners with multiple-choice questions before the inquiry to activate their prior knowledge in physics in a simulation-based learning environment.

Scaffold Cognitive Processing

Prompts and visualization tools are two ways to scaffold cognitive processing. Prompts can elicit elaboration and explanation of a problem (e.g., Ge & Land, 2003, 2004; Lin, Hmelo, Kinzer, Secules, 1999). Learners can be prompted to articulate problem representations, which makes visible their thinking and help learners to self-regulate themselves. Visualization tools are other means to scaffold cognitive processing (Land, 2000). For example, concept mapping can help learners visualize hard-to-see concepts, which have been used extensively in various learning contexts as conceptual scaffolds to support students' articulation of thoughts. In addition, model-centered learning environments (Seel, 2003) using system dynamic tools have been designed to facilitate meaningful learning in complex problem-solving contexts (Milrad, Spector, & Davidsen, 2003; Shute, Jeong, Spector, Seel, & Johnson, 2009; Spector, Christensen, Sioutine, & McCormack, 2001).

Scaffold Regulative Thinking

Regulative prompts encourage students to reflect on their own learning processes and outcomes (Hannafin, Land, & Oliver, 1999). For instance, Ge and Land (2003) designed metacognitive prompts to guide learners in justifying their solutions and evaluating their problem-solving processes. Lin and Lehman (1999) found that metacognitive prompts helped students to develop an understanding of science inquiry processes. Besides using regulative prompts, instructional designers often use expert modeling to scaffold regulative thinking (Ge, Planas, & Er, 2010; Lajoie & Azevedo, 2000). Expert modeling can trigger learners' reflection by allowing them to see the differences between their own thinking and expert thinking. Technologies can be used to support reflections. For instance, Google Classroom and Flipgrid (asynchronous videos) allow students to journal their reflections and progresses over time. The tools can also help learners to capture how their beliefs and motivation evolve over time during the problem-solving processes.

Scaffold Motivation

Belland, Kim, and Hannafin (2013) proposed a framework to scaffold learner motivation. Drawing from motivation theories, such as goal theories (e.g., Elliott & Dweck, 1988; Miller & Brickman, 2004), expectancy theories (Wigfield & Eccles, 2000), and self-determination theories (Ryan & Deci, 2000), Belland et al. (2013) proposed scaffolds to promote learners' task values, mastery goals, belonging, expectancy, and autonomy. Instructional designers can prompt students to set appropriate short-term and long-term goals (Miller & Brickman, 2004; Quintana, Zhang, & Krajcik, 2005). For instance, Quintana et al. (2005) guide students in setting mastery goals in inquiry learning by using prompts that were open-ended, deep, and interesting. Prompts can also guide students to reflect and articulate the values of their learning outcomes (Kolodner et al., 2003). Besides prompting, expert modeling is often used to illustrate the authentic values of a problem-solving task (e.g., Lajoie & Azevedo, 2000).

Scaffold Epistemic Beliefs

Besides cognitive, metacognitive and motivational functions in a scaffolding system (Narciss, 2008, 2013), learners' epistemic beliefs are an important instructional design consideration in ill-structured problem solving. Epistemic beliefs and self-regulated learning are reciprocal in relationships (Muis, 2007). When a learning environment continuously provides learners the opportunity to purposely examine, monitor, and reflect on their problem representations, solutions, and the alignment between the two, learners are likely to garner feedback from these mental activities, which then feeds into their belief schema. Over time, learners' beliefs will undergo changes, especially when they are prompted to become aware of the changes.

As a belief construct, epistemic beliefs are hard to scaffold through direct interventions. Few studies addressed the relationship between epistemic beliefs and ill-structured problem solving, especially empirical studies. Yet, it does not mean that beliefs cannot be nurtured or enculturated. Self-regulated learning plays a role in the development of epistemic beliefs (Muis, 2007). Indeed, a few studies found that some dimensions of students' epistemic beliefs improved through interventions that emphasized self-regulation and metacognition (Huang, Ge, & Eseryel, 2016; Smith, Maclin, Houghton, & Hennessey, 2000).

Scaffold Navigation Between Problem Representation and Solution Generation

In designing learning environments that help learners to overcome challenges in various aspects of ill-structured problem solving, it is important to understand how various strategies and scaffolds interact and work together to facilitate the whole problem-solving process. The purpose of this chapter is to advocate a holistic approach in designing scaffolds for ill-structured problem solving. An integral aspect of the holistic approach is to help learners navigate between two key problem-solving stages so that solutions can be refined and optimized. In this section, we discuss various scaffolds that help guide learners to navigate between problem-solving stages.

To avoid situations where novice learners misjudge the plausibility of problem representations and leap prematurely to solutions, we can guide them to spend more time and effort on problem representations by prompting them to explore relevant prior knowledge with just-in-time information (van Merriënboer et al., 2002). We can also prompt learners to reflect on the quality of their problem representations (Ge & Land, 2003).

Besides prompting learners to consider the plausibility of problem representations, instructional designers should also prompt students to be mindful of the alignment between their problem representations and solutions. Furthermore, we may prompt learners to articulate how their solutions address the original problem according to their understanding of the problem (Lin et al., 1999). In the articulation process, learners may see the dissonance between their problem representations and solutions, which can subsequently prompt them to revisit their problem representations.

Feedback is another effective strategy to encourage iterative self-regulative thinking. Feedback can take different forms. It can be canned feedback provided by a technology system or adaptive feedback from a face-to-face instructor or other digital channels. In the case of longitudinal problem solving, multiple rounds of feedback can be provided requiring learners to showcase process products or submit progress reports (Huang, Ge et al., 2017).

Facilitating Ill-Structured Problem Solving in Technology-Supported Learning Environments

Expert/Instructor Facilitation

Facilitation is a critical and integral part of dynamic scaffolding, as opposed to the predesigned, hard scaffolding discussed in the previous section (Hmelo-Silver & Barrows, 2006; Jonassen, 1997). Facilitators can be experienced teachers, trainers, or teaching assistants who are trained and skillful in facilitating ill-structured problem solving. Schmidt and Moust (2000) suggest that facilitators should have a "suitable knowledge base regarding the topic under study, a willingness to become involved with students in an authentic way, and the skill to express oneself in a language understood by students" (p. 47). Facilitators can play an essential role in facilitating each process of ill-structured problem solving by adaptively employing strategies and tools to guide learners in achieving problem-solving goals (Hmelo-Silver & Azevedo, 2006).

In the process of facilitation, it is critical that a facilitator understand the individual characteristics learners bring into the learning environment, such as their prior knowledge, motivation, beliefs, emotion, and their zone of proximal development.

Understanding learner characteristics helps a facilitator to pinpoint specific needs and address learning challenges with appropriate strategies and tools. Facilitators should identify who needs support, what kind of support, when to provide support, and how to provide support, based on an understanding of learners' characteristics. In addition, facilitators need to keep in mind the learning goals of problem solving. These learning goals go beyond specific problems to include a broader conceptual space as well as relevant situations, which enable facilitators to provide dynamic scaffolding and address various challenges learners may encounter as they engage in iterative self-regulated problem solving (Barrows, 2000).

Hmelo-Silver and Barrows (2006) found that facilitators scaffold learners' problem solving in both cognitive and sociocultural aspects. Facilitators can scaffold an organized and coherent approach to reasoning and inquiry (Frederiksen, 1999), which can address learners' challenge in cognitive processing and reflective thinking. A facilitator also plays an important role in creating a culture where learners can engage in social discourse on the ill-structured problems to be solved, work together to reach a consensus, validate each other's ideas, and establish norms (Palincsar, 1999). The sociocultural scaffolding can help address issues associated with low motivation and unproductive epistemic beliefs.

Empirical studies provide some insight into effective strategies facilitators can adopt to steer the problem-solving process toward a productive direction (Hmelo-Silver & Barrows, 2006). *Reflective toss* (van Zee & Minstrel, 1997), an effective strategy to scaffold deep thinking in inquiry-based learning, can be used to facilitate ill-structured problem-solving processes. A reflective toss is defined as a particular kind of questioning strategy, which typically consists of a student statement or question, teacher question, and additional student statements, which could carry on in more than one cycle. During this process, the facilitator takes the meaning of a student statement or question and throws the responsibility of elaboration back to the student in a way that influences his/her thinking. van Zee and Minstrel (1997) found that the discourses afforded by reflective tosses help learners to make their meanings clear, consider a variety of perspectives, and monitor their own thinking. Given its cognitive and metacognitive nature, the reflective toss strategy can be used to address a variety of learner challenges in the context of ill-structured problem solving, for example, activating learners' prior knowledge, prompting them to elaborate thoughts and make connections, challenging them to monitor and reflect on their thinking, and encouraging them to articulate underlying beliefs to identify any confusions or misconceptions.

Coaching and modeling (Brown & Campione, 1994; Collins, Brown, & Holum, 1991; Collins, Brown, & Newman, 1989; Jonassen, 1999) through teacher–student *conferencing* can help learners to brainstorm ideas, activate prior knowledge, and represent problems. This strategy helps to address cognitive challenges by helping students develop or execute their problem-solving plans. Feedback from the facilitator can help learners to monitor, evaluate, confirm, or reconsider their plan of actions and move forward in the problem-solving process. This process makes the thinking of both the facilitator and students *visible* (Collins, Brown, & Holum, 1991; Collins, Brown, & Newman, 1989) or *transparent* (Hmelo-Silver & Barrows, 2006).

Expert feedback in written format is another strategy commonly used by facilitators, especially in online problem-based learning. Huang, Ge et al. (2017) found that instructor's feedback served to guide small groups to refocus on the problem under discussion, prompt them to articulate or elaborate their thoughts, clarify misconceptions and issues, and summarize the outcomes of a discussion for further problem solving or decision making. More importantly, the instructor can follow up some valuable discussion threads with further thought-provoking questions, a strategy similar to the previously discussed reflective toss in the classroom setting (Van Zee & Minstrel, 1997). The instructor can also prompt learners to navigate out of an immediate problem space into the larger problem space where they can consider such issues as alignment and coherence. While expert feedback can be a helpful strategy, Huang, Ge et al. (2017) found that students processed the same feedback at different levels, which necessitates additional scaffolding to maximize the benefits of expert feedback. For instance, the instructor could have provided a "revise and resubmit" template and asked the students to describe how they had responded to each feedback and summarized the changes they had made (or not made) based on the feedback. This strategy may help students to process the feedback at a deeper level.

Peer Facilitation

In addition to the facilitation by an expert or instructor, we also need to consider the facilitating role of peers and intentionally promote peer interactions, social discourses, and self-reflections in facilitating ill-structured problem solving (Belland, Glazewski, & Richardson, 2008; Ge & Land, 2003). It is essential that we first examine the affordances of peer facilitation in addressing learner challenges in solving ill-structured problems.

When students are placed in groups, they are given the opportunity to share knowledge and ask questions that elicit explanations from peers, the process of which can help them engage in deeper cognitive processes such as clarifying thinking, reorganizing information, correcting misconceptions, and developing understanding (Webb & Palincsar, 1996). Obviously, peer facilitation may help to address the challenge of cognitive processing. King (1992) argued that the amount of available prior knowledge of any group is larger than that of individuals, which means that the elaboration of the pooled knowledge would lead to a more comprehensive problem representation space than that of an individual problem solver. Empirical evidence supports the role of peer facilitation in building collective knowledge for subsequent problem solving. For instance, Canadian students who had prior experience with online discussions successfully facilitated the students in Hong Kong to complete their collaboration tasks (Lai & Law, 2006). In addition, co-regulation among peers promotes self-regulation of individual students during problem-solving processes (DiDonato, 2013). Successful peer interactions can help learners facilitate each other's problem-solving processes toward productive solutions. This process allows peers to challenge one another's thinking and provides a venue for constructing arguments and making justifications (King, 1992, 1994; King & Rosenshine, 1993). In justifying their solutions or decisions, learners often need to examine and share their underlying beliefs. The peer interaction process also enables learners to see each other's views while interpreting the problem or the solution.

Therefore, peer facilitation can help to address the challenge of lacking prior knowledge in ill-structured problem solving. Furthermore, peers may explain difficult concepts to each other in familiar terms or language understandable to themselves (Brown & Palincsar, 1989). Peers can also direct each other's attention to relevant features and meaningful patterns of the problem. In a technology-supported environment, peer questioning can be effective in facilitating problem-solving processes (Choi, Land, and Turgeon, 2005). By helping learners to co-regulate their problem-solving processes, peer facilitation addresses learner challenges in both cognitive processing and regulative thinking. Peer facilitation can also motivate learners to be more engaged at a deeper level in the problem-solving process while helping them to shape their epistemic beliefs.

However, just as Ge and Land (2003) noticed, students do not necessarily engage automatically or fully in productive peer facilitation. Thus, effective scaffolding strategies and tools are needed to maximize the benefits of peer facilitation. Example of scaffolding strategies or tools for peer facilitation includes providing question prompts or templates (Ge & Land, 2003, 2004). Moreover, learners often need training to become effective and productive facilitators. For example, learners often need help generating higher level, thought-provoking questions in order to stimulate challenging and in-depth problem-solving dialogs. We have seen some teacher professional development on guided inquiry-based learning or problem-based learning, which included asking higher level questions as one of the major components (e.g., Kuhlthau, Maniotes, & Caspari, 2012). This type of professional development can equip teachers or facilitators with useful conceptual tools for facilitating effective peer interactions.

Peer facilitation can be supported with online collaboration platforms such as online discussion boards; yet online discussions need to be structured to be productive. The instructor may provide a structure that requires students to interact with each other by asking elaboration or reflective questions and providing feedback to each other (e.g., Huang, Ge et al., 2017; Law, Ge, & Eseryel, 2011). Furthermore, the written discourses in online discussions make students' thinking transparent, which enable facilitators (both instructor and peers) to understand individuals' epistemic beliefs, clarify misconceptions, and shape beliefs and processes for productive solutions. In recent years, there has been some interest and effort in developing online collaboration and facilitation tools to support ill-structured problem solving for both individuals and groups. HOWARD (Hogaboam et al., 2016) is one such tool that features two components serving two main intentions: (1) a student environment in which students engage in problem-solving activities and (2) an instructor dashboard which condenses and visualizes student activities. HOWARD not only helps students to monitor and facilitate problem-solving discussions but also helps the instructor to evaluate individual and group progress and performance by identifying learner challenges and analyzing regulation patterns in collaborative problem solving.

Tying Together: An Illustration of Holistic Scaffolding

In a college digital media class, students are asked to develop an app with the goal to identify, research, and address certain real-world needs or issues while also gaining valuable knowledge and skills. Undoubtedly, as an ill-structured problem, the app development project presents a variety of challenges for students and their instructor. Both hard and soft scaffolding can be incorporated to guide students' activation of prior knowledge, cognitive processing, regulative thinking, motivation, epistemic beliefs, and the navigation between problem presentation and solution. Hard scaffolding is provided through templates and question prompts delivered through a course management system (CMS, e.g., Canvas) and shared document (e.g., Google document or form, or Google Classroom). Soft scaffolding is provided through the facilitation of an instructor who assumes the role of an expert and peer interactions.

Students' lack of prior knowledge can be addressed by providing just-in-time information in a technology-supported environment. For example, the instructor shows a video that documents the development process of a popular app among the students. The instructor then asks students to research other resources that explain the development process. During this time, the students are provided a template with key elements, such as stakeholders, the objectives and goals of the app, and the system requirements (hard scaffold), and asked to fill out the search information about what they find about the development processes. After that, the instructor asks the students to outline an app development process (e.g., ideation, planning, design, app creation, testing, and launch) using visuals (e.g., a diagram). The instructor uses some examples to illustrate the visual processes to scaffold student thinking. The visual representation of the development process can then serve as a hard cognitive scaffold for the rest of the project.

One of the major tasks of ill-structured problem solving is problem representation. To help address oversimplified problem representations, the instructor can invite students to share their experience as app users (a template can be provided to ensure necessary aspects are covered; for instance, students may consider user interface design, compatibility issues, performance issues, etc.). With peer scaffolding, students may see that app development is driven by user needs, not just to satisfy an instructor.

To help students go beyond their own app experience, the instructor guides them to brainstorm and identify factors and parties involved in the app development (stakeholders, business purpose, system requirements, etc.) in the discussion forum. The instructor also asks students to interview different stakeholders using a predesigned template with guiding questions such as "who are the users and project sponsor of the project" (hard scaffold). Then, the instructor asks the students to share their interviews in the discussion forum or the Google Classroom and leads them in a face-to-face class discussion to compare, contrast, and reflect on how different stakeholders' needs converge or differentiate, especially how the findings differ from their personally perceived needs. The discussion guides students to reflect on their understanding of the problem and the alignment between their problem representation and solution, which the students need to journal according to the weekly reflection template and submit to the online system (Google Classroom or a CMS). Question prompts such as "does my app satisfy the user requirements and business needs?" are provided. As a result, students may update their problem representation as needed. In addition, through the self-regulation process and multiple perspectives that they observe, students' epistemic beliefs may be changed as they see the malleability of knowledge.

To scaffold the solution generation stage, the instructor's feedback as well as resources and tools are provided. The instructor provides iterative feedback to students' project-in-progress in various formats, such as written format delivered to students through the technology platform, or one-to-one, in-class conferencing. In addition, just-in-time information is provided regarding available tools, estimated development time when students have no prior knowledge, etc. When students move too hastily to the design phase (solution) without a clear problem representation, the instructor would question the students' readiness. For example, when students suggest some content to be incorporated in their app, the instructor can ask, "which menu link would this content belong to?" In addition, the instructor provides a checklist (hard scaffold) for the students to perform an initial self-evaluation. This way, students would be prompted to revisit their problem representation to develop a better idea.

While motivation may not be an issue at the beginning, students' motivation often declines and thus needs to be sustained as a project progresses. The instructor may scaffold students to research how applications make an impact on people's lives to reaffirm the values students can make in society. A progress report such as a Gantt chart (hard scaffold) can be an effective motivator that engages students to complete smaller goals, highlights the competence that they developed, and aligns their goals for the project.

Discussion and Conclusion

In this chapter, we have synthesized key ill-structured problem-solving models and presented an updated model that highlights two important characteristics of self-regulated, ill-structured problem solving: its iterative nature and the roles of motivation and beliefs. The existing body of literature mostly focuses on the cognitive and metacognitive dimensions of problem solving (e.g., Ge & Land, 2003; Jonassen, 1997; Sinnott, 1989; Voss & Post, 1988) while leaving out such equally important aspects as motivation, beliefs, and the iterative navigations between problem-solving stages (Ge, Law, & Huang, 2016). Based on the updated model, we have identified major learner challenges and discussed how those challenges can hinder learners' problem-solving processes. Then, we propose designing scaffolding strategies with a holistic perspective to support learners through the self-regulated problem-solving processes informed by the updated model (Ge, Law, & Huang, 2016), with a particular focus on the learner challenges identified earlier. In addition to designing *hard* scaffolds, we also address the design of *soft* scaffolding dynamically provided by instructors and peers (Saye & Brush, 2002). We hope that the challenges and strategies discussed in this chapter can shed light on the effort of instructional designers and classroom instructors in supporting learners' endeavor to solve ill-structured problems.

Although scaffolding strategies and tools have been developed in the last few decades, the effects of scaffolding and tools are mixed (e.g., Belland, Walker, Kim, & Lefler, 2017; Cheung & Slavin, 2013; Reeves & Oh, 2017), which warrants additional research in the field of educational technology. The complex nature of the ill-structured problem-solving process makes the design of scaffolding even more challenging. In designing scaffolding for ill-structured problem solving, we advocate a holistic approach because scaffolding in one area or process may help to scaffold another area or process of problem solving. Furthermore, the complicated problem-solving process often requires more than one scaffolding strategy or tool. Yet, there have been limited inquiries regarding holistic or multiple scaffolds. Future research should continue to explore how to design a holistic scaffolding framework that supports self-regulated, ill-structured problem solving. Another important issue for a technology-supported learning environment for ill-structured problem solving is the assessment of ill-structured problem-solving processes and outcomes. Methodologies, such as "Dynamic Enhanced Evaluation of Problem Solving" (Gogus, Koszalka & Spector, 2009; Spector & Koszalka, 2004), are developed to assess learners' problem representations of ill-structured problems. New techniques such as data mining are used to directly or indirectly assess ill-structured problem-solving (Ifenthaler, 2014; Kim & Clariana, 2017). A comprehensive review of the assessment issues in ill-structured problem-solving is needed for future research in ill-structured problem solving.

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A Systematic Review on E-learning Environments for Promoting Critical Thinking in Higher Education

Blanca Puig, Paloma Blanco Anaya, and Inés M. Bargiela

Introduction

With the beginning of the twenty-first century, many challenges regarding the skills students and employees need in today's world have arisen (Rotherham & Willingham, 2010). These challenges are associated with new forms of information and communication technologies (ICTs), which allow for easier ways of moving, presenting, and representing information. Furthermore, ICTs affect teaching strategies, providing different approaches to incorporate core skills into the educational curriculum.

There is some consensus among educators about the need to establish certain core skills that should be taught in schools and included in the curriculum (Binkley et al., 2012). According to Lee et al. (2016), core skills include critical thinking (CT) skills, which are considered relevant because the problems that individuals have to face nowadays are ill defined and require CT in drawing on knowledge from a variety of fields (Gerber & Scott, 2011). Although CT is considered as a seminal goal in higher education (HE), scarce progress has been done regarding which instruction could result in greater CT outcomes (Ennis, 2016; Tiruneh, Verburgh & Elen, 2014). There is a wealth of theoretical studies on CT in HE, in contrast with few empirical investigations about which teaching strategies and learning environments better promote CT. Part of these studies suggest e-learning as a way to enhance CT, using diverse approaches and learning activities for achieving this goal.

This chapter seeks to contribute to the knowledge about what characteristics of e-learning environments help to promote CT among HE students. This review is necessary since no other has been previously performed. The current study develops

B. Puig (✉) · P. Blanco Anaya · I. M. Bargiela
Departamento de Didácticas Aplicadas, Área de Didáctica de las Ciencias Experimentales, Universidade de Santiago de Compostela (USC), Santiago de Compostela, Spain.
e-mail: blanca.puig@usc.es

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a systematic review of empirical research in e-learning environments designed to foster CT in HE. We aim to provide an insight into successful instructional models based on e-learning intended to support CT skills in HE. In this sense, two research questions guide this study:

1. What are the characteristics of e-learning environments interventions intended to promote CT in HE?
2. Which characteristics of those e-learning environments contribute most to successful instructional models for the development of CT?

Learning to Think Critically in Higher Education. Teaching Approaches, Interventions, and Learning Environments

Researchers have offered many definitions of CT (e.g. Ennis, 1962; Facione, 1990; Siegel, 1988). The Delphi panel of the American Philosophical Association (APA), in which 46 leading experts in CT have participated, such as Ennis, Facione, and Paul, offers a consensual and broad definition of CT and identifies six skills (interpretation, analysis, evaluation, inference, explanation, and self-regulation). Furthermore, the findings of the Delphi panel allowed Facione and Facione (1992) to establish seven dispositions (e.g., inquisitiveness, open-mindedness).

According to the experts of the Delphi panel, CT cannot be considered as a body of knowledge to be delivered to students just as any other school subject. CT should be embedded in the content programmes that are specific for each discipline and which rely on the events of everyday life as the basis for developing one's CT. Following Paul's (2005) opinion, CT can be expressed in different ways. CT interventions in HE involve the promotion of higher order thinking skills in diverse disciplines and professional domains. Even though developing CT has been recognized as a primary goal in HE, many college faculty do not fully understand how effectively to teach and integrate CT in their course curricula (Paul, Elder, & Bartell, 1997).

Ten Dam and Volman (2004) highlight some key aspects in order to encourage students to think critically: (a) paying attention to the development of the epistemological beliefs of the students, (b) promoting active learning, (c) stimulating interactions among students, to exchange their point of view (Paul, 1992), and (d) using real-life contexts (Brown, 1997).

According to Ennis (1989), there are four main approaches for the promotion of CT that emerged from the attempt to provide a framework that would help researchers and professionals. The first one, the *general approach*, takes place when the abilities and dispositions and the content are taught separately. In generic courses, CT skills and dispositions are the course objective, without any specific subject matter (Abrami et al., 2008; 2015). The *infusion approach* is a subject-matter instruction in which students are encouraged to think critically about the addressed subject. In this approach, the general principles of CT are made explicit and the content of the courses is important (Abrami et al., 2008, 2015). The *immersion approach* is similar to the previous one: both of them integrate CT into subject matter instruction but, in the immersion approach, the principles are not made explicit to the students, assuming that they will acquire the skills once they have engaged in the subject matter instruction (Tiruneh et al., 2014). The *mixed approach*, named by Sternberg (1986), is a combination of the general approach with either the infusion or the immersion approach. A recent study conducted by Tiruneh, Gu, de Cock, and Elen (2018) has found no significant differences between the immersion and infusion approach. Instead, they concluded that a systematic design of the instruction stimulates CT skills.

Furthermore, there are different approaches of CT interventions and strategies. We draw from Abrami et al.*'s* (2015) proposal who suggest that CT interventions can be categorized into individual study, dialogue, authentic or situated problems and mentoring, which are detailed in Table 1. From a wider perspective than the interventions presented by Abrami et al. (2015), Ennis (2016) proposes two CT teaching strategies. The first one, Problem-based learning (PBL), is one of the most widely used learning approaches nowadays in CT instruction, since it is motivating, challenging, and enjoyable (e.g., Niu, Behar-Horenstein, & Garvan, 2013 ; Norman & Schmidt, 2000 ; Pithers & Soden, 2000). PBL engages students in dealing with a subject matter, usually requiring some research, developing, testing, and discussing hypotheses or solutions and possible alternatives. The second strategy, Lecture-Discussion Teaching (LDT)), is the most common approach to college teaching, according to Ennis, and it consists of a lecture about the subject matter, followed by a discussion. Also, Hitchcock (2015) mentions lectures as a strategy and added computer-assisted instruction with built-in tutorial support using a specific software named LEMUR (Logical Evaluation Makes Understanding Real).

Apart from those aspects, other characteristics of learning environments are relevant for an effective CT instruction. Broadly, the learning environment or the

Table 1 CT interventions. Adapted from Abrami et al.'s (2015)

Categories	Description
Individual Study	Instructional techniques and learning activities that are based on the individual work of the students. Among these activities we can find reading, watching, active listening, reflecting and solving abstract problems on their own.
Dialogue	This instructional intervention has its roots in the Socratic method; that is the reason why the didactic strategy used to integrate the dialogue is the discussion. When engaged in critical dialogue, individuals are discussing a particular problem together. This discussion can adopt multiple forms such as whole-class debates, discussions within groups, and/or online discussion forums.
Authentic or Anchored Instruction	In this category, students are presented with genuine problems related or not with daily-life issues that engage them and stimulate them to ask questions. Simulations, role-playing, and dilemmas (e.g. medical, ethical) are included as possible methods.
Mentoring	Mentoring is one-on-one interaction between someone with more expertise and someone with less expertise. Tutoring, coaching, apprenticeship, or modelling are examples of mentoring.

social climate of the classroom concern the relationship between the characteristics of the group of students and the dynamics of the group, to create an atmosphere that allows for a more effective educational intervention (Fraser, Anderson, & Walberg, 1982). According to these authors, interactions between teachers and pupils or classroom structural characteristics, among others, determine the social behaviour of students, and, as a consequence, their CT skills.

Thinking Critically in E-learning Environments

There is an increasing attention in educational research on how e-learning environments may influence learning (Hirumi & Bai, 2010) and might support the development of core skills for the twenty-first century, such as CT skills.

There are diverse definitions of e-learning environments. This study is framed on the definition provided by Area's and Adell's (2009), who consider e-learning an education offered to individuals who are geographically distant or who interact with the teacher at different points in time using computer resources. According to Szabo and Schwartz (2011), e-learning environments present several benefits such as providing time outside the classroom while students can work collaboratively and discuss the topic through wikis, blogs, or forums. Research points out that this kind of environment favours CT skills among students (e.g. Saadé, Morin, & Thomas, 2012; Szabo & Schwartz, 2011; Yeh, 2009) since it enhances problem-solving, decision-making, collaboration, and higher-order thinking skills (Hopson, Simms, & Knezek, 2002). Drawing from Facione's CT definition (1991), a critical thinker should be a well-informed person, diligent in seeking relevant information and capable of making judgements based on evidence. E-learning offers students the possibility of practising some of these skills. It facilitates a learner-centred education with unlimited access to knowledge that requires contrasting and discerning reliable information (Zhang, Zhao, Zhou, & Nunamaker Jr., 2004), a process for which CT skills are important (Saadé et al., 2012).

According to Area and Adell (2009), there are three main e-learning approaches: (1) *face-to-face or on-site classrooms,* using online learning resources; (2) *blended learning* (*b-learning*)*,* combining face-to-face and virtual classroom; and (3) *online learning*, which takes place strictly in a virtual learning environment (VLE), understood as computer-based learning environments that favour interaction among participants who have access to a wide range of resources (Wilson, 1996). The last two approaches share the characteristic of allowing asynchronous discussions, giving the opportunity to use constructivist perspectives. Both of them also enable personalized learning regardless of time and space boundaries (Şendağ & Odabaşı, 2009). Apart from Area and Adell's (2009) proposal, we consider *flipped classroom* as another learning approach. In this approach, students are expected to prepare, by themselves and using ICTs, what used to be done in the scheduled class, while more practical work is developed in the classroom (Bergman & Sams, 2012), what presents similarities with b-learning environments. Previous studies on e-learning (e.g. DeRuisseau, 2016; Snodgrass, 2011) have reported on the advantages of flipped classrooms and b-learning in promoting CT. For instance, they allow for more time devoted to CT activities in the classroom and favour collaboration among students, increasing their CT skills. In the comparison performed by Schumm, Webb, Turek, Jones, and Ballard (2006), between *face-to-face* and *online* classrooms, the results show that *online* discussions foster CT. They allow students to share knowledge and encourage them not only to analyse and assess themselves, but also to support their assertions or refute the opinions of others (Greenlaw & DeLoach, 2003).

One of the main concerns in e-learning environments, described by Gros (2011), is the creation of specific materials such as videoconference or instructional software. Currently, the e-learning model is testing the collaboration between students and teachers, making use of 2.0 tools. These tools present different functionalities. Hew and Cheung (2013) point out that online collaboration is promoted by *wikis*, since participants interact with each other to create and share information; whereas online reflection may be fostered through *e-portfolios* and *blogs*. In both cases, asynchronous and synchronous discussions take place. An asynchronous discussion is developed when students ask questions and think about their ideas and different points of view after reflective thinking (Cho, Lee, & Jonassen, 2011), whereas a synchronous discussion is carried out by means of virtual worlds and social networks (Hew & Cheung, 2013).

Research in e-learning has shown that students perceived this environment as an opportunity to participate in highly interactive dialogues with the teacher and other classmates, facilitating the discussion and argumentation skills involved in CT (Bolliger & Wasilik, 2009). Both CT and argumentation overlapped in their territories of engagement and both have pedagogical implications for learning and teaching in higher education (Andrews, 2015). Nevertheless, fostering CT through e-learning requires teachers' pedagogical knowledge on how to effectively use e-learning and digital tools (Szabo & Schwartz, 2011). Researchers advocate for active learning, implementing tasks of authentic situations, through project-based learning and challenging work, individualized or in collaborative groups (Ramirez & Bell, 1994). Moreover, teachers must improve their knowledge about (1) how to scaffold collaborative learning and foster dialogue and (2) tools to engage students in contrasting different information to develop CT skills (Kim, 2015; McLoughlin & Luca, 2000).

Despite the existence of previous studies pointing out the advantages of e-learning in promoting CT, further research is needed in this domain in order to know: (1) how to implement instructional strategies, learning philosophies, and collaborative learning in digital media (Saadé et al., 2012); (2) how to design instructional strategies to promote CT in wiki-based learning environments (Kim, 2015); (3) how to teach CT skills by means of the integration of e-learning (Yeh, 2009).

Methods

For addressing the research questions, a systematic review of the international literature is carried out integrating content analysis (Bardin, 2011).

Search Strategy The literature review was conducted by searching relevant peer-reviewed English language papers published from January 2013 to June 2017 (last 5 years). The reason for limiting the search to this period is that e-learning develops at a fast pace, therefore, its potential effects on learning outcomes, and challenges are presumably different now if compared to those of 5 years ago.

Reference Databases ERIC and Web of Science were used to look for relevant articles. The following keywords, closely related to our research objectives were applied in the search: e-learning environment and critical thinking. Moreover, we narrowed the search using Higher Education (HE) as a *descriptor* and focusing on journal articles.

Inclusion Criteria and Study Selection From the total number of papers found ($N = 45$), we selected those studies which fitted in with the aim of this chapter. In order to do so, articles were required to bring together these inclusion criteria: (1) being empirical, since a large part of the literature found appeared to be theoretical, (2) having a clear e-learning scenario, (3) being developed in HE, (4) having a well-defined intervention based on e-learning to promote CT, and (5) describing quantitative and/or qualitative results of this intervention.

The initial corpus of 45 papers from electronic databases was screened to select those relevant for our study. Two authors of this chapter examined the articles independently, applying the inclusion criteria mentioned above. In this examination, the authors performed a thorough reading of the articles to determine which of them were suitable for the study according to the inclusion criteria. The final outcome was a total of 19 studies. Of those, 14 papers were indexed in the Journal Citation Reports (JCR) and 5 in SCOPUS, 2 of which are also indexed in the Emerging Sources Citation Index (ESCI). These studies were finally analysed in order to fulfil the purpose of the present review. Figure 1 summarizes this process.

Data Analysis For addressing the first research question, about the characteristics of e-learning environments intended to promote CT, we analyse four dimensions: (1) general overview (type of study and field), (2) e-learning approach/tool/activity, (3) CT teaching approach (Ennis, 1989), (4) type of intervention (Abrami et al., 2015).

Regarding the second research question, the identification of which characteristics of e-learning environments contribute most to successful instructional models, the analysis focuses on CT assessment methods to get an idea about CT results. The application of fifth selection criteria (quantitative and/or qualitative results of this intervention) allows us to select those papers that describe the results of the

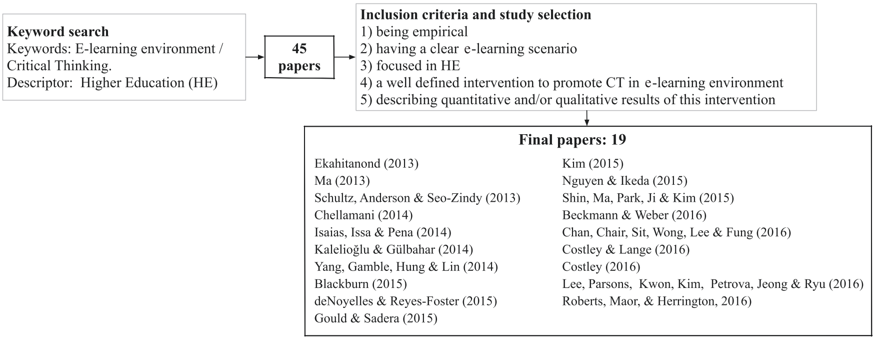

Fig. 1 Process followed for the selection of papers on e-learning

implementation. However, in order to answer the second research question, we pay attention to those that assess explicitly the development of CT. Thus, for the analysis of CT assessment, the process attends to these three aspects: (1) if CT is explicitly or implicitly assessed, (2) the dimension assessed: skills, dispositions or both, and (3) the assessment method followed in each paper. It has to be remarked, that only studies that use explicit assessment methods are considered, since they provide information about the results of the interventions in terms of CT development.

Results and Discussion

This section discusses and addresses the results of the two research questions consecutively.

Characterization of E-learning Environments for Promoting Critical Thinking

A repertoire of the characteristics of e-learning environments identified in the literature review, whose intention and goal is the promotion of CT, is presented in the following paragraphs and summarized in Table 2.

General Overview The studies ($N = 19$) belong to diverse fields in HE: education (4), language (4), nursing (2), earth and environment (1), communication (1), health (1), computer science (1), business (1), and industrial engineering (1). In addition, one of the studies is developed in several fields and two of them do not specify it. It should be highlighted that CT studies using e-learning are more frequent in social sciences than in sciences.

Table 2 Characteristics of the e-learning studies ($N = 19$) included in the systematic review

E-learning approach	E-learning tool	E-learning activities	Interventions (Abrami et al., 2015)
Online ($N = 4$)	VLE (3) (Moodle = 1)	Online discussions about commercials (Ekahitanond, 2013)	Authentic instruction+ dialogue
		Argumentation online about commercials (Ma, 2013)	Authentic instruction
		Create a business plan, eLectures, peer review (Beckmann & Weber, 2016)	Authentic instruction
	Blog & e-portfolio (1)	Assess prompts in an e-portfolio (Roberts, Maor, & Herrington, 2016)	Individual study
b-learning ($N = 13$)	VLE (4) (Moodle = 1)	Create a forecast, search information, lectures (Schultz et al., 2013)	Authentic instruction
		Online PBL about diabetes, heart diseases, and diet therapy (Gould & Sadera, 2015)	Authentic instruction
		Case-Based Learning (CBL) (Chan et al., 2016)	Authentic instruction
		Collaborative online activities, writing and reading in English (Yang, Gamble, Hung, & Lin, 2014)	Individual study + dialogue
	Wiki (2)	Analyse and synthesize articles, case studies, discussions (Isaias, Issa, & Pena, 2014)	Individual study + dialogue
		Criticism, edition, and creation of a wikibook (Kim, 2015)	Individual study + dialogue
	Online posting (2)	Online forum, online posting, and offline discourse (Costley, 2016; Costley & Lange, 2016)	Individual study + dialogue
	Blog (1)	Lectures, discussions, group work (Chellamani, 2014)	Individual study + dialogue
	Mobile learning game (1)	Mobile game-based learning (Lee et al., 2016)	Authentic instruction
	Website & e-mail (1)	Small group discussions around a prompt (deNoyelles & Reyes-Foster, 2015)	Dialogue
	e-portfolio (1)	e-portfolio (Nguyen & Ikeda, 2015)	Individual study
	Chat (1)	Chat (Kalelioğlu & Gülbahar, 2014)	Dialogue
On-site classroom ($N = 2$)	SBLi (1)	SBLi, lectures, real-world simulation, PBL (Blackburn, 2015)	Authentic instruction
	Simulation courseware (1)	Simulation courseware about nursing scenarios (Shin, Ma, Park, Ji, & Kim, 2015)	Authentic instruction

E-learning Approach The majority of studies (13 out of 19) are based on b-learning. The rest of the papers are conducted using online (4 out of 19) and on-site environments (2 out of 19). In these scenarios, we have found diverse *e-learning tools* for promoting CT. The most common ones are virtual learning environments (VLE) (9), like Moodle, which are spaces shared between teacher and students, common in online and b-learning environments. Also, some of these studies comprise blogs (2), e-portfolios (2), wikis (2), online posting (2), and e-mail (1). These tools contribute to asynchronous discussions in b-learning and online environments, allowing students to think about the topics and compare different points of view before giving an answer. Regarding on-site environments, one of the two studies carried out a simulation courseware and the other a Scenario-Based Learning interactive (SBLi).

E-learning Activities Most e-learning interventions promote CT by means of engaging students in discussions about different topics, such as the necessary skills for a teacher to reproduce real situations by applying different strategies (Chellamani, 2014), whereas in other studies, the discussions are related to the content of commercials (Ekahitanond, 2013; Ma, 2013). Another way intended to develop CT identified in some of the analysed papers, is to deal with potential real-life situations (authentic instruction), in which students have to investigate the problem itself and try to find a solution. This is the e-learning activity chosen, among others, by Schultz, Anderson, and Seo-Zindy (2013), who ask students to create a forecast. Gould and Sadera (2015) propose authentic instruction about diabetes, heart diseases, and diet therapy, engaging students in clinical reasoning. Beckmann and Weber (2016) ask students to create a business plan.

CT Teaching Approach Almost all studies follow the immersion approach (18 out of 19) to foster CT, which means that CT is embedded in the content of the discipline without making the principles explicit to the students. Only one study was conducted under an infusion approach, that is, CT principles being explicitly taught. This is the case of Yang et al. (2014), who investigated the effectiveness of CT-infused approach in English literacy instruction. In order to do so, a professor from the Institute of Education teaches students CT concepts and skills during face-to-face workshops and then students apply CT to asynchronous online discussions.

Types of CT Intervention Several papers involved authentic instruction (9 out of 19), that is, problems that students understand and in which they find motivation to think critically. This kind of intervention is closely related to the PBL strategy, which involves students in researching, developing, testing, and discussing hypothesis or solutions and alternatives, situations in which students should transfer knowledge to real situations (Ennis, 2016). According to the analysed papers, there are e-learning activities that follow this type of intervention, for instance, involving students in a case analysis about clinical case scenarios (Chan et al., 2016), mobile game-based learning (Lee et al., 2016), a simulation courseware (Shin, Ma, Park, Ji, & Kim, 2015) or a scenario-based learning interactive presented through cases

(Blackburn, 2015), all of them in a b-learning environment. Besides authentic instruction, other types of interventions identified in those papers are: dialogue (2), individual study (2) and dialogue & individual study (6). While individual study is fostered through assessment prompts in a e-portfolio (Nguyen & Ikeda, 2015; Roberts et al., 2016), dialogue requires being critical during small group discussions around a prompt (deNoyelles & Reyes-Foster, 2015) or in a chat (Kalelioğlu & Gülbahar, 2014).

Critical Thinking in E-learning: Assessment, Good Practices, and Difficulties

The analysis of the second research question, which characteristics of those e-learning environments contribute most to successful instructional models for the development of CT?, pays attention to the implementation and assessment methods used in the aforementioned papers. The reason for doing so is that this assessment allows us to determine whether or not this environment contributes to the development of CT skills and/or dispositions. After a brief description about the assessment methods and CT results, a synthesis of good practices for fostering CT is presented in this section.

Most studies assess CT explicitly (12 out of 19), whereas 5 do it implicitly and 2 papers do not assess CT. The studies that assess CT explicitly measure CT skills (10) and CT dispositions (2), using diverse quantitative and mixed methods. We have not identified any paper that assesses CT skills and dispositions jointly. Table 3 summarizes the results.

Concerning the instruments applied, four papers apply the Likert scale to get information about the students' perception of their own improvement in CT skills and dispositions. Two studies use pre-/post-test to analyse CT based in a reliable test: California Critical Thinking Disposition Inventory (Facione & Facione, 1992), California Critical Thinking Skills Test (Facione, Facione, Giancarlo, & Blohm, 2002), and Holistic Critical Thinking Scoring Rubric (Facione & Facione, 1994). Four studies perform a content analysis by coding the data using the CT diagnosis model established by Newman, Webb, and Cochrane (1995) and another one follows the CT categories proposed by Greenlaw and DeLoach (2003).

Taking into consideration the characteristics of the environment itself, the studies, which report better results, were carried out using diverse e-learning approaches and a large variety of activities and tools.

Regarding those that assess CT skills, some studies have reported good CT results like Ekahitanond (2013), who shows that online discussions about commercials (authentic instruction) promote students' CT skills (knowledge, comprehension, application, analysis, synthesis, evaluation). Also, Lee et al.'s (2016) study reveals that mobile game-based approach (authentic instruction) fosters collective

Table 3 Summary of CT explicit assessment method, CT results and e-learning environment

CT explicit assessment (*N* = 12 papers)	CT assessment method	Results: improvements in CT	E-learning resources and activities
CT skills (*N* = 10)	Survey Likert	Isaias, Issa & Pena (Isaias et al., 2014): Communication, critical review, research, search, and collaboration.	Case study Discussions
		Nguyen and Ikeda (2015): Metacognitive self-regulation and critical thinking.	E-portfolio
	Pre-/post-test and Questionnaire Likert	Ekahitanond (2013): Knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom's taxonomy).	Critical inquiry model and peer feedback.
	CCTST and Holistic critical thinking scoring rubric	Yang et al. (2014): Analysis, inference, evaluation, induction, and deduction (CCTST).	Asynchronous online discussions and CT-integrated reading and writing activities
	Content analysis	Kim (2015): CT levels increase.	Criticism, edition, & creation of a wikibook
		Beckmann and Weber (2016): Knowledge, intensive, justification, and critical assessment (Newman, Webb, & Cochrane, 1995).	Virtual collaborative learning creates a business PPlan, e-lectures, peer review
		Lee et al. (2016): Clarification, assessment and novelty (Newman, 1997).	Mobile game-based learning
		Costley and Lange (2016): Relevance and importance (Newman et al., 1995).	Forum Discussions
		Costley (2016): Relevance, importance, and linking ideas (Newman et al., 1995).	Forum Discussions
	Questionnaire	DeNoyelles and Reyes-Foster (2015): Higher scores of CT are reported.	Discussions Word clouds
CT dispositions (*N* = 2)	CCTDI	Kalelioğlu and Gülbahar (2014): CT dispositions improve when students engage in mixed techniques group.	Chat
	Yoon's CT disposition tool with Likert scale	Shin et al. (2015): Prudence, systematicity, healthy, scepticism, and intellectual eagerness (Yoon's CTD) increase.	Simulation courseware: nursing scenarios

CCTST California critical thinking skills test, *CCTDI* California critical thinking disposition inventory interactions that contribute to develop CT skills such as clarification, justification, and linking ideas. These match the findings of the research of deNoyelles and Reyes-Foster (2015), pointing out that CT and peer interaction have a positive correlation, so they positively affect each other. Costley (2016) examines to what extent participating in forums improves CT, concluding that the more forums students followed, the greater the improvement they experienced on their CT skills (relevance, importance, liking ideas, justification outside knowledge, etc.). Beckmann and Weber (2016) encourage students to create a business plan (authentic instruction) and defend it in a forum context. The results show that students introduce outside knowledge into the discussion improving their CT. Yang et al.'s (2014) study deserves a special mention given that it is the only one that comprises an infusion approach to develop CT skills. Quantitative results manifest a significant increase in overall CT skills (analysis, evaluation, inference, deductive and inductive reasoning) during asynchronous online discussion.

From the studies commented above, it seems that interactions among students and authentic instructions (nursing scenarios, mobile game-based) foster CT skills. However, two studies reveal that interactions among students could have a negative impact on CT skills. Costley and Lange (2016) examine how social presence and CT interact with each other and the results show that both variables have a negative relationship. The explanation given by these authors rests on Rourke, Anderson, Garrison and Archer's (1999) discussion, who indicate that excessive social presence may be detrimental for CT. Also, in the study carried out by Kim (2015), students are encouraged to create and evaluate a wiki, obtaining higher levels of CT when students make their own chapter than when they review peer's chapters.

Considering the studies that assess CT dispositions, the results are quite similar, pointing at interactions among students, and authentic instruction promotes CT dispositions. In particular, Kalelioğlu and Gülbahar (2014) compare different e-learning tools (six thinking hats, brainstorming, role playing, Socratic seminar, anyone here an expert) for fostering CT dispositions. From their quantitative results, they conclude that Socratic seminar group develops lower levels of CT dispositions. However, in the qualitative analysis, the mixed techniques group has shown higher levels of analyticity, open-mindedness, inquisitiveness, self-confidence, truth-seeking, and systematism. According to these researchers, this could happen because mixed techniques help students to notice the relevance of the discussion process thus increasing their motivation. The other study (Shin et al. (2015) concludes that the more the students are exposed to nursing scenarios, the better the scores obtained for CT dispositions. Nevertheless, all students experience a significant increase in the post-test to four dispositions: prudence, systematism, healthy scepticism, and intellectual eagerness.

Although the majority of the aforementioned studies (10 out of 12) have reported good results on the implementation of CT in e-learning environments, most of them point out limitations or difficulties in doing so. The main limitation is related to the small size of the sample. However, other studies have highlighted particular difficulties to be considered in future research. Ekahitanond (2013) and Shin and

Shin et al. (2015) point out that other variables, apart from those controlled in their studies, could contribute to an increase in students' CT skills. Nguyen and Ikeda (2015) consider that the improvement in some CT skills (particularly in self-regulation) could be due to the passage of time rather than to the use of e-portfolio. Furthermore, Kalelioğlu and Gülbahar (2014) have perceived that students were not familiar with virtual discussions and that may have an effect on the final results.

Conclusions and Challenges for Future Research

This systematic review has shown that there are diverse e-learning environments designed to promote CT among HE students. The analysis of the first research question shows that the most common e-learning approach is b-learning. This might be related that it is easy to integrate e-learning in a common classroom by means of different tools like Moodle, wikis, or forums. Forums yield particularly good results on the development of students' CT skills such as relevance, importance, liking ideas, or justification, as reported by Costley (2016). The majority of e-learning activities are based on asynchronous discussions about real situations (e.g. Ekahitanond, 2013; Kalelioğlu & Gülbahar, 2014). These discussions give students time to think about the topic and interact with each other despite spatial boundaries, which are important aspects to consider regarding CT development, which is in line with Şendağ and Odabaşı (2009) and Szabo and Schwartz (2011). Despite previous research pointed out the adequacy of CT instruction before applying it to achieve better learning outcomes (Abrami et al., 2008), the results of this systematic review show that all CT interventions followed an immersion approach, except one (Yang et al., 2014), which obtained good results. Our analysis does not enable to discern the reasons for choosing the immersion approach, nevertheless it allows us to conclude that students improve CT skills, which can be associated to a previous instruction on CT concepts and skills (Abrami et al., 2015).

The examination of the second research question allows us to identify two characteristics that seem to promote CT in e-learning environments. On the one hand, some studies have shown that cooperative or collaborative learning favours CT skills and dispositions, especially when students have to justify their ideas (deNoyelles & Reyes-Foster, 2015; Lee et al., 2016). On the other hand, authentic instruction like discussions about real-life problems (Niu et al., 2013), mobile game-based learning (Lee et al., 2016) or a scenario-based learning interactive presented through cases (Blackburn, 2015), can be associated with PBL strategy that is widely used nowadays in CT instruction, since it is motivating and challenging (Niu et al., 2013). This matches with previous research of Brown (1997), who suggests that, in order to engage students in thinking critically, didactic proposals should include realistic contexts.

Three challenges drawn from these results related to these dimensions of CT: (1) CT assessment, (2) CT dispositions and (3) diverse variables that might affect CT development, apart from the e-learning environment.

Regarding the first one, five (out of 19) studies assess CT implicitly, which means that the focus is not on the assessment of CT skills and dispositions, but on the adequacy of the e-learning environment and/or the development of the activity, since these elements may affect CT development, as Chellamani (2014) and Roberts et al. (2016) suggest. Some studies that explicitly analyse CT do not assess it using reliable methods for the evaluation of CT skills and dispositions. That is, Likert scale or subjective questionnaires focusing on students' perceptions about their own CT development, instead of using an objective method. Since the Likert scale can capture the intensity of the students' feelings for a given item, indicating their level of agree-disagree scale (Barua, 2013), we consider that this assessment method is not appropriate for determining an improvement in the CT capacity of the students. This leads to another limitation of our study, related to the limited number of papers analysed which describe good practices for thinking critically, based on e-learning.

The second challenge refers to the low number of studies that analyse CT dispositions. Only two papers out of 19 focused on some of the dispositions such as open-mindedness, self-confidence, and systematicity, which were also found in a recent literature review on CT in HE developed within the CRITHINKEDU_O2 (2018) European Project. We consider this as an important concern, suggesting that educators and HE teachers should put more emphasis on CT dispositions.

The third challenge deals with one difficulty reported, regarding other variables that might influence CT, apart from those included in the analysis. We must keep in mind that social presence may limit the development of CT in students, as Costley and Lange (2016) point out. Further research is needed in order to deeply understand how social factors, such as personal interactions or mainstreams, could affect the development of critical thinkers.

This review presents some limitations due to the representativeness of the selected articles to answer the first research question, since the search was limited to empirical papers, which implement CT interventions in e-learning environments.

In conclusion, this review seeks to contribute to a better understanding of how e-learning might promote CT in HE, despite the challenges mentioned above. There is a need to develop more experimental research on CT through e-learning in order to improve the knowledge about the daily-work basis that may help to identify which learning strategies and activities better promote CT, ultimately turning it into a better educational practice.

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Supporting Sociocultural Learning in Online and Blended Learning Environments

Casey Frechette

Introduction

This chapter presents a summary of research on how to facilitate sociocultural learning in various contexts, including fully online classes and blended environments, in which learners engage face-to-face with the support of technology. The chapter covers the latest empirical research from the field and provides specific recommendations to harness learners' prior experiences and cultural influences to enhance skills acquisition, knowledge building, and transformative learning. The learners, topics, and contexts best suited for sociocultural learning are also identified.

What Is Sociocultural Learning?

Sociocultural learning encompasses an array of theories, teaching principles, and instructional design models derived from a simple idea: Learning unfolds via relationships and group affiliations. These connections provide opportunities to learn through observation as we model what those around us do and say. Socialization also provides conduits to cultural values, ideas, and ways of thinking; when our parents teach us how to read, for example, they inevitably transmit cultural norms, expectations, and understandings.

Lev Vygotsky's work, and specifically sociocultural theory, provides the bedrock for contemporary understandings of sociocultural learning. Vygotsky, a Russian

C. Frechette (✉)
University of South Florida St. Petersburg, St. Petersburg, FL, USA
e-mail: frechette@mail.usf.edu

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educator and philosopher, conceptualized learning as a series of social experiences (Vygotsky, 1978). Central to Vygotsky's paradigm is the zone of proximal development—the gap between a learner's current and potential ability, as defined by the growth possible with the assistance of a guide or facilitator (Fernández, Wegerif, Mercer, & Rojas-Drummond 2015). As we move through different zones of proximal development, we learn directly first from family members and, later, in school, in our communities, and in organizational contexts, Vygotsky observed. Indirectly, we learn via the cultural norms embedded in society and then relayed to us, both through the people we know and through the mass media we consume or to which we become exposed. These norms shape how we think, the resources we draw on when solving problems, and how communication unfolds with both teachers and peers.

According to sociocultural theory, learning manifests at three levels: within cultural frameworks; through social interactions in our homes and communities; and via the meaning-making that transpires in our minds (Karpov, 2014). Knowledge can be created and preserved at each level, and the interplay between how we interact and then internalize experiences constitutes the core of learning.

Through a sociocultural lens, learning can be understood as a distributed, interactive, contextual process. Learning is distributed because it happens both within and outside formal settings, in various venues, and at myriad times. It is interactive because socialization—conversation, modeling, and reflective dialog—often serves as the catalyst. It is contextual because the depth and quality of learning depend on far-ranging factors, some specific to the learner and others particular to the environment.

Other theoretical perspectives provide context for sociocultural theory. Jean Piaget's theory of cognition postulates that human development involves distinct cognitive stages, each with its own constraints and abilities (Bormanaki & Khoshhal, 2017). Certain ways of understanding can't be achieved at lower levels of development, and we achieve growth by balancing changes to ourselves and our environments. Constructivism extends these ideas by emphasizing the personalized knowledge-creation processes we embark on while learning in and about the world. Although largely compatible with, and complementary too, sociocultural theory, neither constructivism nor Piaget's paradigm emphasizes the role of the social environments in which we learn to quite the same degree.

On the whole, Vygotsky's work serves both as a description of how we learn and a prescription of how to foster more effective learning experiences. Sociocultural theory emphasizes social interactions but also individual differences, providing opportunities for instructional designers, teachers, and educators-at-large to develop learning experiences that benefit all learners, regardless of backgrounds, affordances, or constraints.

Facilitating Sociocultural Learning

Kim and Hannafin (2011) presented a problem-solving framework helpful for understanding how to facilitate sociocultural learning, in which learners work with teachers and technology plays a mediating role. Their framework involves a cyclic, non-linear process wherein learners identify problems, explore resources, propose solutions, share results, and defend and amend ideas. Scaffolding, they argued, can happen in each step, as a teacher facilitates the experience.

Based on their work, the existing theory base, and recent empirical research into diverse learners' experiences, opportunities to facilitate sociocultural learning can be tracked along two dimensions: *types* of support and *sources* of support. Possible types of support include design models and frameworks, which guide instructional designers to develop learning experiences conducive to sociocultural learning; technical platforms, across which experiences are delivered; communications tools, through which learners interact; and instructional techniques, with which effective communication and interactions can be cultivated. *Source* refers to the scope and placement of the support. Support can be situated with the instructor; with the course itself; with the institution or organization responsible for the learning experience; or via a supplemental or external source.

Significant strides can be made toward cultivating sociocultural learning experiences, despite constraints on resources and time. Considering the types and sources of support for sociocultural learning in light of Vygotsky's theoretical framework and a review of findings from empirical research leads to several important conclusions:

1. *Not all types and sources will be available in all contexts.* Instruction may be delivered without the benefit of a design model, or institutional support may be unavailable, for example.
2. *Not all types and sources will be customizable in all contexts.* Puntambekar and Hübscher (2005) distinguished between static and dynamic forms of support. Static support typically takes the form of software and outside resources unable to adapt to learner feedback. Dynamic support encompasses teachers, peer-coaches, and other facilitators able to respond to individual learners' needs. Only dynamic support, they argued, could be counted as true scaffolding.
3. *A multipronged approach to cultivating sociocultural learning works best.* In line with the principles of universal design for learning (Barajas & Higbee, 2003; Elias, 2011), providing many ways to facilitate sociocultural learning makes it more likely that students with diverse needs, constraints, and affordances will benefit.
4. *The best mix of support will depend on a range of factors.* Some variables, such as content domain, may be predictable by the designer or facilitator. Others, such as learners' prior experiences, likely will not be, making a flexible approach important. However, research to date suggests that collaborative learning holds benefits across a spectrum of content domains, from the hard sciences to the arts and humanities.

Summary of Relevant Research

Research into sociocultural learning from the past five years has, by and large, been exploratory in nature, with methodological limitations that curtail the extent to which overarching principles can be derived. Empirical efforts have mainly focused on small-scale samples and qualitative methods, providing nuanced insights into specific learners and learning contexts. Studies have focused on cohorts in a variety of regional and national contexts, resulting in rich data about diverse learners, but further complicating efforts to draw comparisons between studies. These factors, combined with the complex nature of human learning, limit the generalizability of findings to date and leave unanswered questions about how best to facilitate sociocultural learning, particularly online, where rapid technical advances are creating new opportunities—but also new design and delivery challenges.

Moreover, emerging technologies such as virtual reality and artificial intelligence promise to redefine how we think about learning, in both virtual and physical spaces. Nonetheless, empirical research into collaborative learning through the lens of sociocultural theory provides valuable confirmation of some critical assumptions about how people learn and how best to facilitate that learning in online and blended settings. Those assumptions can be seen as core principles that could be used to inform the design or facilitation of learning experiences built on communication, including small- and large-group discussions, game-based experiences, and other collaborative experiences.

Much of the research presented in this chapter used sociocultural learning theory as a theoretical frame. This resulted in patterns in the kinds of insights researchers have attempted to glean, with distinct focuses on learners' internal thought processes, how they collaborate with instructors and peers, and how overarching institutional or societal norms, values, and expectations shape learning experiences. Methodologically, qualitative data collection and analysis tools have mainly driven work in the field, including case studies, focus groups, and interviews. Direct analysis of transcripts in online discussion forums and other collaborative spaces has also emerged as a popular methodology.

Principle 1: Facilitator feedback enhances sociocultural learning, especially when it both encourages and prompts Coll, Rochera, and Gispert (2014) found that teacher feedback plays an important role in online collaborative learning environments when students engage in small-group work. Through a case study, the researchers tracked 145 instances of teacher feedback within two groups of students. They found that the teacher engaged in two distinct types of feedback. *Verification* involved confirming whether student-supplied ideas were correct or incorrect and, if flawed, how they should be refined. *Elaboration* involved introducing new concepts and questions to facilitate students' attainment of learning goals. They found that the mix was beneficial and appropriate, and that timing mattered: Feedback delivered promptly had the greatest impact.

Coll, Rochera, and Gispert's findings reinforce the value of an instructor's presence, even in learning environments that involve a great deal of student–student communication. Well-timed teacher feedback, they found, can enhance collaborative learning by reinforcing correct answers, dispelling misunderstandings, and introducing the kind of probing questions and ideas that push learners closer to desired outcomes.

Sprow Forte and Blouin (2016) studied the conditions in which precursors to transformative learning, or shifts in perspectives, arise when instructors engage students in learning experiences based on the sociocultural techniques of dialogue, collaboration, and other forms of interaction. Using a purposeful sampling method, the researchers recruited 24 study participants. The participants, all active teachers, had enrolled in an online program for teaching English as a second language. As part of their program requirements, the teachers completed six to eight reflective journals per semester.

The researchers studied the contents of these journals and coded them for so-called "precursors" to transformative learning, such as "exploring new roles" and "critically reflecting on assumptions." They found that the teachers had succeeded in engendering precursors to transformative learning when they explored social issues with their students, particularly around the themes of race and class. The precursors were most prominent when the teachers strived to encourage critical reflection among their students. The results also showed that learner readiness plays a critical role in the onset of precursors to transformative learning, with learner motivation being especially important.

Facilitators can also provide valuable feedback to learners by prompting them to engage directly in conversations about sociocultural theory. In a large-scale quantitative study, Johnson (2015) analyzed data from more than 45,000 cases from the 2009 Multi-Institutional Study of Leadership, a dataset comprised of respondents from more than 100 four-year institutions of higher education. Johnson focused on the relationships between a set of interrelated variables—social-change behaviors (e.g., community service), discussions of sociocultural issues, and social perspective taking (i.e., empathizing with others' circumstances)—and considered how they impact how students conceptualize their civic identities.

Of these factors, social-change behaviors played the biggest role in shaping students' civic identities. Social perspective taking also correlated strongly to civic identity. Discussions of sociocultural issues, meanwhile, correlated to civic identities to an extent that was four times weaker. Johnson also found that race plays an important role in developing a civic identity, and educators should focus on supporting students in connecting discussions about sociocultural issues to civic identity.

Principle 2: Learner motivation determines success and should be cultivated Barak, Watted, and Haick (2015) examined how language of instruction and social engagement affect participation and completion rates in massive open online courses, studying participants enrolled in English and Arabic versions of a course on nanotechnology. The researchers did not find language of instruction to be a predictor of how or to what extent participants engaged with the course. They did, however, observe correlations between motivation and completion rates: More motivated students were more likely to finish. But the researchers also posited that course engagement, for example, regular postings to discussion boards, could enhance feelings of motivation. Working collaboratively was also tied to higher levels of motivation, suggesting a complex relationship between motivation and engagement in which each variable potentially enhances the other.

Barak, Watted, and Haick also examined why learners who complete MOOCs do so, given the high attrition rates associated with the format, and they identified five categories of so-called "completers." *Problem solvers* find motivation in discovering novel solutions to contemporary, real-world challenges. *Networkers* hope to expand professional relationships and cultivate collaborative partnerships. *Benefactors* seek ways to enhance society through education. *Innovation-seekers* value knowing about cutting-edge technologies and trends. And *complementary learners* want experiences to supplement formal studies, typically a college or university course. Their findings suggest motivation can spring from many sources.

Also critical to cultivating motivation is an understanding of the expectations learners bring to their experiences. Liljedahl, Boman, Falt, and Bolander Laksov (2015) conducted 15 interviews with students in face-to-face clinical learning environments and performed a content analysis on the conversations. The researchers studied both medical and nursing students and found notable differences between the two cohorts, particularly with regard to their expectations of the experiences, which tended to be higher among the nursing students. Their findings suggest role-related differences, defined by societal expectations, stature, and cultural norms, can have an important effect on learning outcomes. Other differences were observed with regard to how learners perceived the clinical supervisor, who also functioned as a learning facilitator, or guide. Medical students saw their facilitator as an expert and gatekeeper who managed their experiences. Nursing students, in contrast, saw their supervisor as a means to integrate within the group, but also as a potential threat to their ability to operate autonomously. Liljedahl, Boman, Fält, and Laksov also determined that the structure, resources, and the typically well-established intention of a clinical learning environment encouraged students to socialize while learning, both in their current roles as students and toward their future aspirations as working professionals. Socialization in these cases can be thought of as "learning how to learn" and "learning how to work" through interactions with peers and facilitators.

Principle 3: Flexible support resources enable collaboration Using qualitative methods and an exploratory approach, Haraldseid, Friberg, and Aase (2015) studied nursing students' perceptions of the design of in-person clinical skills laboratories (CSLs). Such learning environments provide students with opportunities to practice hands-on skills, become acclimated with relevant equipment and technologies, and mimic the kinds of interactions they will experience on the job, all in a structured environment designed to facilitate learner-centered instruction. The researchers studied 19 students enrolled in a single course via focus groups and content analysis, with the assumption that the effectiveness of situated learning environments such as CSLs varies depending on how well such environments are designed. Based on the interviews and observations, they identified three design characteristics of particular importance: authenticity, the facilitation of motivation, and resources.

These characteristics can inform both the physical and conceptual design of the environment. *Authenticity* concerned the extent to which participants felt the CSL reflected the kinds of spaces they would occupy in a professional context, after graduating. Participants raised concerns, for example, about using old equipment. However, since it was not clear how many, if any, participants had first-hand experiences in professional settings, their desire may not have been for an authentic environment so much as an ideal one. Regarding *the facilitation of motivation*, Haraldseid, Friberg, and Aase focused specifically on the need to cultivate learners' intrinsic motivation in CSLs. Unlike extrinsic motivation, the desire to perform well on an exam, for example, intrinsic motivation taps into the natural desire to learn to and grow, something constructivist researchers and practitioners have long identified as essential to successful instruction. Lastly, the focus on *resources* reflected the need to provide a flexible set of tools, information, guides, and coaching to help learners navigate through situated learning environments without requiring one predefined path. With appropriate scaffolding, learners can take the initiative to define their own learning processes, adjusting as needed, based on teacher or facilitator feedback.

When designing learner support, it is also important to recognize that what appears to be deficiencies could, in fact, merely be different ways of understanding. In a pair of case studies, Lewis (2016) examined the kinds of errors made by students with mathematical learning disabilities when working with problems involving fractions. Lewis used a sociocultural lens to design and implement the study, leading to a focus not on how many errors students made but instead why they made the errors and what problem-solving approaches were used. Sociocultural theory frames learning as a product of both biological and sociocultural growth. So-called learning disabilities can arise along either dimension, but a sociocultural perspective emphasizes not perceived deficiencies but rather different ways of processing information that could encumber students who are not afforded alternative pathways to mastery. In this context, students who previously struggled to solve problems could excel, if they employed new sets of cognitive strategies with appropriate resources and support.

Learner support can also come in the form of co-mentoring. Kibler (2017) highlighted the value of peer scaffolding in collaborative learning environments. In addition to learning from experts, Kibler noted, interactions with classmates can lead to valuable learning experiences via co-learners who may or may not have superior skills and expertise. In cases where a peer is less skilled, interaction can lead to collaborative learning outcomes by giving students opportunities to teach what they already know. In the case of similarly skilled classmates, interaction can lead to dynamic collaboration and mutual support. And in cases of more-skilled classmates, collaboration provides additional opportunities to acquire new knowledge and insights. These interactions can also be understood as a kind of co-mentoring (Gunawardena, Frechette, & Layne, 2019).

Principle 4: Collaborative learning groups take both time and structure to form, and facilitators should shift roles at different stages of group development Using network analysis methods, Ouyang and Scharber (2017) examined how the design of online discussions impacts how a learning community develops. The researchers studied a class with 20 students and found that a dynamic learning community emerged over time, with the instructor shifting roles as the course progressed. Overall, the researchers found that the instructor, an online educator with 15 years of experience, assumed a facilitative role. The exact nature of that role shifted over the 14-week course. Initially, the instructor served as a guide. In the middle portion of the course, a more collaborative role emerged, in which she exchanged ideas with students as a peer. In the final weeks, the instructor assumed a less-involved observer role, participating less actively in the discussions over time. Overall, the instructor communicated with each of the 20 participants in 72 distinct interactions.

The network analysis methods that Ouyang and Scharber employed led to a detailed understanding of the connections between the instructor and participants by quantifying individual interactions and creating maps across participant interactions, treating each person as a node within a larger system. The researchers concluded that collaborative learning cohorts mature over time, and adept instructors shift roles depending on the community's growth and the shifting needs of individual learners. On the whole, they found additional evidence for the value of a facilitative role focused on symmetrical relationship between instructors and students, and they emphasized the value in creating space for student replies by eschewing a "more is better" approach to instructor communication.

Researchers have also shown the importance in establishing a structured environment in which learners can communicate and collaborate. Deng, Chen, and Li (2017) used qualitative methods to research the use of both formal and informal platforms to facilitate cross-cultural discussions among 75 university students in Hong Kong and Taiwan. They studied interactions in both formal and informal settings online, finding differences in student experiences from one setting to the next. The formal section involved structured small-group discussions on Moodle, and the informal component involved an unstructured large-group discussion on Facebook. Overall, the students reflected positively about their experiences, especially those in the more formal context. Deng, Chen, and Li concluded that the large-group dynamics inhibited robust discussion rather than enhanced it, and a lack of direction stymied students who might otherwise have been interested in joining in. The researchers also surmised that a lack of time to engage prevented the leaning cohort from fully coalescing, and language barriers—the experience was conducted in English, although it was not the native language for the students—also prevented deeper involvement.

Principle 5: Learners' past experiences inform their current learning Pratt, Tedder, Boyask, and Kelly (2015) tracked how doctoral students progress through a professional Ed.D. program in education. They applied a sociocultural approach to gain insight into how students perceived their experiences and interactions via interviews and textual analysis of email correspondence, along with documentary evidence in the form of program descriptions and related materials. Through a series of interviews with eight participants, the researchers developed case studies about learning experiences and how students related both to one another and to the pedagogy presented to them. They found that Wenger's (1998) concept of learning via communities of practice mapped well to the cohort's experiences. Wenger defined learning as a kind of change across one or more dimensions: *identity*, or a change in self-concept; *community*, or a change in relations to others; *meaning*, or a change in understanding; and *practice*, or a change in behavior. Pratt, Tedder, Boyask, and Kelly found evidence of all four types of changes in their interviews.

However, they also identified historicity as an important theme. In the context of sociocultural theory, historicity refers to the fact that learners bring a wealth of previous social experiences to any given educational context that influence how they communicate and behave. Often, these influences play an important role in forming learning cohorts in the first place. The researchers also found that students described their experiences in both professional and academic terms, suggesting that they sensed connections not just to their previous experiences but to current or future work in the profession. Overall, Pratt, Tedder, Boyask, and Kelly (2015) found that students experience professional doctorates in complex and individualized ways, connecting their learning to both past experiences and contemporary experiences in professional settings.

Past learning experiences also need to be considered with regard to learners' epistemological beliefs. Lee, Lee, Makara, Fishman, and Hong (2015) examined Korean and American students' perceptions about their learning abilities. They first studied students at a top Korean university and found that participants rated their creative and critical learning abilities lower than their receptive learning abilities. That is, they believed they were more adept and recalling and understanding information than evaluating and creating it. In a follow-up study, the researchers found that American students rated their creative and critical learning abilities higher than their receptive learning abilities. For Korean students, self-appraisals of creative and critical learning abilities did not increase as they progressed through higher education, but, for American students, they did.

Creative and critical thinking were stated learning goals at both universities. The researchers cautioned, however, that cultural norms and expectations may have influenced how students self-rated. These norms contribute to different epistemological beliefs: Whereas Western students tend to see learning as a process through which the external world can be understood and mastered, Eastern students see learning as a means to master their inner thinking and advance their moral development. Nonetheless, they also conclude that the results provide some evidence the universities do not prepare students to think critically and creatively to the degree that they espouse.

Principle 6: Both physical and virtual spaces should be designed to promote collaboration Rook, Choi, and McDonald (2015) considered how expertise with learning theory can inform the design of physical learning spaces. They interviewed two individuals involved in the design of a new innovation studio—the architect and the studio's director—to understand the roles they played in designing the space and the rationale they used for their design decisions. Based on those interviews and additional conversations with relevant stakeholders, including university administrators, they determined that the architect and director arrived at similar decisions on all major design decisions, but often applied different reasoning to their choices.

Whereas the architect tended to focus on creating spaces built on physical design principles, the director employed an understanding of human learning, particularly through the lens of sociocultural learning theory. That resulted in three critical design decisions: Diverse spaces should be incorporated to encourage a range of interactions between individuals and among small and large groups; rather than outfit computer labs, students should be encouraged to bring their own devices to reinforce the idea that the space is for communication and collaboration, not technology; and technology-enabled furniture (desks with built-in audio and video cables, for example) should be used to facilitate sharing ideas in different formats. The researchers determined that, although it is often overlooked, learning theory expertise can, and should, be used to inform the design of physical learning spaces, allowing principles two inform design ideas, at least for a physical space.

Virtual spaces also need to be designed to facilitate communication. Tubman, Oztok, and Benachour (2016) analyzed six MOOCs across subject areas, from literature to virology. They studied how participants interacted with one another for evidence of in-depth conversations, defined as multiple replies between two or more learners around the same root post. Conversation, the researchers posited, is a critical vehicle through which sociocultural learning, as conceptualized by Vygotsky, manifests. Deeper conversations—those with more replies to the same root post or other replies in the same thread—provide more opportunities for sociocultural learning to occur. Across 10 sessions, with thousands of participants, Tubman, Oztok, and Benachour found just nine conversations that had reached 10 or more replies, less than 1% of all conversations.

Most conversations contained just one or two replies, the researchers found. These results were consistent across subject matters, suggesting that the overall low reply-rate is attributable not to content domain but rather platform limitations and instruction. With regard to platforms, the researchers discussed the possibility that a learning system that provided more exhaustive updates, for example, email alerts on any reply to a conversation—not just a direct reply to the person who began the thread—would promote deeper conversations. They also suggested that instructors and facilitators should focus on providing clear-cut instructions that set expectations and remove ambiguity about the technical know-how needed to navigate a platform's communications tools.

Conclusion

This chapter outlined the best ways to facilitate sociocultural learning based on recent research. Vygotsky's theory of sociocultural learning provided an overall theoretical frame for the exploration, and the importance of understanding learners' internal states, their communications, and the broader societal norms and values that shape their experiences was established. Six principles, derived from empirical research conducted in the past five years, since the publication of the fourth edition of the Handbook of Research on Educational Communications and Technology, were presented to highlight the most important ways to facilitate sociocultural learning. These principles reflect the value in considering a broad mix of both types and sources of facilitation for sociocultural learning. The principles highlighted the importance of (1) facilitator feedback, (2) learner motivation, (2) flexible support resources, (3) providing both time and structure to form collaborative groups, (4) the role learners' past experiences play in shaping their current learning outcomes, and (5) the need to consider the design of both physical and virtual spaces to promote collaboration.

Limitations in research designs were also highlighted. Many of the studies reviewed were exploratory in nature, and small samples sizes and qualitative methodologies limit the extent to which findings can be extrapolated to diverse learning contexts. Rapid technological progress also complicates efforts to establish definitive insights. Yet, taken together, the studies reviewed in this chapter reveal a core set of principles, or values, consistent with broader literature. These principles translate into tangible guidance for instructional designers, instructors, and others interested in crafting effective sociocultural learning experiences. Going forward, additional research focused on different learning cohorts and emerging technologies will continue to clarify how to design experiences that capitalize on the benefits of communication and collaboration.

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Instructional Design for Learner Creativity

Jason K. McDonald, Richard E. West, Peter J. Rich, and Brad Hokanson

Creativity is a critical learning outcome for the twenty-first century (Pellegrino & Hilton, 2012; Soulé & Warrick, 2015). Changing economic conditions throughout the world, the demand for fresh solutions to difficult societal problems, and the personal benefits that arise as individuals fulfill their creative potential, all indicate the importance of creativity becoming not only part of, but deeply integrated into, all types of educational environments (Naghsh, Abari, & Motlaq, 2013; Sawyer, 2012; Wadaani, 2015). This includes learners at all levels—in elementary and secondary education (Beghetto, 2016b); higher education (Livingston, 2010); and workplace learning (Carnevale, 2013).

Because creativity is so crucial to both individuals and societies, helping people become more creative is a task that educators, policy makers, and other stakeholders cannot ignore (Paniagua & Istance, 2018). Yet factors within the educational system challenge our ability to foster learner creativity. Unfortunately, many people, teachers included, believe that creativity is innate and cannot be developed (Aljughaiman & Mowrer-Reynolds, 2005). Additionally, even when attuned to the need, many teachers are ill-prepared to teach in a manner that nurtures creativity (Liu & Lin, 2014). Similarly, outside of the arts, curriculum is typically underdeveloped in the area of creativity skills (Sternberg, 2015; Wyse & Ferrari, 2015). Some teachers feel that systematic conditions, such as high stakes testing, have imposed barriers that interfere with their ability to encourage creativity within students (Olivant, 2015). And finally, although research has shown that most people can become more creative to some degree (Beghetto & Kaufman, 2014), there is still much progress to be

J. K. McDonald (✉) · R. E. West · P. J. Rich
Brigham Young University, Provo, UT, USA
e-mail: jason@byu.edu; rickwest@byu.edu; pjrich@byu.edu

B. Hokanson
University of Minnesota, St. Paul, MN, USA
e-mail: brad@umn.edu

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made in understanding how to design instruction that promotes creativity. As Barbot, Besançon, and Lubart (2015) concluded, “despite over half a century of systematic research on this topic, [teaching creativity] is still incompletely understood” (p. 371).

We do not mean to understate the important body of academic research on creativity nor the many practical techniques that educators have developed to nurture creative potential in their students, neither of which we can fully address in this chapter. What we do wish to highlight, however, is the opportunity that still exists for developing potent approaches that encourage creativity in all learners. This leads to the issue we address in this chapter: if educational environments can be better designed to nurture learner creativity, what can instructional designers and educational technologists do in helping to accomplish this goal? By learners, we refer to people of all ages engaged in either formal or informal events of learning. And by instructional design/educational technology we draw from the AECT definition, as “the … application of theory, research, and best practices … [to] mediate and improve learning and performance through the strategic design, management, and implementation of learning and instructional processes and resources” (Association for Educational Communications and Technology, 2018).

Our discussion is structured as follows: first, we briefly review the literature of creativity, both to describe some attributes that are important to nurture when fostering learner creativity, as well as to identify common conditions for promoting creativity in learners. Next, we examine some examples learning environments that foster learner creativity, particularly as related to helping people develop an integrated creative identity and not just the acquisition of intellectual or skill-based components of creative action. Third, we discuss implications from the research and examples and offer recommendations for the practice of instructional design and technology, to help designers better address learner creativity through the instructional environments they create.

Understanding Learner Creativity

While newer terms continually emerge (e.g., design thinking, twenty-first century skills, disruptive innovation, etc.), the reality is that “the field of creativity research and practice often repeats the same kinds of words and concepts decade after decade” (Glăveanu, Tanggaard, & Wegener, 2016, p. 2). The study of creativity is broad and often examined in one of two ways: by studying “eminent creativity” or what is often described as “Big-C” creativity (see, for example, Csikszentmihalyi, 1997; Simonton, 2013) and the examination of creativity in the individual, that is, everyday creativity. Recent research has further categorized creativity into four types, adding “mini-c” and “Pro-c” creativity to the previous categories (Beghetto & Kaufman, 2007; Kaufman & Beghetto, 2009), to explain the creativity involved when engaging in new experiences, and the development of professional creativity skills, respectively. Whatever the words used, however, Beghetto and Kaufman

(2014) explained that for at least six decades the simplest definitions that researchers have developed for creativity include at least two key criteria: the creative product is both novel and useful (or sometimes phrased as intentional) for its context.

Our purpose in this chapter is not to replicate the expansive reviews of the literature on creativity. Nor do we discuss all the nuances that could be added to basic definitions of creativity, with additional qualities that scholars have emphasized in various contexts. Rather, we selectively examine and discuss research relevant to our aims. For a more thorough exploration of creativity definitions and research, we recommend many of the excellent handbooks on the topic, such as Feist, Reiter-Palmon, and Kaufman (2017), Kaufman, Glăveanu, and Baer (2017), and Mumford (2018).

In the context of instructional design, creativity becomes a focus as practitioners attempt to design learning environments that nurture creative potential in end learners. Recent scholarship includes exploration of many attributes that influence a person's creativity. The sources we examine were selected to represent, as best as possible, the breadth of research and theory on creativity, in order to summarize several key ideas in the literature that instructional designers may find relevant and applicable. We do present some historical views to provide foundational context; however, most of our sources are more recent to provide a current view. We also recognize there are differences in creativity research across cultures, with North American researchers often focusing on quantitative, psychological measures of creativity, with other areas (Europe, the Middle East, South America, Asia) generating insights based on interdisciplinary and mixed-method approaches (Craft, 2008). As appropriate, we draw upon sources of both types in our study. And finally, while recognizing the value of creativity as expressed by domain-changing experts, we focus on the wider application of developing the creativity of learners in their everyday lives.

We summarize our discussion under six headings, although within each we refer to other attributes that have also been found to correlate with creativity:

- Divergent and convergent thinking
- Creative self-efficacy
- Autonomy
- Improvisation and playfulness
- Willingness to accept failure
- Abstract thinking

Divergent and Convergent Thinking

Divergent thinking, or attempting to generate many ideas, is regularly found to correlate with higher creativity (Nusbaum, Silvia, & Beaty, 2014). One reason seems to be that as a person generates more ideas, later ideas are typically more original than those produced earlier. This is both a consistent finding in creativity research, and also one of the oldest, extending back to the 1950s (Beaty & Silvia, 2012). Divergent thinking also correlates with a willingness to accept risk, including acting in ways contrary to social norms (Runco & Selcuk, 2012). Finally, divergent thinkers tend to have an "openness to experience," meaning they are receptive to the new or unfamiliar, which is also associated with creativity (Im, Hokanson, & Johnson, 2015, p. 4).

While literature frequently emphasizes divergent thinking, scholars have also stressed the importance of its complementary construct, convergent thinking. Convergent thinking is identifying the most correct, or appropriate, idea/response for a given context (Cropley, 2006). While this may seem somewhat antithetical to the notion of creativity as imagining something novel, convergent thinking emphasizes the other key component of creativity—being able to critique ideas, choose appropriate ideas, and develop those novel ideas into something useful. As Dietrich and Haider (2017) noted, "an ingenious idea is often the first step toward a creative product but this is neither necessary nor sufficient" (p. 2). One must also engage in processes of evaluating alternatives and refining possibilities to develop concepts into truly creative (both novel and useful) solutions (Mehta, Henriksen, & Mishra, 2017). Additionally, drawing attention to the creative nature of convergent thinking can help certain types of people, such as those uncomfortable with risk, to recognize that they can also contribute to creative solutions and develop their creative potential, as much as those who are more comfortable with uncertainty (Shen, Hommel, Yuan, Chang, & Zhang, 2018).

Creative Self-Efficacy

Creative self-efficacy is the belief that one can "produce creative outcomes" (Tierney & Farmer, 2002, p. 1138). Closely related is the construct of creative consciousness, which is being aware of one's own creativity, and which Davis (in his review of over 200 different personality traits that researchers have used to help explain creativity) concluded was "the number one trait" associated with people's' potential to actually act in creative ways (Davis, 2004, p. 87). Creative self-efficacy has been found to correlate with peoples' curiosity (Karwowski, 2012), which is associated with creativity to the extent that it improves the quality and originality of ideas (Hardy, Ness, & Mecca, 2017). Creative self-efficacy tends to be higher among teenagers and young adults, declining as people age (Karwowski, 2016).

Autonomy

Autonomy is the condition of people feeling meaningful ownership over, and responsibility for, their own lives. Autonomy has been found to correlate with creativity in ages ranging from young children (Craft, Cremin, Hay, & Clack, 2014; Davies et al., 2013) to adults learning in the workplace (Karakas & Manisaligil, 2012). Autonomy has been postulated as an essential attribute in developing intrinsic motivation (Deci & Ryan, 2000) and in school settings for increasing student satisfaction and engagement (Zhao, 2012), all of which factors can lead to enhanced creativity (Beghetto & Kaufman, 2014; de Jesus, Rus, Lens, & Imaginário, 2013).

Improvisation and Playfulness

Improvisational activities allow people to explore ideas in low-stakes environments, reflect on their own knowledge, and engage productively with others about emerging ideas—all of which are inputs into creative thought and action (Sawyer, 2006). While improvisation exists in non-playful scenarios as well, it commonly exists alongside playfulness, often correlated with spontaneity and emergent improvisation to react to a situation at hand (Martocchio & Webster, 1992). Perhaps the archetypical case of this spontaneity and improvisational creativity is child's play. Beghetto and Kaufman (2014) observed that children's creativity is improved when they have access to materials that allow them to express playful ideas in tangible forms, and Davies et al. (2013) concluded play was one of the factors of creativity most well-supported by empirical research. Play and improvisational activities have also been found to be important in developing creativity in some adult contexts, such as the field of design (Loudon, Wilgeroth, & Deininger, 2012) or in the development of new consumer products/services (Sawyer, 2014).

Willingness to Accept Failure

Creativity is associated with accepting the possibility of failure as an opportunity for learning and growth. Failure is almost an inherit companion to creativity, given that novel responses to challenges or questions simply may not be successful, and only people who persist have the possibility of eventually generating a solution that works (Friedman, 2013; Tahirsylaj, 2012). However, as He (2015) pointed out after studying group failure, "it takes practice, training, and learning" for many to learn to deal productively with failure (p. 76). Kapur (2016) calls this "productive failure" and distinguishes it from other types of failure (that do not promote creativity), in that it creates conditions that prepares people "to learn better from the subsequent instruction that follows" (p. 290). Aversion to failure has been found to decrease creativity in such diverse groups as nurses (Chan, 2013), engineers (Cropley, 2015; Toh & Miller, 2016), and honor students (Wintrol & Jerinic, 2013).

Abstract Thinking

Psychologists typically define abstract thinking as considering concepts symbolically or through generalized properties and relationships, rather than through direct, concrete connections to the real world (Dumontheil, 2014). It is this property of viewing situations conceptually that allows one to recognize non-conventional or new ideas not previously connected to the problem at hand (Sternberg & Lubart, 1999). As psychological research into creative mental processes increased from the latter half of the twentieth century to the present, abstract thinking has frequently been associated with creativity (Förster, Friedman, & Liberman, 2004). As an example, consider the Torrance Tests for Creative Thinking. While also assessing fluency (the number of ideas), originality (how unique the ideas are), premature closure (how open to new ideas the person is) and elaboration (elaborating and building upon an idea), the Torrance Tests also include abstractness as one of the main attributes of creative responses (Bart, Hokanson, & Cain, 2017).

Fostering Creativity in Learners

The efficacy of developing creativity in learners has been documented through extensive research, including individual studies and meta-analysis. Scott, Leritz, and Mumford (2004) examined 70 studies of creativity training with a diverse range of methods. They particularly found that creativity training helps in the development of divergent thinking skills, echoing the findings of Torrance (1972) and Rose & Lin (1984). Additionally, Smith (1998) cited more than 190 approaches that have been shown to positively impact learner development of creativity. These broad research studies on the actionable conditions involved in fostering people's creativity take different forms, two of which are relevant for this discussion: (a) developing individual creative attributes and (b) improving learners' holistic creativity.

Developing Individual Creative Attributes

Some research has focused on individual attributes of creativity and how teachers can nurture development of these attributes in learners. For example, autonomy is often developed by allowing students to engage in entrepreneurial activities. As West (2014) stated, research has found that "self-directed activity can substantially improve student morale, motivation, learning, and performance," all qualities associated with higher creativity (p. 56). Research indicates that a feeling of ownership improves people's potential to be successful in teams (Gard, Baltes, Wehle, & Katzy, 2013), instead of interfering with creativity by making it more difficult for students to receive critique from others within the group (Baer & Garrett, 2016).

This even extends to small children, as in Glăveanu, Branco, and Neves-Pereira's (2016) study of child–child preschool interactions that indicated cooperative learning also stimulated their autonomy.

As another example, researchers have examined the role of exposing people to diverse ideas as a way to help them develop the individual attribute of thinking more divergently, concluding that to become more creative, people should interact with thoughts, ideas, and perspectives different than their own (Harvey, 2014). Exposure to different ideas is so important, in fact, that Beghetto (2016a) called it "the heart of the creative process" (p. 11). Diverse ideas stimulate people's imagination and help them make a conceptual leap from the known and familiar into the unknown, which is the hallmark of a creative solution (Mumford, Medeiros, & Partlow, 2012). In other words, exposure to diverse ideas can give one the raw materials from which to compose novel, unconventional, or divergent concepts.

Improving Learners' Holistic Creativity

Other researchers have focused on the interconnected nature of creative attributes, and, in fact, assert that attributes of creativity are not improved in isolation from one another. Creativity is holistic (Csikszentmihalyi, 2014), and activities designed to improve one's creativity interact with, and build on, each other. Researchers have attempted to model these interdependencies in various ways. For example, Beghetto (2016a) developed a theoretical model that identifies the "relationship between individual and sociocultural factors at play in creative learning" (p. 10), emphasizing a process of learners:

- Attending to optimally discrepant stimuli;
- Combining those new stimuli with existing knowledge;
- Attempting to make sense of the combination;
- Experiencing a change in their understanding;
- Validating their new understanding as they express it to others;
- Evaluating how discrepant others' understanding is in light of their own views;
- Attempting to understand seemingly incompatible views held by different learners;
- Determining how different views can be made compatible with their own knowledge; and
- Recognizing how discrepant ideas are creative contributions to their own understanding. (see pp. 10–16)

Mumford et al. (2012) developed a different model, focusing on activities one participates in when engaging in creative behavior: "problem definition; information gathering; information organization; conceptual combination; idea generation; idea evaluation; implementation planning; solution monitoring" (p. 32). Still other perspectives focus on environmental or pedagogical influences on creativity, such as

Davies et al. (2013), who reviewed over 200 studies on the topic from which they synthesized research-based factors for promoting creativity in children:

> Flexible use of space and time; availability of appropriate materials; working out- side the classroom/school; 'playful' or 'games-bases' [sic] approaches with a degree of learner autonomy; respectful relationships between teachers and learners; opportunities for peer collaboration; partnerships with outside agencies; awareness of learners' needs; and non-prescriptive planning. (p. 80)

Translating Creativity Research into Practice

Perhaps these rich connections between the attributes of creativity help explain why it has not been easy to translate creativity research into practice. Although creativity has been studied by psychologists and other researchers for almost 70 years, educating for learner creativity still does not happen consistently (Beghetto, 2016b). This is not for lack of trying. A number of researchers have attempted to translate their own and others' findings into practical guidelines to assist teachers in better developing students' creative potential (e.g., Beghetto, 2016b; Kapur, 2016; Sawyer, 2006; Sternberg, 2015). Large-scale reviews of creativity research are also published on occasion, further summarizing research findings into guidelines for educators to use (for recent examples, see Abdulla & Cramond, 2017; Davies et al., 2013; Jindal-Snape et al., 2013; Simonton, 2012).

But as Beghetto and Kaufman (2014) summarized, "most strategies [for teaching creativity] are, at best, a curricular add-on and, at worst, something that seems completely irrelevant to the academic curriculum" (p. 56). By implication, while explicit creativity training should play a role in education, "supporting students' creative potential is [not] about trying to find sure-fire creativity techniques" that teachers can replicate regardless of other contextual factors (p. 56). Rather, the challenge that Beghetto and Kaufman see is to strengthen and reinforce teachers' existing practices so they might better contribute toward creative ends.

An example of fostering creativity by enhancing methods many teachers already use is found in disciplines that teach methods of prototyping or the creation of tangible representations of ideas so they can be discussed, explored, evaluated, and improved. Prototyping has long been used in design fields as part of idea generation when developing products for market, and in this sense has close associations with divergent thinking (Dow et al., 2012). But prototyping can also help people practice improvisation and play (Sawyer, 2006), as well as practice recovering from failure in relatively safe ways (Gartner, 2013). Prototyping has been used in educational contexts for students in the arts (S. Smith & Henricksen, 2016), innovation (Brown & Kuratko, 2015), engineering (Starkey, Toh, & Scarlett, 2016), architecture (Kirsch, Lubart, & Houssemand, 2015), and even marketing (Lee & Hoffman, 2014). It has also been used to encourage creativity in elementary and secondary students, in areas such as science (Dohyun, Yoon, & Kang, 2015) and technology (Hirschmanner, Lammer, & Vincze, 2015; Amanda Sullivan, Elkin, & Bers, 2015).

What is important in this example is that prototyping is not used in these disciplines as a specialized technique that "teaches" creativity to students, but is a disciplinary process within the domain that already correlates with creative activity. In providing this example we do not assert that all educators need to formally teach prototyping techniques. But we do believe that within every discipline are ideas, processes, or skills that could already be considered creative (Torrance, 1959). And so our encouragement, in the spirit of Beghetto and Kaufman's (2014) observation, is for teachers, instructional designers, and educational technologists to identify those existing disciplinary practices they can use—or improve on—as a strategy for fostering creativity in their own learners.

Fostering Creativity Through Instructional Design and Technology

It is our belief that the field of instructional design and technology has much to offer in helping to foster learner creativity, especially in the sense of developing learning environments that have structural affordances that encourage creative expression. To illustrate, we examine recent examples of innovative learning environments that seem to provide this benefit. Although the techniques and technologies we examine did not originate within the field of instructional design, most are receiving attention from instructional design scholars who are contributing toward both their theoretical rigor and practical application. We note in advance that these are not cases in which creativity is necessarily "taught" as an isolated outcome, although we can imagine how educators within each case might explicitly discuss creativity as well as techniques for developing it. Rather, these are a sampling of some of the rich environments that nurture many types of human potential, including creativity, and are provided as a starting point for readers' exploration. We provide this list in the spirit of making much of the preceding discussion more concrete, as well as providing models of how sound pedagogy and technology can be integrated into forms that encourage meaningful outcomes such as creativity:

- Making and makerspaces (Papavlasopoulou, Giannakos, & Jaccheri, 2017)
- Robotics education (Benitti, 2012; Danahy et al., 2014)
- Studio learning environments (Cennamo et al., 2011; Neuman, 2016)
- Student entrepreneurship programs/boot camps (West, Tateishi, Wright, & Fonoimoana, 2012; Wright, Skaggs, & West, 2012)
- Integrating arts education into traditional STEM topics (Guyotte, Sochacka, Costantino, Kellam, & Walther, 2015; Guyotte, Sochacka, Costantino, Walther, & Kellam, 2014)
- Technology enhancements for informal learning environments, such as museums or galleries (Hou et al., 2014)

Space does not permit a detailed review of all these examples; we do, however, provide discussion of the first three: makerspaces, robotics education, and studio learning environments. In each example, we highlight how the techniques and technologies that researchers have explored are integrated together. We also draw attention to findings of researchers who describe outcomes of the approach that are similar to various attributes of creativity. But in doing so, we emphasize that the connections we make are provided as commentary on the researchers' findings; we do not claim that the original researchers were explicitly testing theories of creativity such as those examined in this chapter. Our purpose, rather, is to suggest how instructional designers might draw inspiration from scholarly research, by pointing out possible interpretations of that research in a manner that is compatible with how each case has been viewed as a means for fostering learner creativity. Finally, even though we foreground discrete attributes in our discussion, we do so to facilitate readers' study of creativity. We emphasize that in actual practice the elements of each approach work together as a system to nurture creativity in a holistic sense.

Makerspaces

An emerging method for fostering creativity is through the use of makerspaces or spaces where people are given the physical tools of creation and as well as the time to tinker, practice, and build their own creations. Papavlasopoulou et al. (2017) described the emergence of makerspaces as part of a broader trend of "making" in general:

> During the last few years, the Maker Movement has appeared as a new trend that derives from the general maker culture, which is also described as a philosophy or phenomenon. The definition of the Maker Movement is very broad and builds on an individual's ability to be a creator of things, a 'maker.' There is a growing community of hobbyists and professionals with diverse skills and interests who make their own functional devices, from technological gadgets to home decorating. (p. 57)

The Maker Movement, and makerspaces as one expression of the movement, are based on strongly supported theories of effective learning, including experiential learning (Kolb, 2014) and constructionism (Harel & Papert, 1991). Makerspaces are also closely linked to a material and technological culture, as people are provided the physical and cognitive tools they need to express their ideas (Hsu, Baldwin, & Ching, 2017). These tools can range from simple construction supplies like wood and glue, to complex technologies like 3D printers, to computer programming languages. Makerspaces can be found in K–12 school classrooms (Taylor, 2016), universities (Wong, 2016), and even community centers (Smith, 2017). Recent studies have identified the development of creativity as an important purpose of these makerspace environments. Papavlasopoulou et al. (2017), in their study of over 40 peer-reviewed studies of makerspaces, concluded that part of their appeal was the chance for people "to express themselves creatively by designing and building digital or tangible objects" (p. 58).

One example of how makerspaces foster creativity is T.S.J. Smith's (2017) study of the Hacklab—a community makerspace in Edinburgh, Scotland. The Hacklab is a not-for-profit organization where people socialize, discuss, and create together, without oversight or formal direction. Although the space focuses on electronics, members can also make music, software programs, or even BioArt (art from biological material such as molds). Smith completed an ethnographic study of the Hacklab, observing and interviewing members, as well as participating in maker activities himself.

One of Smith's findings was the *improvisational* attitude cultivated in some members of the lab. As one woman prepared a new supply of mold (for making BioArt), she announced to the group that she welcomed anyone else who wanted to use the mold "to play," as she did (p. 138). Smith also observed similar "playfulness" and "experimentation" as musicians would assemble for regular exploration sessions (p. 144). This general attitude toward improvisation and experimentation also seems to have helped members develop a sense of *creative self-efficacy*. One man, who was told by an outsider that making certain types of technology was too difficult for amateurs, simply replied, "stand back and watch us" (p. 146).

The Hacklab also appears to have encouraged other aspects of creativity among its members. Participation allowed for a high level of *autonomy*. Members began projects when they found something interesting, and while they offered each other ideas, or supported each other through their individual expertise, no one would take responsibility for a project that was owned by another member. Additionally, it appears that people were encouraged to *think divergently* about projects in which they were engaged through the process of being exposed to other's *diverse ideas*, as well as to think *convergently* and *abstractly* as they discussed general principles of how objects work, and what would ensure their project would work, before trying to make it in concrete form.

Smith's findings are not isolated. James (2015) described the use of a makerspace with kindergarten students, striving to give her "students the freedom—within the rules—to make anything they want" (p. 1038). This led to high levels of engagement—"my students would spend all day, every day, in the Maker Space"—and students gained creative confidence as they saw the results of divergent thinking, improvising, and prototyping (p. 1038). Makerspaces have been used to foster similar creative results with engineering students (Saorin, Melian-Diaz, Bonnet, & Carrera, 2017), student librarians (Bowler, 2014), and nurses (Marshall & McGrew, 2017).

Robotics Education

A technology-centric case that is showing promise in fostering learner creativity is robotics education. Initially, one might be tempted to believe that working with robots is an activity for older students. However, robots are increasingly being used with students as early as preschool and throughout their formative years. This is in part due to increasing requirements that children learn computing throughout their education. Beginning in the 2014–2015 school year, for example, all children in the

UK were required to begin learning computing starting in Kindergarten (Furber, 2012). The recently revised Australian educational standards include a "digital technologies" component and suggest that students begin using "robotic devices" as early as second grade (http://www.australiancurriculum.edu.au/technologies/digital-technologies/curriculum/f-10?layout=1). New Zealand's standards include similar language (http://dtg.tki.org.nz/What-is-the-DTG). With over 20 European countries having committed to make computing education compulsory at some level by 2020 (Balanskat & Englehardt, 2015), and several U.S. states following suit (CS4RI, 2017; Ribeiro, 2013; Senate File 274, 2017; Smith, 2015), robotics may become a common element to formal education within the next decade.

A recent study conducted on the Student Robotics Initiative (SRI) reports on the creative activities of fourth to sixth grade students who engaged with robotics during normal school hours (Nemiro, Larriva, & Jawaharial, 2017). The SRI was conducted in three elementary schools representing a diversity of students. Over a 3-year period, researchers observed student and teacher behavior during robotics lessons. Students were each taught to program Lego NXT robots over seven lessons throughout the course of the year, culminating in an open-ended district-level challenge between students. Researchers observed the nature of student–student interactions, teacher–student interactions, and the effect the environment had on creativity. Students kept daily journals to indicate what they were working on, what they learned that day, and any frustrations they were experiencing. Their research may have been best summarized by a 4th grade student who said, "my favorite thing about working on robotic projects is that it gives you more creativity" (p. 70). In this study, it is clear that students were conscious of their own creativity and how it may have been affected by learning robotics, suggesting the attribute of *creative self-efficacy*.

Researchers observed three different classroom setups at each location, from a free-form open environment, to an increasingly traditional "chairs-in-rows" arrangement. They noted that the more open space lead to nearly seven times more comments from students about creativity and open ideas, thus promoting the notion that the way a physical space is set up can influence freedom of thought and behavior. At all three locations, researchers noted a high level of enthusiasm from students and a natural interest in the topic. While students were given specific tasks to work on, they seemed to demonstrate a high level of *autonomy* in figuring out solutions to those tasks. Not only did they demonstrate autonomy in their thinking but they also took responsibility for their own designs and learning, asking teachers for guidance when they were stuck on a problem or asking other students to quiet down if they could not hear an explanation.

Students at all three schools worked in teams of two or three; within each team students discussed *diverse ideas* as well as *divergently* generated ideas to solve each problem. These solutions were not always the most efficient, and researchers noted that in some cases, students required the teacher's guidance to *converge* toward a plan for solving a problem rather than using trial-and-error approaches. Nevertheless, researchers noted four distinct ways in which students used idea-generating techniques to stimulate their creative thought and training (use of analogies, probing questions, examples, and robotics journals). Furthermore, though the task was the same for each group, researchers noted that teams generated distinct and novel solutions in every case. In addition, working with robotics was a highly iterative process wherein students worked toward a specific goal, breaking a problem down into its respective parts, creating and refining *prototypes* until they had reached an acceptable solution.

Working with robotics was not without its frustrations. Students experienced repeated failure as they sought to control their robots. As one student stated, "although we made a lot of mistakes, we learned from them and we never gave up. The experience overall was that even through all the trial times, keep trying to accomplish your goal and everything could be possible" (p. 81). Students learned that *accepting failure* was part of the learning process, and they developed resilience in order to overcome these failures.

This case does not stand alone in its observation that working with robotics can be a highly creative activity. A recent study surveyed teachers around the world who are involved in teaching coding in K–8 classrooms (Rich et al., 2019). Teachers from 23 different countries responded to the survey. When asked in an open-ended question what successes they had noted in children, many indicated an increased level in student creativity, with some teachers specifically attributing the change to students' participation in a robotics competition. Others indicated, "many girls discovered a new way to express their creativity" (p. 324). Similar results have been noted by others (Bers, Flannery, Kazakoff, & Sullivan, 2014; Okita, 2014; Sullivan & Bers, 2016).

Studio Learning

In contrast to our previous examples, our third case, the design studio, has a long history in education. Traditionally, the studio has been a means of initiating people into the professional culture and practices of a design discipline, like architecture or industrial design. This enculturation is one of the ways studio learning differs from other forms of project-based learning. While students do typically work on project challenges in studio environments, they also engage in reflection and other activities designed to assimilate them into the culture, traditions, and way of thinking of their chosen profession (Cennamo & Brandt, 2012). Studios are also often recognized by their dedicated learning spaces where students spend extended hours of time and learning being facilitated through feedback on work, more so than through direct forms of instruction (Brandt et al., 2013).

In recent years, the studio approach has also been explored in other educational settings, as disciplines beyond traditional design fields have incorporated design inquiry into their curriculum. This has happened both within higher education (Lande & Leifer, 2010) and in secondary education (Ke, 2014), often in the context of STEM subjects. Often, these modern configurations of the studio also integrate technology into the system, both to encourage greater collaboration between participants (Blevis, Lim, Stolterman, & Makice, 2008), and because the subjects taught are sometimes based around the design of technologies, such as in human–computer interaction (Brandt et al., 2013).

Research on the studio often viewed it as an environment that encourages creative action (Knowlton, 2016). As Wang (2010) stated:

> All things considered, the culture of the design studio might be described as a vital complex of material representation, social collaboration, creativity, emotionality and a tolerance for uncertainty—if not outright confusions—balanced with a faith that meaningful designs will eventually emerge. (p. 176)

A study conducted by Cennamo et al. (2011) specifically explored how the design studio can foster creativity, in the contexts of architecture, human–computer interaction (HCI), and industrial design education. They contrasted studios from each discipline, noting how different practices in each either encouraged or discouraged student creativity. On the surface, the studios were very different environments. Architecture and industrial design studios met for longer periods of time, for a total of 12 hours in class each week. Students also had unlimited access to the studio outside of class time. The HCI studios, in contrast, were more similar to traditional courses in the amount of time students spent in class—about 3 hours a week.

The studios were also different in their instructional practices, some of which affected the level of creativity students exhibited. For example, the architecture and industrial design studios focused on "idea generation," as opposed to the "idea refinement" more common in HCI studios (p. 651). This took the form of industrial design students engaging in wider varieties of brainstorming activities than those from HCI, with the goal of generating as many ideas as possible for solving their problem (*divergent thinking*). It also included encouragement from the industrial design instructor to consider how everyday objects could take "completely ridiculous, different forms," before committing to a concept for further exploration (p. 652). Students in the industrial design studio were also encouraged to *think abstractly*, by focusing first on the conceptual principles of an idea before trying to generate it in concrete form. All of these examples contrast with the HCI studio, where students spent much of their time adapting familiar interface concepts to address the design problems they were given in class. Cennamo et al. (2011) identified these differences as "primary challenges to creative thought" in the HCI studio (p. 651).

Cennamo et al. (2011) also identified other factors that also impacted the creativity between the different studios. The industrial design instructor modeled a positive attitude about ideas even if they would ultimately prove unproductive—"there are no bad ideas in the beginning!"—thereby encouraging students to *accept failure* as part of their creative process (p. 652). In contrast, HCI students often seemed to self-limit their own ideas, not wanting to explore concepts that might prove difficult for them to later implement. And, while students in all studios were encouraged to *prototype* their design ideas, and expected to exercise *autonomy* in choosing which ideas to prepare for more formal critique, early in the study, HCI students limited their prototypes to creating PowerPoint mockups of interface ideas. The researchers observed this formal tool inhibited student creativity because the high-fidelity of their rendering discouraged critical evaluation of the underlying concepts. They contrasted this with students from other disciplines who seemed to use multiple forms of modeling in a more *improvisational* way, both technologically based, “software, scanners, 3D printers, digital photography,” and material, “hand-built modeling, hand sketching, workshop construction,” to explore more deeply their creative impulses (p. 653). Later in the study, when HCI students also started using lower-fidelity, more improvisational forms of prototypes like sketching, the researchers concluded that the creativity of students’ work correspondingly increased.

Other studies of creativity in the design studio have generated similar results. Hargrove (2012) explored idea generation methods in the design studio such as “reverse brainstorming … metaphorical thinking … [and] random input” (p. 11) that encourage students to think more divergently and abstractly, help them become more conscious of their own creative activities, as well as help them model ideas in forms that would allow for beneficial evaluation. And Vyas, van der Veer, and Nijholt (2013) focused on the interplay between collaborating and prototyping in the generation of creative ideas in an HCI studio, concluding on a positive, two-way relationship between the variables. They also explored uses of technology to facilitate both collaboration and prototyping, finding technology to be effective when it was used to help students better interact with prototypes/models, explore creative ideas, and communicate with students or others not physically located in the studio itself.

Implications and Recommendations

The research we have examined in this chapter suggests that there are meaningful and practical actions that instructional designers can take to better foster learner creativity in educational systems. In this section, we share some of these implications: supporting creativity though system and space design; teaching that nurtures creativity; and promoting holistic creative development.

Supporting Creativity Through System and Space Design

The research on makerspaces and design studios indicate that qualities supportive of creativity can be intentionally designed into the systems in which people learn, meaning the culture and practices of a situation make it easy for people to express their creative potential. Wanqing, Tianyu, Zhichou, Jian, and Jianhu (2018) called this the design of a “humanistic” environment to support learner creativity. Learning environments seem especially supportive of creativity when they promote participating working together across disciplinary boundaries (Guyotte et al., 2015). As one instance, at Brigham Young University, the Creativity, Innovation, and Design faculty group has been exploring how to teach creativity in interdisciplinary ways. What began as monthly meetups grew into an interdisciplinary creativity and design studio (Rich, West, & Warr, 2015) and then into an interdisciplinary design minor (McDonald, West, Rich, & Pfleger, 2019). Key to this initiative has been an intentional programming of disciplinary diversity into the entire system. For example, students are required to take a certain number of courses outside their major. They also participate in capstone interdisciplinary projects where they are expected to work in creative teams with students from other majors. Another example is the popular Stanford d.School, where one of their stated goals is to encourage out-of-the-box thinking. Their system both allows for, and encourages, this kind of thinking through the frequent "pop-up" courses that participants can create, that work outside of traditional academic calendars and emerge for possibly only few weeks in order to complete an interesting project.

Additionally, although there is some disagreement about the influence space design can have on learner creativity (Mulcahy, Cleveland, & Aberton, 2015), others have argued that favorable physical spaces are critical to nurturing creativity (Moultrie et al., 2007). This seems supported by the learning environments we examined earlier, such as Bieraugel and Neill's (Bieraugel & Neill, 2017) conclusion that active learning makerspaces and collaboration-focused spaces do support learners' expressions of creativity. Extending this conclusion, Moultrie et al. (2007) also argued for spaces that promote teamwork, are flexible and able to be modified for many uses, embody design values through imagery (and we would add messaging), incorporate useful informational technology, support modeling and visualizing activities (e.g., prototyping supplies and next-door spaces), and is responsive to continual "evolution." We would add that having easy access to tools and the people are important. For example, having prototyping equipment immediately available rather than in a different building (such as in the HackLab example) is helpful to support learners as they express and shape their creative ideas.

Teaching That Nurtures Creativity

While we have emphasized that learning creativity is holistic and encompasses more than only developing a few key traits, the research we have examined does seem to support that there are aspects of creative thinking that can be taught. In this chapter, we have discussed several of these: divergent and convergent thinking, creative self-efficacy, autonomy, improvisation and playfulness, willingness to accept failure, and abstract thinking. Researchers have found it is possible to help students develop these attributes, but the key is that this is done intentionally. Consequently, another implication of this chapter is that instructional designers should help their stakeholders recognize the value of these creativity attributes and advocate that they be included as intentional outcomes of a learning experience. This would also imply that resources and time are dedicated toward teaching these attributes directly. For example, divergent thinking can be taught through idea-generating activities applicable in a wide range of disciplines (Kousoulas, 2010). With younger children, pretend play has been shown to be effective (Wallace & Russ, 2015), even when experienced in short interventions (Doron, 2016).

Similarly, attributes such as autonomy, entrepreneurship, improvisation, and abstract thinking can be intentionally addressed through creative learning opportunities. We refer again to robotics education programs as initiatives that often have a stated purpose of developing attributes such as these (Nemiro et al., 2017). Another example is Odyssey of the Mind (https://www.odysseyofthemind.com/). In this program, children work in teams to solve abstract problems with light adult supervision, requiring them to take ownership for their designs (Wasik & Barrow, 2017). Wright, Skaggs, and West (2012) explained still a different approach toward teaching skills that can draw out creative attributes in junior and senior high school students, by emphasizing design thinking processes in an innovation boot camp. In this example, groups of students were asked to identify their own design opportunities and prototype solutions that responded to those opportunities.

Other aspects of creative potential, however, may require more time to develop in students and require more systemic educational designs. In these cases, an implication may be that instructional designers support their clients or other stakeholders as they explore such solutions. For example, teaching students creative self-efficacy, the willingness to accept failure, or "creative consciousness" (Davis, 2004, p. 87) will likely require systemic changes in educational systems to promote and reward these behaviors. This could involve a movement away from typical grading practices that sort students based on success and failure, toward models that emphasize growth and mastery. Instructional designers could play a supportive role for such changes by prototyping and testing them so stakeholders can experience their effects in low-stakes settings.

Promoting Holistic Creative Development

Despite the value in learning creative attributes, creativity is a holistic, gestalt quality (Csikszentmihalyi, 2014). In other words, teaching students divergent thinking (or similar attributes) is likely helpful, but not sufficient in itself, to foster learner creativity. This is a key lesson we take from examples such as makerspaces and design studio learning. In these environments, creativity is developed because educational challenges are open, complex, and sometimes even messy, extending beyond didactic content delivery models into rich educational forms that recognize the importance of all attributes of creativity (West, 2014). We therefore recommend that instructional designers consider how learning activities can be shaped for students' overall creative growth by increasing flexibility, recovery from failure, and working through complicated and authentic problems.

Additionally, in these learning environments, creativity is not isolated as a discrete trait, taught independent of anything else. Rather, creativity is nurtured as people engage in work that is inherently creative. Students in the design studio, for example, learn creativity by engaging in the same kind of work done by creative professionals, albeit with a greater focus on thinking and process and with a greater emphasis on exploration and failure than in most pragmatic learning environments. Similarly, in makerspaces, people learn creativity as they make things that bring their creativity to the surface. This is not to say creativity is never explicitly addressed in these environments; indeed, reflecting on what has been learned explicitly is an important component of effective learning. Instead we recommend, as did Beghetto and Kaufman (2014), and Mishra, Fahnoe, Henriksen, and the Deep-Play Research Group (2013), that whatever explicit instruction learners receive in creativity should be supported by learning environments where they actually gain experience with authentic creative processes.

These examples also emphasize that instructional designers should be flexible when fostering creativity, rather than attempting to find static techniques that can be uniformly applied across situations. In this spirit, instructional designers themselves might see the wisdom in Beghetto and Kaufman's (2014) further suggestion to teachers, that they should worry less about "sure-fire creativity techniques" and attend more to "exploring what [is already being done] that might help or hinder the development of creative potential" (p. 56) especially because "many of the features of optimal learning environments [for creativity] are quite subtle and even counterintuitive" (p. 54).

We also recommend a similar philosophy applied when using technology to help foster learner creativity: it should be integrated into the learning environment in a way that advances overall creativity and removes barriers. This should not be an unfamiliar recommendation to instructional designers; yet, we emphasize it here given the qualitative difference we notice between technology added on to an otherwise sufficient learning experience (where it seems to contribute little other than a sense that the teacher is able to keep up with current trends) and the use of technology in our examples of makerspaces or robotics education. In the latter instances, students think and work with the technology as an essential part of their overall learning experience. It is not a supplement, but is inseparable from the overall environment. Instructional designers should also consider how technology-enhanced environments may create barriers to creativity. For example, creative improvisation often seems to be most easily achieved in face-to-face, and even low-technology, situations (Sawyer, 2004).

Conclusion

Our purpose in this chapter has been to explore what instructional designers and educational technologists can do to better design educational environments that nurture learner creativity. Our examination of the research on creativity, and how creativity can be holistically fostered in educational environments, laid a foundation for our in-depth discussion of three different learning environments that help illustrate the implications of this research for practice. Taken together, the research and examples suggest that when designing environments to promote learner creativity, instructional designers should (a) support creativity through system and space design; (b) encourage teaching in a manner that nurtures creativity; and (c) promote holistic creative development.

Of course, much work remains to be done before we can state that instructional design or technology is consistently used as an effective means for actually fostering creativity. As West (2014) stated, we can no longer afford to focus on "what is easier to teach" through instructional technology, but "instead [focus] on what is more difficult but also important" (p. 60). This is especially true given the growing importance of creativity as an educational outcome for learners at all ages. In making this point, we also recognize that as creativity continues to be studied, it is likely that research will emphasize even more the importance of rich, holistic environments as a necessity for fostering creative potential. This could lead instructional designers to become discouraged, as the task begins to look more challenging than they may anticipate.

Yet even with these potential challenges, we see reason for optimism. Instructional design is a field continually innovating new and powerful approaches for achieving important and idealistic learning goals. There is no reason why the field cannot develop such approaches for fostering creativity. So, we encourage readers to engage in the research. Engage in more experiments. Take inspiration from all sources. All contributions will be necessary to engage in a truly systemic approach to fostering learner creativity in the twenty-first century.

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Educating with Technology for Youth's Civic Engagement

Lesley S. J. Farmer

Introduction

As the sense of community and citizenship has expanded to encompass both physical and virtual mutual spaces and agreed-upon identities, the need for citizen education has also increased. Individuals need to access, evaluate, and use increasing amounts of information for individual and group sustenance and improvement. As early as 1974, United Nations Educational, Scientific and Cultural Organization (UNESCO) recommended:

> Member States should promote, at every stage of education, an active civic training which will enable every person to gain knowledge of the method of operation and the work of public institutions, whether local, national or international; and to participate in the cultural life of the community and in public affairs. Wherever possible, this participation should increasingly link education and action to solve problems at the local, national and international levels. (p. 1)

More recently, the National Center for Learning and Civic Engagement (2016) recommended five essential actions:

1. Reinvest in the fundamental civic and democratic missions of schools.
2. Explain narrative about civic literacy and aims.
3. Develop a contemporary comprehensive framework for civic learning.
4. Leverage K-12 and higher education interdependence.
5. Expand civic alliances and partnerships. (p. vi)

Technology has served as a catalyst for such information transformation and can also be used to educate citizens for civic knowledge and engagement. For example, government agencies increasingly include e-government initiatives that use

L. S. J. Farmer (✉)
California State University Long Beach, Long Beach, CA, USA
e-mail: Lesley.Farmer@csulb.edu

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information technology tools and systems to provide better public services and transform relations with citizens and businesses. Scientists are employing crowd-sourcing techniques to solve societal programs. Political activism, facilitated by social media, crosses international borders, as witnessed in the phenomenon of Arab Spring. For technology to play its role in citizenship and its education, especially for youth, several factors need to be in place.

Definitions

Citizens

A citizen may be strictly defined as a person who is a legally recognized subject of a state or nation, who has the rights and protection of that government. Heater (1990) defined a citizen as "a person furnished with knowledge of public affairs, instilled with attitudes of civic virtue and equipped with skills to participate in the public arena" (p. 336). The first definition perceives people more passively, while the second definition implies active engagement.

The second perspective also extends the concept of the citizen to that of a member of a community, beyond that of a state or nation. The International Association for the Evaluation of Educational Achievement (Schulz, Fraillon, Ainley, Losito, & Kerr, 2008) defined community as:

> A group of people who share something in common (for example, history, values, loyalties, a common goal). In this framework, community membership includes membership based on externally defined criteria relating to the function of the community (such as attending a school as a student) and membership defined by individuals' own belief of their membership (such as through identification with "like-minded" people regarding a political or social issue). (p. 15)

Explicit attention needs to be made to address emerging citizens of Society 3.0, which aligns with the above concept of community. Ronald Van der Hoff (2013) explained:

> They are the people we call global citizens: people of the new world. These Society 3.0 citizens cannot and will not deal with the thinking of the establishment anymore. They want to add value in their work and life in a significantly different way, namely by creating value instead of growth. (p. 163)

Similarly, Freelon, Wells, and Bennett (2013) analyzed civic websites and found that today's youth, as digital natives, have a different citizen identity from previous generations. Rather than seeing citizenship as a duty, contemporary youth see it as a self-actualizing activity through social expression in self-defined loosely coupled networks. Peer-generated knowledge leads to peer action, blurring the line between consumer and producer. The main communication media are digital in nature, and content is largely interactive. Bauman (2012) asserted that such civic interaction exposes youth to different perspectives on issues and can lead to action based on mutual interests.

Civic Engagement

The generally accepted definition of civic engagement is "individual and collective actions that address issues of public concern" (Delli Carpini & Keeting, 1996, p. 14). The underlying goal is to improve the quality of life within a community through actions that may be political or nonpolitical.

With this definition, consuming civic information, such as reading about the justice system, does not constitute civic engagement. However, blogging about the justice system could be considered a minimal level of civic engagement, be it passing on existing information or voicing a personal opinion. Participating in an online forum about an upcoming election by asking questions and deeply discussing issues exemplifies the idea of public deliberation, which is a vital component of civic engagement (Rheingold, 2012). Voting for a local judge would constitute more active involvement in that each vote does count toward a legal decision and consequence. Helping a judge run for office shows more committed and significant engagement and could involve technology such as creating a donor list spreadsheet.

Increasingly, the term "participatory politics" is used to describe peer-based interactive grassroots civic engagement (Jenkins, 2009). While participatory politics predates the Internet, it is now much more common because of the ubiquity and relatively cheap cost of digital social media. In their research on learning and participatory culture, Kahne, Middaugh, and Allen (2015) found that youth use media to communicate, share information, collaborate, and generate information. These actions are changing their cultural contexts.

Citizen and Civic Education

The term "citizenship" education sometimes has a narrow meaning: to prepare a noncitizen (e.g., an immigrant) to become a citizen of a county. Echoing the second definition of a citizen, Fien, Cox, Colliver, and Calder (2010) asserted that citizen (or citizenship) education teaches the skills to enable citizen participation: a willingness to investigate community issues; the ability to recognize and analyze socioeconomic, political, and ecological factors that need to be addressed in order to solve community issues; and the ability and willingness to act to help the community to have a sustainable future. Block (2011) studied citizenship as a communicative achievement in global spaces and affirmed the idea of citizenship as a way that people position themselves in participatory events.

The terms "citizen education" and "civic education" are often used interchangeably. Technically, the term "civic" refers to:

> any community in which the shared connections between people are at a level larger than that of the extended family (including the state). Civic also refers to the principles, mechanisms, and processes of decision-making, participation, governance, and legislative control that exist in these communities. (Schulz et al., 2008, p. 15)

In that regard, civic(s) education might be applied to a greater variety of communities than governmentally defined citizens. For the purposes of this discussion, the term civic education will be used in this document in order to make it clear that it is not limited to citizenship or even citizens in the traditional definition. Furthermore, most of the literature reviewed for this discussion used the term civic education, which also aligns better literally with civic engagement.

Citizen Education Curriculum

According to Gould (2011), citizen education curriculum and co-curriculum may consist of several different frameworks:

- History curriculum: studying social and political history and accompanying significant documents such as constitutions
- Government/civics curriculum: studying the structure and processes of government, its laws, and politics
- Critical thinking: active evaluation and analysis of content and issues
- Community service: volunteer work at community agencies
- Service learning: community service that applies academic curriculum, usually with the intent to identify and solve community issues
- Voter training: studying electoral issues and voting processes.

The International Association for the Evaluation of Educational Achievement (Schulz et al., 2008) identified four content domains in their term "citizen education":

- Civic society and systems: civic relations between individuals and groups of citizens, state institution elements, and civil institutions that mediate citizens' contact with government (e.g., schools, media, religious institutions, companies)
- Civic principles: equity, freedom, social cohesion
- Civic participation: decision-making, influencing, and community participation
- Civic identities: civic self-image (i.e., individual's values and roles) and civic connectedness to their communities.

The Center for Civic Education (Branson, 1998) offered a three-pronged curriculum for civic education: civic knowledge, civic skills of critical thinking and methods of participation, and civic dispositions that support democracy. They emphasized the need to address both rights and responsibilities of citizens and their communities. The Center noted the importance of both formal and informal curriculum, such as experienced in school's clubs and student governance. That philosophy can be extended to informal settings such as libraries and, indeed, to noninstitutionalized environments such as neighborhoods.

Lin (2015) analyzed a literature review to evaluate K-12 citizenship education (his term) in the United States. He identified three kinds of programs: character education, which characterizes primary grades; political simulations, which feature in high schools; and service learning, which provides real-life community context for middle and high school civic education. The underlying goal across grades is personally responsible and participatory citizenship. Nevertheless, although scholars emphasize the importance of school-level civic engagement, few civics programs include this aspect. In determining the effectiveness of reviewed programs, Lin found that programs leading to increased community-level engagement provided opportunities for students to communicate with peers and political candidates about authentic controversies and to reflect on their personal development of civic engagement; impactful strategies included student-adult collaboration in service learning, family-school bonding (in primary grades), and the incorporation of teacher development and media technology.

In examining existing civic education curricula, Bennett, Wells, and Rank (2009) found that most civic classes focus on teaching government basics and encourage students to follow political events, but they do not provide opportunities for students to self-express their opinions in the public arena and engage in thoughtful civic deliberations (Kahne, Lee, & Feezell, 2012).

Linking the Definitions

As members of one or more communities, citizens have rights and responsibilities because of that membership. As their communities encounter problems, they try to solve them; civic engagement means being involved in those problems, at the least showing some interest. However, discussion in that public sphere effectively requires some knowledge of how communities operate as well as literacy and communications skills. The question becomes: how does one gain that civic education and become civically engaged? Furthermore, how can youth act civically to solve those community problems?

Impact of Technology on Citizens

Technology and Communities

Today's technology has substantially changed the face of society. First, technology significantly expands and speeds up access to the world of information. Telecommunications have collapsed time and space. People potentially have more access, more quickly, to information around the world. Moreover, people can respond to each other and share group information much more easily than in the past. The convergence of communication industries such as telephony and television further expands the dissemination of information. These changes impact the global society, including political practices (Kahne et al., 2015).

The nature of the information itself has been affected by digital technology. Besides the obvious combination of text, image, and sound, technology facilitates the repurposing and transformation of information to address different objectives or different audiences. Applications such as Google docs and wikis enable participants to literally change documents on the fly, thereby chipping away at the idea of a permanent recorded document and replacing it with the idea of collective dynamic knowledge (Iacono, 2010).

That kind of collective contribution of ideas aligns with the assertion that the twenty-first century has marked the democratization of information (Tewksbury & Rittenberg, 2012). Particularly with the advent of social media and low-cost Internet-connected equipment such as mobile devices, a substantial percentage of the population can not only access digital information but can also comment on, and create, information (Bauman, 2012). Such ease of content generation can also lead to a loss of quality control; information is more readily available but might not be accurate, legitimate, or objective. The citizen has to employ critical thinking and draw upon past knowledge and experience to determine the validity, relevance, and significance of information accessed; so concluded Journell (2009) upon conducting content analyses on representative US political commercials.

Certainly the use of technology has exploded in recent years. In 2017 90% of US households had at least one Internet-connected device, and the typical household having five such items (Blumberg & Luke, 2017). More specifically, 96% of millennials have access to a smartphone at home. There was a positive correlation between educational attainment and Internet use, a positive correlation between household income and Internet use, and a negative correlation between age and Internet use (just 56% of seniors use the Internet).

Because today's world includes the digital community, a strong case can be made that a person may be considered a citizen of that digital community. The term "digital citizenship" can then refer to behaviors within that digital construct: using technology safely, responsibly, critically, productively, and civically. As the physical society intersects with the digital one, those behaviors can apply to the physical world as people interact using technology. Individuals build and impact their digital reputation every time they go online, especially when doing social networking. Furthermore, their online behaviors can impact other people's reputations to a degree unknown before the advent of social media because of the global dissemination and exchange of information. In addition, because online activity can be monitored, individuals need to be aware of their technology behavior at all times. In the most proactive sense of digital citizenship, individuals use technology to improve their communities, whatever form that community assumes (Ribble, 2011).

Technology and Civic Engagement

Technology can facilitate civic engagement and action because it offers more varied and convenient ways to access, communicate with, and contribute to civic organizations and their information. Over 50 years ago, Marshall McLuhan (1962) posited the existence of the "global village" whereby a worldwide electronic "nervous system" would connect popular culture in real time, resulting in global citizens. Potentially, technology-mediated information can expose people to different ideas that can promote deeper understanding and appreciation of various views and lead to greater belief in democracy (Kahne et al., 2012). Social media has ramped up the opportunities for civic engagement because it facilities many-to-many communication. In some circles, social media is thought to have democratized widespread dissemination of information. It should be noted that digitally initiated civic engagement can lead to offline civic action, just as prior face-to-face political interest can be expanded online; the two environments can feed off each other. The result can be more participatory politics, which encourages peer-based acts and the deliberation and action of diversified perspectives (Hargittai & Shaw, 2013; Kahne et al., 2015).

The idea of the public sphere plays into technology's role in civic engagement. According to Habermas (1989), the public sphere consists of an environment where all people can express their ideas and challenge others rationally without retribution based on ideas rather than speaker status and can influence public agenda without external coercion or systematic distraction. Social media has sometimes been heralded as the democratization of information in that more people can "publish" or broadcast their ideas. Furthermore, many-to-many communication is facilitated; in that respect, social media may be called "participatory media" (Freelon et al., 2013). VanFossen's (2006) review of the literature on Internet use and civic engagement revealed that when people use the Internet to exchange information, they are more likely to be civically engaged.

Mossberger, Tolbert, and Hamilton (2012) claimed that the Internet is now integral to citizenship because of the pervasiveness of e-government, use of the Internet to inform citizens about civic issues, and equality of opportunity in the marketplace (even at the level of finding and applying for jobs). Their research of Chicago population's online activity found that gathering news from the Internet increased political interest, discussion, and knowledge and led to a greater likelihood of individuals exercising their political rights. Longitudinal studies also found that civically engaged youth are more successful later in life (Rheingold, 2008).

A new area of study, civic technology, combines data, design, and civics to address community concerns (Boehner & DiSalvo, 2016). Researchers interviewed stakeholders about Atlanta's civic tech space. Barriers to civic action included difficulty accessing data, fragmented infrastructure, and data literacy. While this study raised more questions than answers, the role of technology design processes to generate opportunities and solve civic problems was consistently valued.

Issues with Technology for Civic Engagement

Along with the promise of technology to facilitate civic engagement exist several caveats.

Conflicting and negative communication While social media offers a verdant virtual environment for public deliberation (Ito et al., 2015), the reality trails the ideal as people are more apt to express their own opinions, including dismissing alternative viewpoints, rather than engage in extended rational and open discussion that influence public opinion. The recent furor about "fake news" has emphasized the human tendency to confirm and reinforce current beliefs when confronted with conflicting information, and technology has further enabled people to remain within the intellectual filter bubble (Lewandowsky, Ecker, & Cook, 2017). Kahne, Middaugh, and Allen (2015) also noted that the features of social media that permit anonymity and ease of access can result in less impunity in communicating fake, negative, oversimplified information or hacks. Ironically, social media's accessibility and anonymity can also lead to more powerful surveillance and less privacy.

Commodification of information From another angle, Habermas (1989) noted his concern about the commoditization of culture and its resultant consumerism attitude; people get caught up by, and distracted by, media messages that treat people as target markets rather than encourage people to actively seek solutions for the common social good. Deuze (2009) noted that the line between consumerism and activism has blurred in that the cause or politician that youth may "consume" through T-shirts or Facebook "likes," for instance, could be considered an intentional civic act.

Access inequity Nevertheless, the issue of public engagement also reveals the continuing issue of access: the opportunity and ability to use technology. To this day, poorer and more rural families have less access to the Internet. Language barriers, illiteracy, and inadequate education all impede intellectual access to civic information. Furthermore, when learners have limited access to technology, particularly outside of instructional hours, they may have fewer opportunities to practice civic engagement than those learners with ready technology on hand (Portman Daley, 2012). In their analysis of Internet-supported citizenship efforts, Mossberger et al. (2012) recommended that governments insure free municipal Internet bandwidth and provide free digital citizenship education. Thus, as much as physical access to technology can facilitate civic engagement, technical skills must also be employed.

Literacy gaps Technology access and skills is a prerequisite for online civic engagement, but information literacy skills are also needed. A 2016 research study by the Stanford History Education Group focused on students' ability to perform news-literacy tasks and found that middle and high school students, and even some in college, had trouble distinguishing which online resources were credible. The researchers stated a strong need for curriculum focused on developing students' civic online reasoning. Furthermore, youth often do not have academic technical and critical thinking skills or know how to express themselves effectively online in public discourse (Middaugh & Kahne, 2013; Rheingold, 2012).

Media literacy also constitutes part of the literacy gap, especially as news and other civic information is transmitted electronically. Media literacy is a subset of information literacy, where the information is developed by the mass media, including social media, done for profit/influence/power as its main objective. At its core, media literacy is the ability to access, evaluate, interpret, and respond to mass media (including social media) messages. In a white paper on digital and media literacy to support democracy, Hobbs (2010) asserted:

> To fulfill the promise of digital citizenship, Americans must acquire multimedia communication skills that include the ability to compose messages using language, graphic design, images, and sound, and know how to use these skills to engage in the civic life of their communities. These competencies must be developed in formal educational settings, especially in K–12 and higher education, as well as informal settings. (p. 6)

Because of the power of media, civic education should also include media literacy: teaching people to examine media messages critically by considering the process by which the message is made, the message's framework and content, and the production value of the message (Center for Media Literacy, 2012). Jenkins (2009) extended media literacy practices to include collective intelligence to pool knowledge and negotiation to discern and respect multiple perspectives. On a political conscious-awareness level, the Alliance of Civilizations (Douglass, 2006) contended: "Teaching viewers and listeners to recognize rhetorical and psychological techniques employed to persuade, to demonize and to incite violence or intolerance provides significant defense against violent ideologies of many types" (p. 15). Media literacy thus ties technology literacy, digital citizenship, and information literacy. In surveying of the civic engagement of 537 undergraduate students at three universities, Ashley, Maksl, and Craft (2017) found positive relationship between news media literacy and political engagement (based on self-reporting, which may be skewed).

Youth-Specific Attitudes About Technology and Civic Engagement

While many young people feel comfortable using technology for entertainment or communicating with friends, their social and recreational uses of the Internet are negatively related to civic engagement, as measured in YouTube activity (Kirk & Schill, 2011). Rather, today's youth have a growing distrust in mainstream politics and are the least likely generation to exercise their voting rights. Many youth are dissatisfied with conventional politics and government; they do not like negative campaigns and think that most politicians ignore them (Bennett et al., 2009). Those civic groups who have websites tend to emphasize top-down content and limit ways to empower youth to propose their own action plans, thus further dis-incentivizing youth to participate.

Nevertheless, youth are likely to get most of their news online or through social commentary television (e.g., The Daily Show) rather than mainstream news outlets, and over two-thirds of teenagers participate at least monthly in social causes (Freelon et al., 2013). They tend to prefer a self-actualizing approach to civic engagement such as lifestyle politics on the local or global scale, such as pollution, pay equity, and gay rights. Drawing upon his experiences as a communications professor, Rheingold (2008) mentioned several instances of youth civic engagement and action: volunteering for local projects (e.g., beach cleanups, donating books today care centers, Los Angeles Civic Youth Leadership Academy) or blogging about their stances. Particularly in the social media arena, youth are not just passing on or commenting on existing information; they are also generating knowledge (Freelon et al., 2013).Unfortunately, as these researchers analyzed youth civic webs, they also noted that teen online discussion forums tend to assert personal opinions more than promote respectful and deep deliberation. Furthermore, because so many online social networks exist, it is hard for youth voices to be heard among the din of the Internet for a couple of reasons: the extent of so many social networks and youth's marginalized role in institutional engagement (Kahne et al., 2015).

Countering these barriers, Giroux (2005) asserted that general formal education offers tools for systematic critique of power and social contexts and language for creating democratic change. Giroux also saw the need to connect pedagogy practices and spaces of language, culture, and identity to application in public spaces. However, education – even when connected to the public sphere as in civic education – is not enough; underlying attitudes by both adults and youth must change, which is a tall order. Generations need to get to know other generations better and at least to treat them with more respect. Educators and other adults need to provide more opportunities for people to express their interests, concerns, and talents. To strengthen online voices in social networking sites, educators of civics can build on people's self-organizing principle as they link similarly minded websites to help them reach relevant civic decision-makers, thereby offering a higher profile for civic action (Bennett et al., 2009). Finally, educators of civics need to broaden their definition of political engagement to include lifestyle politics, issues-specific focus, and citizen-directed advocacy. Youth already practice this approach, and educators of civics need to acknowledge and get up to speed with this paradigm shift (Kahne, Hodgin, & Eidman-Aadahl, 2016).

Research Questions and Methodology

The issues above illustrate the changing nature of technology and its possible impact on civic engagement, bolstered by civic education. To investigate effective practices that incorporate technology, a good starting point is Mandarano (2015), who identified three tiers of civic education impact: personal gains in knowledge, skills, and attitudes; personal engagement (i.e., active interest) in community contexts, which can lead to greater community "capital"; and civic action that can lead to community improvement. Even with this framework, measuring effectiveness is challenging as studies do not necessarily fall into these neat categories.

This framework frames three important research questions:

- What practices demonstrate how technology supports civic education for youth?
- What practices demonstrate technology's integration in civic education leading to civic engagement for youth?
- What practices demonstrate how viable technology is in civic action for youth?

As the following discussion details, the intersection of technology, civic education, and civic engagement is in flux because of changes in technology and the dynamics of complex and ambiguous contexts. Even establishing a framework for assessing the effectiveness of possible solutions can be daunting.

To answer the research questions, a literature review was conducted using EBSCO's collection of databases and ProQuest's database of dissertations and theses; other databases were not used, which is a limitation. Key terms included "citizen education, civic(s) education, civic engagement, technology, social media" in combination with the target population terms: "youth, teenagers, adolescents." Studies identified by these key words also had to address the research questions, which may have shortchanged other potential studies. As much as possible, studies were limited to the last 5 years as the rise in social media has changed the civic engagement picture significantly, and recommendations needed to be based on current technology rather than older practices. This time frame may have precluded older seminal works.

The studies below range from one class within a single course to representative samplings from national populations mentioned in one study's meta-analysis of other studies. The literature review found that qualitative, quantitative, and mixed methods were used. Evidence in the studies included both direct and indirect measures. Instruments in the studies varied: surveys, interviews, blogs and other narrative forms, media products such as YouTube videos and news reports, and community projects and their deliverables. The studies' analyses likewise varied: descriptive and inferential statistics and content analysis. Probably the most frequent approach found in the literature reviewed was small-scale exploratory work that used content analysis to reveal patterns leading to recommended practice.

The studies were then reviewed and categorized according to the research question. A first section includes studies that emphasize how technology supports civic education. The studies that focused on engaging practices were found to include these factors: local needs, local resources, local broad-based planning, accessible and appropriate technologies, opportunities for community building and socializing, and locally meaningful content and outcomes. The third section of studies focused on practices that led to student civic action.

Technology Support of Civic Education for Youth

The following studies emphasize the need to gain civic knowledge through incorporating technology.

Recognizing the realities of today's society, the National Center for Learning and Civic Engagement (a component of the Education Commission of the States) stated in 2016 that civic education curriculum still needs to include civic knowledge and processes. However, educators also need to address information and communication technology policies and issues such as the intellectual property, privacy, and digital divide. The Center also stated that formal education needs to incorporate technology, especially social media tools.

While civic education is often framed in terms of formal K-12 education, postsecondary institutions also see a need for such education for their students. Lewis (2014) asserted that societal renewal through civic knowledge and civic action should be a core function of the university. Using Northwestern University as a case study, Lewis and his colleagues built on a longitudinal survey of undergraduate students' interface with their communities on- and offline and found that students who had taken courses that stressed civic engaged, especially online. The faculty then shaped curriculum to incorporate social media to help students gain agency in engaging in civic matters, which led to online political engagement over time, as self-reported by the students (a possible limitation, to be fair).

Based on a nationally representative survey of postsecondary civic educators, Kahne, Hodgin, and Eidman-Aadahl (2016) tracked new practices in participatory politics as part of curriculum. The researchers confirmed traditional content but also noted the potential of participatory politics where youth can advance their own civic priorities, incorporating technology. To make these practices more prevalent, the researchers also asserted that educators needed to modify and redefine instruction in light of digital social processes, echoing Lewis's findings.

In counterpart to the impact of political knowledge, Kahne and Bowyer (2017) asked a national representative survey of youth to judge simulated online posts. The research found that media literacy rather than political knowledge improved judgments of information accuracy.

Portman Daley's 2012 dissertation investigated the role of social media in student learning and civic rhetoric by conducting a content analysis of ten undergraduate students' civic engagement as captured through time-use diaries, screen-capture analysis, and interviews. While the data are rich, the sampling is small. Upon analyzing the participants' online behaviors, she urged the inclusion of digital civics into education, stating that educators should focus on teaching multiliteracies, especially since digital literacy competence correlates with civic awareness and participation. In addition, Portman Daley recommended bridging formal and informal educational settings so that students can transfer their personal social media into the realm of civic education and subsequent civic engagement.

Fedorov, Levitskaya, and Camarero (2016) surveyed international experts about essential content and learning outcomes of media literacy curriculum. Priority content included role of media representations, media languages, media access and use, sociopolitical role and implications of media, media of media in society, and media and media users' legal and ethical use; the most important learning outcome was the critical analysis of media. The educators recommended the curricula of UNESCO, Media Literacy Clearinghouse, Australian Curriculum, Assessment and Reporting Authority, CLEMI (France), Grupo Comunicar (Spain), Canadian Centre for Digital and Media Literacy Media Smarts, Media Education by Renee Hobbs, and Digital International Media Literacy ebook *Media Literacy* (DIMLE) and works by Art Silverblatt, Frank Baker, and J. W. Potter.

Current Practices in Technology's Role in Citizen Education for Civic Engagement

Increasingly, technology is being integrated into civic education, be it in formal educational settings or settings such as libraries and youth organizations that provide informal educational opportunities. The literature review identified several factors that were found in efforts that engaged students: local needs, local resources, local broad-based planning, accessible and appropriate technologies, opportunities for community building and socializing, and locally meaningful content and outcomes (Center for the Study of Social Policy, 2011; Hobbs, 2010).

Middaugh and Kahne (2013) asserted that new media provide novel ways to find and share civic information, as well as organize political activities. Synthesizing their literature review of new media's role in civic learning, the researchers suggested several ways to leverage media to facilitate civic education, particularly for youth:

- Design authentic learning environments: issues-based website that shows steps to engage in civic action (e.g., http://www.dosomething.org, http://generationon.org); digital games to conceptualize civic issues and actions (e.g., Fate of the World, iCivics); virtual environments (e.g., Quest Atlantis, United Nation's Virtual Reality Program).
- Connect to community: mapping as community building; online youth leadership communities (e.g., Black Youth Project, http://digitalyouthnetwork.org).
- Support individual's civic voice: e.g., Adobe Project 1324 (http://project1324.com/) for emerging civic-minded artists, Youth Radio.
- Facilitate engagement with social justice issues: participate in web-enhanced civic issues (e.g., ProjectVote.org, http://www.civicaction.center), Civic Action Project (http://www.crfcap.org), DeafBlindInternational.org, Taking It Global (http://www.tigweb.org); address technology citizenship issues such as net neutrality, digital divide, intellectual property, and online privacy (e.g., http://gofccyourself.com, https://action.aclu.org/secure/FCC-privacy).

Online Curricula

Several online curriculum resources exist to support citizen curriculum:

- UNESCO Teaching and Learning for a Sustainable Future: Citizenship education http://www.unesco.org/education/tlsf/mods/theme_b/mod07.html
- National Center for Learning and Citizenship: http://www.ecs.org/html/projectsPartners/nclc/nclc_main.htm
- Center for Civic Education: http://www.civiced.org/index.php?page=online_curricular_materials
- iCivics: https://www.icivics.org
- Harvard Kennedy School: Teaching civic education: http://www.hks.harvard.edu/programs/saguaro/our-research/teaching-civic-education

In addition, the Annenberg Institute for Civics provides a lengthy list of high-quality civic sites for teachers: http://www.annenbergclassroom.org/page/best-civics-sites-for-teachers.

Action Civics

One trend in civics education is action civics, in which learners are taught to "do civics and behave as citizens" (Levinson, 2012, p. 224). Action civics enables youth to participate in authentic democratic activities as adults guide them in community change and personal growth. The National Action Civics Collaborative reviewed civic education and youth development literacy to identify key learning outcomes of action research: civic and cultural transformation, informed and engaged citizenship, civic creation, and positive youth leadership (Gingold, 2013, p. 2).

To achieve these outcomes, learners need the following competencies: civic knowledge, civic values, critical thinking, communication, collaboration, agency, professionalism, and general academic skills. Four principles guide curriculum:

- Action, especially collective action
- Youth voice, including experiences, knowledge, concerns, and opinions
- Youth agency, including action, authority, and leadership
- Reflection, especially as it enriches the process (Gingold, 2013, p. 6)

Learners identify key concerns in their community, research the issue, plan, and act; in their part, instructors teach political and civic knowledge to facilitate success. Authentic service learning and community involvement are also key components of action civics education so that learners can understand local political systems.

To investigate ways that youth learn through "connected civics," Ito et al. (2015) conducted a meta-analysis of youth affinity network interviews and case studies. The researchers found that youth used technology to mine their own cultural context to identify with civic themes that resonated with them, and technology-enhanced affinity networks lowered barriers to entry and youth participation in civic action.

Community-Based Civic Education

Civics educators should comprise part of community organizations to improve technology integration in order to optimize active citizen participation (Portman Daley, 2012). Educators can design the conditions for learning by helping those organizations conduct needs assessments, define appropriate learning goals, locate or develop relevant learning resources, design activities that optimize learning and technology application, and assess efforts. Especially with the advent of social media, instructional design can provide a coordinated framework consisting of a participatory network; members can access information and each other, as well as share their expertise and generate new ways to incorporate technology. Addressing the personal needs of citizens, social media tools permit social tagging for customizable access to these resources and learning activities (Bauman, 2012). Skinner, Smith, Brown, and Troll's (2016) collection of community-based education highlights local development efforts for capacity building and social change that incorporated technology.

Struck (2017) used an ethnographic methodology to study a teen tech crew who gained civic knowledge through participating in a community-based organization: the Youth Science Center. Within this social space, the staff taught the marginalized group of teens technical skills needed to take civic action. The crew collaboratively created social justice displays for the center and developed civic identities.

Community-based civic education needs effective assessment in order to optimize impact. In analyzing five community academies (Las Vegas; Rockville, MD; Orange County, FL; Philadelphia; Sacramento) that taught citizen planning for capacity building, Mandarano (2015) identified three tiers of impact: personal planning and sociopolitical capital, leading to community sociopolitical capital, which led to community improvement. Observation and direct assessment revealed that participants became more active in the communities, which resulted in a better quality of life for the community. One of the significant factors was improving skills and trust in the planning process, which included developing positive relationships with governmental institutions.

Citizen Science

Science education constitutes one of the most fruitful academic domains for citizen instruction (Gaydos & Squire, 2012). Indeed, the term "citizen science" has gained importance as scientists and science educators realize the importance of ethics in the field. Another trend underlying citizen science is the democratization of science due to participatory technology. Science educators laud citizen science because it enables youthful participation in authentic scientific investigations. Such engagement helps students appreciate the diversity of science fields and aids in recruiting students into the profession. Not only do students help collect data, reflecting a crowdsourcing strategy, but they are also engaging in civic action.

Green and Medina-Jerez (2012) introduced Project Citizen to their high school science students. This online curriculum, which is administered by coordinators in every state, gives students a means to monitor and influence public policy. These teachers asked students to examine environmental problems through this lens and supplemented the online curriculum with local civic action. Their students gathered information about several science issues and then identified water pollution as their community project.

Gaydos and Squire (2012) illustrated the occasional tension of incorporating video games into citizen science. They used a digital game called "Citizen Science" to help student develop citizen scientist identities within a lake ecology context. Students who were comfortable with game play understood the content better, although those same students were disappointed in the game's less than commercial quality. The teachers also discovered that the game was more effective when complemented by other curricular activities. On the other hand, Marino and Hayers (2012) examined several off-the-shelf commercial video games such as River City and Resilient Planet and found that such games promoted global citizenship and civic scientific literacy.

Citizen Journalism

Another workplace-centric approach to civics education focuses on journalism. Citizen journalism may be defined as user-centered news production and participatory journalism. It is associated with blogs and their comments, videos and photos, and social networking site news stories. Results can lead to better local coverage and more varied perspectives, as well as greater interactivity, but can also lead to mediocrity, infotainment, and reinforcement of bias (Siapera & Veglis, 2012).

To help learners communicate effectively in this public arena, educators can teach investigative skills, critical thinking, and ICT (information and communications technology) skills. Educational institutions can facilitate community workplace service learning and intern opportunities where learners gain privileged access and insights into the professional world of the media and their ethical stance. This form of civic education aligns well with participatory politics in that increased involvement not only helps citizens have easier and closer access to governmental officials, and vice versa, but that it facilitates public discourse. This public voice serves as a bridge between media production and civic engagement (Tewksbury & Rittenberg, 2012).

Citizen journalism holds special promise for today's young people. Youth particularly like interactivity that is the result of co-production, where they participate in producing and manipulating information. Furthermore, youth respond well when given responsibilities to serve their communities, which leads to more positive personal development (Bennett et al., 2009). By collecting and disseminating news about community concerns and collaborating with media outlets, teens can act as social agents and see themselves as contributors for societal development (Dahlgren, 2005). In this role, they model twenty-first century manifestation of Habermas's (1989) public sphere with its unfettered ability to discuss social issues without outside interference. In reviewing examples of citizen journalism taught in K-12 schools, Bennett, Wells, and Rank (2009) discovered that youth contributions were balanced with professional mentoring and monitoring.

Here are three examples of youth-oriented citizen journalist curricula:

- American Press Institute: https://www.americanpressinstitute.org/youth-news-literacy/resources/news-literacy-curriculum/
- Ontario Ministry of Education: http://cjmp.ca/wp-content/uploads/2013/11/CitizenJournalismStudyguide.pdf
- MIT Center for Civic Media: https://civic.mit.edu/courses

Conclusions

The opportunities for civic engagement and action have grown largely because of technology; media outlets and social media have expanded ways to access and share information. However, to take advantage of those opportunities requires addition conditions: physical and intellectual access as well as critical thinking and communication skills.

Effective civics education is a lifelong endeavor that can occur in both formal and informal education. Content should include civic society and systems, civic principles, civic participation, and civic identities. Information and media literacy, along with effective communications skills, must be incorporated into instruction and application.

Technology, particularly as it supports interactive learning communities, now also plays a central role in civic education, both in gaining skills and applying them. Educators need to design instruction, curriculum, and programs that offer customizable learning and socially rich learning environments, built on learner interests and contexts. Successful civic education efforts to incorporate technology tend to include these factors: personal and local interests and needs, local resources, local broad-based planning, accessible and appropriate technologies, opportunities for community building and socializing, and locally meaningful content and outcomes. The ultimate goal is not only civic engagement but civic action that can improve the community, in whatever from that community takes.

To support both learning and civic engagement, organizations should insure that a robust and equitable technology infrastructure is in place and that training be appropriately supported as a right of every citizen. Some of the current trends to foster technology integration in citizen education, engagement, and action include:

- Enriching the repertoire of instructional strategies, including interactive online projects and service learning, social justice focus, social media, gaming, geospatial use, virtual reality experiences, and community-based problem-based learning

- Focusing more on STEM, STEAM, and cross-disciplinary aspects of civic engagement and action
- Focusing on inclusivity for civic education, engagement, and action
- Encouraging lifelong civic learning in formal and informal educational settings as well as noninstitutional environments
- Developing community-based and peer-to-peer learning and mentoring, at all levels from site to international
- Encouraging youth-led civic networks and activism in both physical and virtual environments
- Producing more multimedia civic products
- Fostering virtual crowdsourcing and collective intelligence for effective civic action
- Creating repositories to facilitate community-supported civic education.

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Section IV
Understanding How Instructional Design/Technology Contributes to Learning Outcomes Within Specific Subject-Matter Domains

Minding the Gap: Lacking Technology Inquiries for Designing Instruction to Retain STEM Majors

Phillip Andrew Boda and Vanessa Svihla

Introduction

While there are many lines of research within science, technology, engineering/computer science, and mathematics (STEM) education, we argue that the most pressing and crosscutting problem remains how researchers can showcase ways to provide equitable and inclusive learning experiences that engage a more diverse population of learners, providing a foundation for later STEM participation as professionals and citizens. There is now a well-established tradition of calls for increased capacity in STEM fields, due in part to the dynamic demands and increasingly technical nature of the world and workplace (Augustine, 2006). Many such demands are expressed as an urgent need (Langdon, McKittrick, Beede, Khan, & Doms, 2011) or related to a particular field in STEM as needing more workers (Xue & Larson, 2015). However, others have argued there is not a shortage of STEM graduates at all (Charette, 2013). Regardless, the focus on a STEM pipeline has done little to diversify the STEM workforce, leading some to advocate for the term *pathways* instead of pipelines; the term pipeline suggests a single narrow route, while pathways suggest multiple routes of growth, as well as a diverse set of points where entry to the STEM field is plausible (Cannady, Greenwald, & Harris, 2014).

In turn, this shift in language becomes representative of the larger shift in educational research that emphasizes the importance of relevancy of research to practice

P. A. Boda (✉)
CERAS, Stanford University, Stanford, CA, USA
e-mail: paboda@stanford.edu; Boda@exchange.tc.columbia.edu

V. Svihla
Organization, Information & Learning Sciences, University of New Mexico, Albuquerque, NM, USA
e-mail: vsvihla@unm.edu

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(Gutiérrez & Penuel, 2014) and the challenges of urban education more broadly related to diverse students' learning affordances being leveraged (Emdin, 2016). Tolbert, Schindel, and Rodriguez (2018), in turn, argue that STEM and science education research should be evaluated in terms of its transformative potential, a critique that extends past concerns about the boutique nature of many research projects that build vitas but do not lead to lasting change (Barab & Squire, 2004). With this position in mind, this chapter first presents the barriers and drivers of change within STEM education before illuminating the ways research on technology and learning designs might play a role toward more equitable and inclusive STEM learning. Through this structure, our goals for this chapter are to highlight the most current research in the field of STEM education, elaborate on the challenges in providing novel learning experiences for diverse youth, and describe the affordances of this recent literature in pursing equitable STEM education for all.

Barriers and Drivers of Change

In K-12 settings, reform-oriented STEM standards have been strong drivers of change, while assessment practices and textbook publishers have tended to create barriers to change. For instance, in the USA, the Common Core State Standards for Mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) and the Next Generation Science Standards (NGSS Lead States, 2013) have brought a new focus to STEM *practices*. This focus has been supported through both national and private funding agencies and the research that these agencies approve for funding opportunities. Unfortunately, textbooks tend to conserve traditional STEM education approaches, despite strong evidence that changes should be made (Sherman, Walkington, & Howell, 2016), while also not considering the many opportunities afforded through the integration of current technological advancements. The question remains: How can we mediate this reality?

The global trend of increased reliance on standardized testing as a means to evaluate teachers and schools has led to less and lower-quality science teaching, especially for those from groups already underrepresented in STEM fields (Aydeniz & Southerland, 2012; Peters, 2014). Even with advances in technology and learning analytics, most assessments still predominantly measure conceptual understanding, rather than STEM practices. Even more so, when national assessments do adopt a scientific practices framework for evaluation, the context in which the application of these practices is situated is often geographically and historically foreign to those students who have been underserved by these standards (such as youth of color from low economic communities; Basile & Lopez, 2015). These realities, in turn, encourage STEM teachers to focus on concepts at the expense of practices, as well as remain centered on a myopic view of learning related to the normative center of schooling (Leonardo & Broderick, 2011) that disregards the impact that cultural relevancy has on scientific practices (Brown, 2017). This strategy, sometimes pressed onto teachers in the form of scripted curricula by school and district leaders seeking to improve school evaluations (Timberlake, Thomas, & Barrett, 2017), can make it challenging to do transformative research and improve the learning experiences for all students. This is not only true for K-12 education, though; postsecondary education also shares this problem.

In higher education settings, professors have been notably resistant to change in the types of pedagogy, curriculum, and assessments provided to postsecondary students. Due to the nature of how STEM disciplines are typically taught in these contexts (such as large lecture halls with hundreds of students using the dissemination model of teaching), students who express self-efficacy in creative problem-solving tend not to persist, suggesting a need for curricular and programmatic changes (Atwood & Pretz, 2016), yet more effective strategies are slow to be adopted (Borrego & Henderson, 2014). This is not to say that attempts to resign postsecondary learning environments in STEM are not present in the literature (see Boda & Weiser, 2018). Rather, this has led to funding agencies having a major influence on these types of changes in both K-12 and higher education settings. The most recent funding priorities in postsecondary STEM education have emphasized technologies and openly licensed materials—a significant opportunity in STEM education to include participation from all students. However, this has come at a cost, as education policies have simultaneously deemphasized teacher professional development (Pareja Roblin, Schunn, Bernstein, & McKenney, 2018).

Given the abundant evidence that K-12 and postsecondary instructors need support to integrate technology effectively (Herring, Koehler, & Mishra, 2016; Svihla, Reeve, Sagy, & Kali, 2015) and that they may not be confident engaging their students in STEM practices (Marshall, Smart, & Alston, 2017; Stroupe, 2015), teacher professional development should be a central focus and one that can effectively be folded into research partnerships with teachers (Koh, Chai, & Lim, 2017; Pareja Roblin et al., 2018). Likewise, for higher education faculty to change, supports are needed that align to institutional reward structures, such as being supported to engage in discipline-based education research (Singer & Smith, 2013). Focusing on systemic change—rather than boutique or individual efforts—may be the key to lasting change (Kezar, Gehrke, & Elrod, 2015), a view taken up by the National Science Foundation's program to revolutionize engineering and computer science departments (Ingram, Litzler, Margherio, & Williams, 2017).

We argue that researchers should consider these barriers and drivers of change as they build on key insights from STEM education research. These considerations could include engaging students at all levels in agentive STEM practices with appropriate scaffolding based on learners' personal epistemologies (Barger, Wormington, Huettel, & Linnenbrink-Garcia, 2016), building on students' cultural practices and experiences to leverage motivational factors that influence learning (Brown, 2017; Kumar, Zusho, & Bondie, 2018; Lee, 2003), and incorporating technology in contextually relevant and thoughtful ways (Boda & Brown, 2019; Metcalf, Grotzer, & Dede, 2015; Miller & Roehrig, 2018).

Engaging Learners in Agentive Practices

To understand how to support students' participation and learning from STEM practices, researchers typically conduct classroom-based studies, often using design-based research to understand how a learning design functions in context. A number of recent meta-analyses have provided greater clarity on the value of long-used designs. For instance, in general, active learning techniques result in greater learning gains compared to traditional lecture-based instruction (Freeman et al., 2014), and participating in STEM practices confers an advantage for learning, retention, and understanding (Kuhn, Arvidsson, Lesperance, & Corprew, 2017). These gains are also typically higher when student engagement with STEM practices is scaffolded (Kang & Keinonen, 2018; Korur, Efe, Erdogan, & Tunç, 2017; Qureshi, Vishnumolakala, Southam, & Treagust, 2017), though more research is needed on the impact of various types of scaffolding (Lazonder & Harmsen, 2016). Recent research on scaffolding has also raised concerns that directive scaffolding may produce learning gains in the short term, but may also have lasting negative attitudinal impacts (Roll et al., 2018). This has led some to argue for a need to explore alternatives to directive scaffolding, such as supports for individually relevant discovery practices, which is a stance that aligns with the focus of, and purpose for, STEM practices that was illuminated in the prior section.

Engaging students in STEM practices requires more agentive STEM learning experiences and highlights a need for research that investigates how to support students to direct their own use of STEM practices in ways that are contextually and culturally relevant to their lived realities—the ways they understand the world outside of formal learning contexts. Specifically, this means investigating metacognitive, affective, self-efficacy, and self-regulative supports and how these relate to students' learning in particular contexts. To engage with this process of applying scientific practices to localized and/or sociopolitical issues that students face, researchers need to be engaged with the nature of their own positionality, their relationship to the students they seek to serve, and define their research purposes in ways that are guided by a relationality that is designed purposefully in these experiences (Tolbert et al., 2018).

Learners' self-efficacy (i.e., confidence in their competencies) and a "sense of belonging" (i.e., relationality to the content being learned) predict higher outcomes in science, especially for students from groups that are underrepresented in STEM (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011; Hilts, Part, & Bernacki, 2018). Thus, providing students with opportunities to engage in STEM practices gives them a chance to evaluate their interest in STEM careers (Mody, 2015). When students participate in STEM practices authentically, they experience emotions related to their engagement, such as feeling excitement about an insight or frustration about an unexpected result. Such emotions are endemic to professional practice realities and epistemological challenges students will likely face as practitioners should they choose to pursue STEM careers (Jaber & Hammer, 2016). Adding onto these studies in attempts to leverage technological innovations, investigations into how students manage these types of discovery learning in online environments suggest that environments should be designed to focus on learning rather than minimizing feelings of frustration or maximizing fun (Adler, Schwartz, Madjar, & Zion, 2018). This, however, also requires stakeholders in STEM education to recognize and ameliorate any barriers some populations may face in their active participation with these novel learning experiences.

Building on Students' Cultural Practices and Experiences

While many studies cite broadening participation as a goal, few tackle these issues directly (Svihla, Marshall, Winter, & Liu, 2017). Doing so typically requires careful, in-depth qualitative analyses and/or sample sizes large enough to permit quantitative disaggregation by subgroup. Recently, more STEM education research has taken a social justice stance, partially in response to systemic inequalities that have become more visible through increasingly punitive uses of standardized testing and recognition that traditional instruction systematically underserves non dominant youth. For example, qualitative analysis of diverse classroom mathematics instruction clarifies that commonplace instructional strategies systematically exclude students who do not conform to the expectations of the mainstream culture regarding who is good at math and what that looks like in K-12 classrooms (Louie, 2017). This has led more scholars to consider frameworks such as culturally responsive and sustaining pedagogies, Native and Indigenous science, intersectionality, and, more generally, focus on the roles that context and cultures play on the process of learning (Bang & Marin, 2015; Boda & Brown, 2019; Kolonich, Richmond, & Krajcik, 2018; Leyva, 2017; Paris & Alim, 2014). In turn, researchers are increasingly using research methods that engage students as co-researchers (Birmingham et al., 2017) to gain a more holistic understanding of how these learning experiences can be changed for the betterment of all demographics learning STEM disciplines.

Indeed, the importance of social context and community is underscored in recent research on engaging students from groups that are underrepresented in STEM. Designing consequential learning experiences (Calabrese Barton & Tan, 2018) that matter in students' lives and communities, such as through environmental projects, can lead to deep engagement (Birmingham et al., 2017; Schindel Dimick, 2016), especially when content is intertwined with cultural and community views and histories (Bang et al., 2014). Moreover, engaging students' cultures can support their participation in practices and development of identity in STEM (Meyer & Crawford, 2015) and may help students to have some ownership or authority over their learning. This, in turn, can contribute to the development of learners' identities in STEM and help them envision themselves as STEM practitioners (Brown, 2017; Langer-Osuna, 2017; 2018), which supports their persistence in STEM degrees (Carpi, Ronan, Falconer, & Lents, 2017).

Involving students in meaningful learning experiences that invite them into new STEM learning experiences can reignite lost interest (Jack & Lin, 2014).

This matters because interest often predicts effort (Patall, Vasquez, Steingut, Trimble, & Pituch, 2016) and persistence in STEM. There is no clear age by which such interest needs to be cultivated, meaning efforts to develop interest can be usefully invested along the entire educational trajectory (Maltese, Melki, & Wiebke, 2014). More research is needed on instructional designs that are based in equitable and inclusive teaching, including asset-based approaches, early interventions that reduce opportunity gaps, and theoretical frameworks that include equity and inclusivity (NCTM Research Committee, 2018). Through these research agendas, STEM education for all is seen as attainable, especially when considering the affordances of educational technologies and their capabilities to improve student learning beyond traditional learning models.

Supporting STEM Learning with Educational Technologies

Researchers have emphasized that technologies are neither inherently good nor are they bad, but rather that the pedagogical uses of technological advances must be considered to truly highlight their promises and impacts (Clements & Sarama, 2017). Educational technology can both scaffold students' engagement in STEM practices and contribute to equitable and inclusive learning. Here, we review recent research that provides a foundation for educational technology use, prior to discussing more transformative possibilities on the horizon.

To understand the relative impact of four approaches to improving science learning—providing extensive professional development about inquiry, technologies to support conceptual understanding, science kits, and textbook innovations—Cheung, Slavin, Kim, and Lake (2017) conducted a meta-analysis that found professional development and technology had the greatest impact. However, given that the largest barrier to K-12 teachers adopting technology is their beliefs about what effective teaching and learning looks like (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012), thus the approach that professional development models take to educate STEM instructors should be carefully considered. Combining these two strategies—technology and professional development—may be particularly useful to help teachers understand both the strengths and limitations of appropriate technology use (McKnight et al., 2016). This combination has also been shown to enhance instructor buy-in for such novel learning experience integrations (Buabeng-Andoh, 2012; Potter & Rockinson-Szapkiw, 2012).

A key role for educational technology has been to provide scaffolding within learning environments where previous models of scaffolding may not have leveraged the affordances of technology use in the classroom. For instance, in secondary classrooms, programs like the Web-Based Inquiry Science Environment (WISE; wise.berkeley.edu/) have been shown to enhance content acquisition compared to traditional learning environments and also to narrow achievement gaps (Raes, Schellens, & De Wever, 2014). Such environments typically support students to learn from computer simulations using metacognitive scaffolding (Moser, Zumbach,

& Deibl, 2017). Additionally, some interactive textbooks blur the lines between textbook and learning environments like WISE, providing automated formative feedback and distributed practice through quizzes and interactive simulations, a strategy that has proven successful in introductory undergraduate STEM courses (D'Angelo et al., 2014; Edgcomb et al., 2015). Other technologies like mathematics games and online mathematics homework tools provide similar supports—automated feedback and repeated practice—to significantly increase performance on standardized tests (Bakker, van den Heuvel-Panhuizen, & Robitzsch, 2015; Roschelle, Feng, Murphy, & Mason, 2016).

In higher education settings, the movement from face-to-face to blended or entirely online settings has frequently resulted in positive outcomes, in part because faculty receive professional development to make the transition (Baepler, Walker, & Driessen, 2014; Bernard, Borokhovski, Schmid, Tamim, & Abrami, 2014; Bernard, Broś, & Migdał-Mikuli, 2017; Spanjers et al., 2015). In doing so, faculty have incorporated research-based strategies, such as more frequent formative assessment and distributed practice. Like many uses of online courses, serious educational games support learning through feedback and reflection, while also enhancing engagement through realistic context, story, and interactivity (Ravyse, Blignaut, Leendertz, & Woolner, 2017). When aligned to curricula, such games can support the development of STEM practices (Wallon, Jasti, Lauren, & Hug, 2018). However, like many curricular innovations, implementation can enhance or minimize learning (Wilson et al., 2018). While well-designed and well-implemented games can result in narrowed achievement gaps (Schacter & Jo, 2016), comparison of gains related to high-quality science instruction and a game designed to cover the same content showed that students performed equally in both conditions, raising concerns over whether the benefits outweigh the high cost of designing such games (Sadler, Romine, Menon, Ferdig, & Annetta, 2015). However, more research is needed on long-term impacts and other impacts of educational uses of games (Sadler et al., 2015).

Future Directions for More Equitable Technology-Enhanced STEM Education

Finding ways to support STEM practices in online learning remains relatively understudied (Jaber, Dini, Hammer, & Danahy, 2018). While inquiry-based learning management systems can scaffold students to participate in STEM practices using simulations and to learn from them (Donnelly, Linn, & Ludvigsen, 2014), it is not yet clear if students learn to transfer STEM practices when the scaffolding is faded. After using such learning designs, do students exhibit *framing agency*—the ability to make decisions that are consequential to their learning and further designing? Can they pose their own questions and design ways to investigate them? Supporting this kind of learning is particularly challenging because of its unpredictability—an area, therefore, that has been difficult for technology to support effectively. When answers do not converge on a single correct path, it is difficult for technologies to provide automated feedback and guidance. Likewise, designing technologies capable of supporting students to make connections between normative, textbook science and students' own, everyday, and cultural experiences remains a challenge. However, supporting teachers to make effective and contextual adaptations that align to students' cultural experiences is more easily accomplished than previously articulated in the field. Educative curriculum materials that are designed to support teachers to make such adaptations would be particularly fruitful (Davis et al., 2014) and serve as a potential area of inquiry for future projects.

In order to realize the promise of new STEM standards that emphasize practices, more development and research on assessments that can equitably measure progress in these areas is also needed. Despite the availability of multimedia, such as interactive simulations, few standardized tests incorporate these, revealing a mismatch between the resources to support learning and the means to measure understanding (Van Rooy & Chan, 2017). As technology continues to play a central role in assessment, researchers must attend to novel ways to equitably help students to share what they actually know. For example, technology might provide scaffolding for students to better ensure they understand what they are being asked, using familiar context and allowing students to use both writing and drawing to respond (Kang, Thompson, & Windschitl, 2014). Significant progress has been made with computer-based and learning analytics assessments of science practices (Gobert, Sao Pedro, Raziuddin, & Baker, 2013; Kuo, Wu, Jen, & Hsu, 2015), but further research is needed to expand such approaches and relate outcomes to particular learning experiences, such as serious games (Westera, Nadolski, & Hummel, 2014). These learning analytics tools can also usher in change by supporting formative data use. For instance, Reinholz and Shah (2018) created a tool to identify subtle inequalities in classroom participation. Such technologies should make it easier for teachers to sensibly collect and use learning data in their instructional decision-making (Cai et al., 2018).

With a now well-established body of research showing that gesture and embodiment can support and reveal learning (Alibali & Nathan, 2018; Lira & Stieff, 2018; Williams-Pierce et al., 2017), advances in wearable technologies are also allowing researchers to explore ways to integrate these into STEM teaching (Lee, Drake, & Williamson, 2015; Norooz et al., 2016). While new technologies offer more accessible ways to engage in STEM, they also risk widening opportunity gaps; any bring-your-own-device approach runs this risk. Likewise, researchers have raised concerns about equitable access to and use of technologies in STEM classrooms (Kitchen & Berk, 2016), including the fact that technologies that end up in schools serving marginalized groups are less likely to include professional development for faculty and less likely to engage learners in agentive ways (Kitchen & Berk, 2017). It is also important to note that access gaps persist in many parts of the world; as of 2017, less than 55% of the world population had Internet access ("Internet World Stats," 2017). This is a tension our field needs to address and treat with critical reflection.

Ultimately, to support transformative uses of technology, researchers will need to collaborate closely with teachers and consider designs that support them to use innovations expansively, while also engaging students agentively (Cai et al., 2017; Davis, Janssen, & Van Driel, 2016; Linn, Gerard, Matuk, & McElhaney, 2016; Rubel & Stachelek, 2018). In order for our learning designs and technologies to be transformative, they must both fit into and modify many resilient structures that maintain inequities—a call over 15 years in the making (Lee, 2003). While continued qualitative and quantitative studies of classroom interventions are needed, research studies should therefore also attend to the systems and contexts at play and how these do or do not change in response to our interventions. Without such contextually dependent modifications that meet the needs of the students we seek to serve, integration of such novel technologies may fall short of responsive and relational applications to support the learning needs of diverse, under-represented populations in STEM.

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The Role of Instructional Design in Supporting the Transfer of Mathematical Knowledge and Skills

Fatih Ari, Ismahan Arslan-Ari, Fethi A. Inan, and Raymond Flores

Introduction

The twenty-first century has evolved to an era in which the citizens of the world produce and consume massive amount of quantitative information every day. This, in turn, has triggered a demand in the global society for individuals with skills such as making sense of and reasoning and decision-making with quantitative information outside of the school context (Steen, 2001). In other words, individuals in today's world are expected to use mathematical knowledge and skills to solve problems of real-world contexts (Rosen, Weil, & von Zastrow, 2003). Despite the number of years receiving formal mathematics education, however, a large number of high school and college graduates in the USA do not demonstrate the ability to transfer mathematical knowledge and skills outside of school (Hughes-Hallett, 2003). Recent results of the international assessments, such as the Program for International Student Assessment (PISA)), also confirm the existence of this problem. According to the 2015 PISA results, for instance, 29.2% of 15-year-old students in the USA performed lower than the proficiency level 2, described as the baseline mathematics proficiency by Organization for Economic Co-operation and Development (OECD) (2016). This indicates that these students can possibly answer well-structured questions in familiar contexts such as those presented in mathematics textbooks where questions and givens are clearly defined, but are not expected to answer more complex questions in novel situations. With the

F. Ari (✉) · I. Arslan-Ari
University of South Carolina, Department of Educational Studies, Columbia, SC, USA

F. A. Inan
Texas Tech University, Department of Educational Psychology and Leadership, Lubbock, TX, USA

R. Flores
Texas Tech University, Department of Teacher Education, Lubbock, TX, USA

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mathematics domain of PISA, OECD, in fact, aims to assess students' mathematical literacy, which can also be called quantitative literacy as it is defined within the field of mathematics. To an expert in the field of instructional design and technology, both constructs might capture a very similar meaning for the ultimate goal of education, the transfer of learning or transfer of knowledge and skills specifically gained in mathematics into unfamiliar contexts and situations.

At a macro-level, the solution to the abovementioned problem would definitely call for systemic initiatives including reforms in the policy, pedagogy, and curriculum (Hughes-Hallett, 2003). Yet, at the microlevel, we think traditional mathematics instruction can be supported with instructional design strategies and theories that have been found effective in fostering the transfer of mathematical knowledge and skills (e.g., problem solving) into novel situations. Therefore, parallel to the editors' vision for this version of the handbook, we will focus on the role of instructional design and technology in supporting the teaching and learning of quantitative literacy. Because our aim is not to distinguish between different types of mathematical knowledge and skills, we will adopt a broader perspective by using several definitions associated with quantitative literacy interchangeably and by mainly focusing on the utilization of instructional design strategies and theories to facilitate the transfer of mathematical knowledge and skills, not on the use of certain hardware or software technology. Furthermore, readers should note that our aim with this chapter is not to propose a new theory or framework for teaching and learning of quantitative literacy in general.

Quantitative Literacy, Mathematical Literacy, and More

Educators often emphasize the necessity for the transfer of learning into real world. It is almost imperative that knowing facts and concepts by itself is not enough anymore, and thus one should be able to use knowledge and skills to solve real-life problems in today's world (Jonassen, 2004). Although learning mathematics is necessary and important for school, being able to use mathematical knowledge and skills outside of school to understand the world around us and to reason and make information-based decisions is not only crucial but also has become a part of our daily lives. For example, before making an offer to buy a new home, a buyer might review different sources of information to better estimate the true market value of a home. This process might include reading and understanding quantitative information (e.g., percentages) as well as interpreting visually represented information.

So, what is quantitative literacy? We can simply define it as applying mathematical knowledge and skills in a variety of contexts, primarily outside of the school context. Various other definitions of quantitative literacy were proposed in the literature. The International Life Skills Survey defined quantitative literacy as "an aggregate of skills, knowledge, beliefs, dispositions, habits of mind, communication capabilities, and problem solving skills that people need in order to engage effectively in quantitative situations arising in life and work" (as cited in De Lange, 2003, p. 76). Similarly, Hughes-Hallett (2001) described it as "the ability to identify, understand, and use quantitative arguments in everyday contexts" (p. 91). OECD (2013) adopted a slightly different definition but used the term *mathematics literacy* instead:

> An individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens. (p. 17)

It is not uncommon to find other definitions that use the term *quantitative literacy* with slightly different descriptions. However, for the purpose of this chapter, the definitions above provide a comprehensive coverage for a wide range of mathematical knowledge and skills associated with the term. In addition to these definitions, others used different terms such as *numeracy* and *quantitative reasoning*. In fact, numeracy is the first expression used to describe quantitative literacy in the literature (see UK's 1959 Crowther report), but quantitative literacy has become the commonly used term in the USA. On the other hand, *quantitative reasoning* emphasizes the use of higher-order thinking skills to understand and to develop data-driven sophisticated arguments in real-world contexts (The National Numeracy Network, 2017).

It is evident that there are nuances that differentiate these terms (Karaali, Villafane Hernandez, & Taylor, 2016). However, all definitions share one goal in common, using mathematical knowledge and skills in real-world contexts. Steen (2001) emphasizes that quantitative literacy is the mathematics acting in one's own world. To be quantitatively literate, some basic understanding of mathematics is required. However, quantitative literacy is not solely related to the amount of mathematical concepts and principles gained through formal mathematics education. For instance, being able to solve a function problem on an exam in a Calculus course does not make an individual quantitatively literate. Individuals can possess knowledge of abstract mathematical concepts (e.g., functions, derivative, integral), but quantitative literacy focuses on understanding the usage of these concepts in real world and actually using them to solve problems in context. Therefore, the amount and the level of mathematics education an individual receives does not necessarily ensure high levels of quantitative literacy (Hughes-Hallett, 2003).

Jonassen (2004) emphasized that people deal with problems, big or small, every day which results in meaningful learning or learning that has value and practical importance for individuals. Therefore, it is plausible to place problem solving in "the heart of quantitative literacy" (Pollak, 1997, p. 91). In the remainder of this chapter, we will consider quantitative literacy, mathematical literacy, quantitative reasoning, and numeracy as similar terms emphasizing a common goal, use of mathematics to understand and to solve real-world problems.

The Issues with Teaching and Learning for Mathematical Literacy

As discussed earlier, the ultimate goal of teaching for mathematical literacy is to help students equip with skills and knowledge required not only in their formal mathematics education journey but also in their lives after graduation. In order to achieve this goal, however, educators face with many challenges some of which might be factors that exist outside of school (Cai et al., 2017). In this chapter, we will mainly focus on the challenges related to instructional interventions in the classroom.

Decontextualized Instruction

Traditional mathematics education is oftentimes disjoint from one's own world focusing on the mastery of abstract mathematics knowledge (De Lange, 2003) and does not focus on developing intuitive understanding of why and how to use mathematics in real world (Hughes-Hallett, 2001). On the other hand, teaching for mathematical literacy is not trivial job. Hughes-Hallet also points out that many mathematics teachers do not have experience with teaching for mathematical literacy. Especially with the current emphasis on high-stakes assessments, "teaching to the test" approach has become the primary concern of mathematics teachers (Hughes-Hallett, 2003). This, in turn, creates classroom environments where instructional interventions mainly focus on honing problem solving strategies required to be successful in these assessments. As a result, teachers' focus shifts to modeling how to solve well-structured test problems with a known solution so that students understand the rules and procedures of solving slightly different problems (Thomas, Alexander, Jackson, & Abrami, 2013). Furthermore, many mathematics textbooks offer practice problems that are well-structured and mostly require application of "a limited and known number of concepts, rules, and principles being studied within restricted domain" (Jonassen, 2004, p. 3). In such a system, many students, not surprisingly, give more importance to studying for the tests by solely memorizing the mathematical concepts, rules, and principles (Bray & Tangney, 2017; Foster, 2013). All of these factors, directly or indirectly, contribute to the problem of decontextualized mathematics education.

Need for Individualized Instruction and Scaffolding

In the past couple of decades, the need for mathematical literacy in general has placed problem solving skills at the center of the curriculum changes in mathematics education (Panaoura, 2012). Despite this growing interest, many teachers are challenged by the difficulties of teaching problem solving every day (Harskamp & Suhre, 2006). Part of the reason may be tied to the heuristic nature of problem solving and to the classroom settings that pose challenges in creating opportunities which consider the unique learning needs of each student (Harskamp & Suhre, 2006). Each student learns at a different pace and comes to the classroom with a different learning agenda (e.g., expectations, goals, experiences, etc.) that is influential for supporting one's problem solving skills. It is not fair to expect teachers to deal with such a diversity in the classroom and to adjust their instruction accordingly while focusing on mathematical literacy when the pressure of high-stakes testing is permanent. More importantly, most teachers do not possess knowledge and skills needed to adapt instruction based on their students' needs (Harskamp & Suhre, 2006). In addition, large classroom sizes and strict curriculum timelines make the situation further challenging for teachers. On the other hand, students oftentimes fail in problem solving not because they don't possess the required mathematical knowledge (e.g., rules and principles) but because they lack the knowledge of problem solving strategies and the ability to use mathematical tools properly (Harskamp & Suhre, 2006). Also, learning to apply mathematics in unfamiliar contexts is different than memorizing mathematical concepts and principles to solve problems, a common strategy many learners employ when learning mathematics. Because each learner is different in regard to their expectations, learning needs, knowledge levels, etc., the extent to which each learner needs scaffolding and feedback will differ, and this would require individualized support from teachers.

Students' Perceptions, Attitudes, Motivation, and Confidence

Students usually find mathematics harder than any other subject they study in school (Stodolsky, Salk, & Glaessner, 1991). Part of the reason might be because they perceive mathematics as an abstract subject only and do not realize that they will need to use mathematical knowledge and skills outside of school, especially in real-life situations (De Lange, 2003). De Lange also emphasizes that in addition to mathematical knowledge and skills, learners need confidence in their ability to use mathematics. Unfortunately, many learners develop negative attitudes toward learning mathematics during their formal mathematics education (Hughes-Hallett, 2001). In addition, many students demonstrate lower levels of motivation toward learning mathematics than any other subjects (Chao, Chen, Star, & Dede, 2016; Plenty & Heubeck, 2013; Star et al., 2014).

Role of Instructional Design in Addressing the Issues of Mathematical Literacy

Diligently designed instruction, learning environments, and/or instructional materials utilizing instructional design theories and strategies found effective in addressing similar issues in the field of educational technology might offer pedagogically sound solutions to the issues associated with mathematical literacy. Although each technology, software or hardware, offers unique features and benefits, we believe it is the synergy between instructional design strategies and a specific technology that enables us to design effective and efficient solutions to educational problems. Therefore, technology, if combined with appropriate pedagogy, might facilitate the teaching and learning of mathematical literacy and increase student engagement with mathematics in general (Bray & Tangney, 2016).

Situating the Mathematics Learning in Context

Over the past two decades, several theories and instructional strategies have been proposed to be effective in situating the learning experience in context. Among those are situated learning or cognition, cognitive apprenticeship, anchored instruction, case-based learning, goal-based scenario, and inquiry-based learning. Situated learning theory and the instructional approaches that focus on the role of context in learning assume that learning cannot be abstracted from the situation or context in which the learned skills or knowledge should be used (Brown, Collins, & Duguid, 1989). In addition to this, learning activity should be perceived as authentic, meaningful, and relevant (Dabbagh & Dass, 2013). In this section, we will provide a synthesis of the last 5 years of instructional design and technology research that utilizes a theory or instructional strategy proposing to situate the learning experience in context to enhance students' mathematical literacy, the ability of understanding and applying mathematical knowledge and skills in real-world-like situations as we defined for the purpose of this chapter.

Cognitive Apprenticeship Saadati, Tarmizi, Ayub, and Bakar (2015) examined the effects of an Internet-based cognitive apprenticeship model (i-CAM)) on postgraduate students' statistics problem solving performance. In a blended learning environment, more specifically, whether providing expert support in the form of modeling, coaching, and scaffolding in an asynchronous learning environment helps postgraduate students improve their statistics problem solving performance was tested. At different phases of their study, an expert modeled the solutions of problem scenarios and guided students through question prompts and hints to solve problems in different scenarios. As students gain mastery in solving statistics problems, the amount of scaffolding were faded. As a result, Saadati et al. reported that postgraduate students studying with i-CAM demonstrated significantly higher statistics problem solving performance than students who did not receive expert support during their learning process.

In the context of an engineering course on mathematical modeling and problem solving, Wedelin and Adawi (2014) utilized the principles of cognitive apprenticeship and inquiry-based learning as their framework and designed the learning activities around realistic, challenging problems that students were asked to solve in pairs. Problems used in their course varied in terms of complexity and difficulty, but were representative of problems students could encounter in their professional lives. Coaching and scaffolding were provided through questions and hints aiming that students' metacognitive skills were improved as well. Further, they modeled problem solving process in several ways which could help students how expert approach solving similar problems in different situations.

Anchored Instruction In a recent study, Zydney, Bathke, and Hasselbring (2014) examined the effects of different methods of guidance with anchored instruction in a computer-supported learning environment on fifth-grade students mathematical problem solving skills. In the first design of the software, students received explicit guidance prior to working with the software, and then they used video anchors, presenting mathematical problems in real-life scenarios, to practice and apply the mathematical skills and knowledge. In the second design of the software, the only difference was that the scaffolding was provided as needed while students were trying to solve problems cooperatively. Results of this study indicated that scaffolding when provided as students need during problem solving along with video anchors of real-life scenarios helps students perform better on solving conceptually easier problems. However, a different type of guidance method might be needed for more complex mathematics problems as results did not indicate any differences between students' performances between two different methods of guidance.

Similarly, Gunbas (2015) designed a computer-based story to improve sixth-grade students' mathematics word problem solving skills. Adhering the principles of anchored instruction, the computer-based story presented word problems within a real-world scenario that is relevant to the students. According to the results of the study, sixth-grade students studying with the computer-based story outperformed those who studied with either the paper-based story version or the nonstory version. Although the scenario was presented as a text in the computer-based version, audio narration along with synchronous highlighting of text was used to help students follow the story. The computer-based story version also provided students with feedback in the form of partial solutions in a conversational style.

Overall, the studies described above have provided some evidence for the impact of situating mathematics learning in context to improve students' problem solving skills. However, this does not mean that situating the learning experience in context is simply embedding word problems in a story. The context of the story or the scenario used to situate the problem solving experience should be familiar to students and require students practice higher-order thinking skills (e.g., evaluating, comparing, etc.) in addition to the application of principles and rules. Similar to simple word problems (see story 1), mathematics problems when presented in a shallow story describing a real-life situation may not engage students in problem solving that is authentic and relevant (Dabbagh & Dass, 2013) and thus may not result in transfer of learning. Therefore, mathematics problems should be crafted in a way that makes students perceive the problem situation relevant to their lives and that requires them to practice skills and knowledge other than basic calculation skills. For example, to solve the problem presented in the story 2 below, students not only need to make calculations but also need to compare different combinations of song(s) and/or album(s) in order to find the most efficient solution, a situation each student might have experienced or can experience at one point in their lives. Evaluating different options and making a decision based on the results of our evaluations are necessary skills in the twenty-first century.

Story 1 You have an mp3 player with a storage capacity of 1000 MB. If you already used 600 MB of the available space, how many more songs can you store in your mp3 player if a song is 40 MB in size?

Story 2 You have an mp3 player with a storage capacity of 1000 MB. And you already used 600 MB of the available space. Using the available space in the most efficient manner, what combination of song(s) and/or album(s) would you store in your mp3 player? Note: Each album has five songs:

- Song A = 25 MB, song B = 100 MB, song C = 50 MB, song D = 50 MB
- Album X = 375 MB, album Y = 250 MB, album Z = 175 MB

Individualizing the Mathematics Learning

Although there is a social aspect of learning such as learning within a collaborative environment through dialogue with peers, individuals have unique learning goals and needs. Individualized learning environments, adaptive learning systems, intelligent tutoring systems, and similar initiatives have been proposed as a remedy for addressing the individual differences in educational contexts.

In a recent study, Haelermans and Ghysels (2017) studied the effects of an individualized software on seventh-grade students' numeracy skills. The software provided individualized practice and feedback based on students' knowledge level on sub-domains of numeracy. Students were tested at certain intervals and as they gain expertise, the exercises were adjusted according to their new skill levels. Compared to the nonindividualized version, individualized software helped students improve their numeracy skills significantly.

Similarly, Chu, Yang, Tseng, and Yang (2014) tested the effects of an intelligent system on fifth-grade students' performance in solving fraction problems. The intelligent system was designed to diagnose the problems students experience while solving fraction problems so that individualized feedback can be provided. Problems were divided into steps within the system and students' performance at each step was monitored. As a result, to-the-point, just-in-time feedback was provided while students solve problems. Although both groups received the same instruction during the experiment, Chu et al. concluded that the problem solving performance of the students who worked with the intelligent system was significantly higher than the students who did not use the system.

At the college level, Flores, Ari, Inan, and Arslan-Ari (2012) designed an adaptive tutorial aiming to support undergraduate students' statistics problem solving skills (e.g., probability, sample spaces, etc.). The tutorial provided a web-based learning environment in which the instructional explanations, examples, and practices are adapted based on students' existing knowledge and motivation levels. For example, students with low prior knowledge on a subsection of the tutorial were given opportunities to study additional content, to work with guided practices, and to have less control over the tutorial navigation as suggested by the instructional design theory and research. Flores et al. reported that the adaptive tutorial was more effective for low prior knowledge learners to improve statistics problem solving skills.

In another study, Inan, Ari, and Flores (2012) studied the impact of a similar adaptive problem solving system, named APS4Math, on junior high school students' word problem solving skills. APS4Math divides problem solving process into smaller steps representing different sub-skills (i.e., text comprehension, problem categorization, problem representation, solution planning/execution, and self-evaluation). By monitoring student expertise level through the Knowledge Tracing Algorithm for each problem solving sub-skill, the problem difficulty, guidance, and help are adjusted accordingly while students solve problems. For instance, low performers start with easier word problems until they become proficient in solving problems at their current level, whereas high performers work with more complex word problems and receive no or limited guidance. Inan et al. reported positive results from the implementation of APS4Math indicating that low prior knowledge students benefitted more from the system.

As a result, adaptive learning systems can offer the most appropriate learning trajectory for each learner considering various individual difference factors. It is evident from the results of the above studies that adaptive systems are more effective in helping low prior knowledge learners to improve their mathematical skills. This might indicate that the designs and techniques implemented in these systems that are found effective for low performers can diminish their effects for high performers (Kalyuga, Ayres, Chandler, & Sweller, 2003). With these and similar learning systems, the aim is not and should never be to replace the current methods of teaching mathematics but should be to support them.

Enhancing Motivational Outcomes and Confidence

Salient features of technology combined with appropriate pedagogical strategies can be effective in increasing as well as sustaining learners' motivational outcomes and confidence in mathematics (Calder & Campbell, 2016). For instance, educational games have been reported as effective solutions to facilitate learning and motivation (Ke, 2008; Vogel et al., 2006). This section will review the instructional design and technology research implementing strategies to enhance motivational outcomes and confidence in using and applying mathematics.

A good example for integrating various instructional strategies into an educational game can be found in a study conducted by Pareto, Haake, Lindström, Sjödén, and Gulz (2012). They designed a math game for third-grade students to promote not only conceptual understanding of mathematics problem solving but also to facilitate such cognitive skills as reasoning about and reflecting on solutions that are important for mathematical literacy. A pedagogical agent was also integrated in the game who can learn from the student player. Based on the cognitive apprenticeship model, students assume the role of experts and teach their agents how to play the game. The math game also provided opportunities to compete and collaborate with peers and/or pedagogical agents which helps sustaining student motivation toward learning within the game environment. The results of Pareto et al.'s study showed that studying with the math game in addition to the regular mathematics classes over a 9-week period improved third-grade students' mathematical literacy skills. In addition, game-playing was found effective in improving students' confidence with explaining mathematics to the others. The qualitative findings of the study also revealed that collaborative and competitive activities within the game environment sustained students' motivation toward learning with the math game.

In a relatively similar context, Jackson, Brummel, Pollet, and Greer (2013) investigated the impact of game-based collaborative learning delivered through an interactive tabletop on fourth-grade students' mathematics problem solving performance and attitudes toward learning with interactive technologies. Students worked as a group of four to solve mathematics problems about the concepts learned in the classroom. The results of the study suggest that students increased their problem solving performance and attitudes toward learning with interactive technologies after being exposed to game-based collaborative learning activities delivered through an interactive tabletop. There could be several possible explanations for the positive results such as collaborating with peers, learning in a game-like environment, and possessing higher levels of overall motivation due to being exposed to a technology that students haven't experienced before.

In a recent study, Calder and Campbell (2016) looked at the effects of iPad apps, mainly apps with game-like features, on 16- to18-year-old reluctant learners' beliefs and attitudes toward mathematics. The apps selected for the study provided learners with visual and verbal, immediate feedback and challenged them by increasing the difficulty and pace of the learning activities as learners succeed at a level. Furthermore, teachers used the apps in a way that facilitates an environment where group of learners work on tasks collaboratively to compete with other groups. Calder and Campbell's study demonstrated that students developed positive attitudes toward mathematics after using game-based apps in a collaborative and competitive learning environment for about 6 months. The opportunity to discuss with peers and the teacher while solving problems combined with visual and verbal feedback increased learners' engagement with mathematical tasks.

In another study, Panaoura (2012) evaluated a web-based implementation of a mathematical model proposed by Verschaffel, Greer, and De Corte (2000) on fifth-grade students' self-representation, self-regulation, and problem solving performance. The model emphasized the importance of various cognitive processes at different stages of problem solving such as understanding the problem in a situation, creating a mathematical model of the problem, and interpreting the results. A pedagogical agent in the form of a cartoon animation was integrated into the web-based learning environment, who modeled a peer depicting how to handle the difficulties one might face when solving problems. The pedagogical agent guided students' thinking by asking questions and providing hints to improve students' self-regulation skills. Results from this study indicated that students working with the pedagogical agent in the web-based learning environment exhibited enhanced self-regulation skills and thus better problem solving performance. As Panaoura emphasizes, real-world problem solving is challenging and creates obstacles that problem solvers should overcome at different stages of the problem solving process. Hence, it is important to provide scaffolding when students experience difficulties while solving mathematical problems so that students do not lose confidence in their ability to solve problems.

Conclusion

Teaching and learning for the transfer of mathematical skills and knowledge is a challenge. The large classroom sizes, unique learning needs and agenda of each student, and the negative beliefs and attitudes toward mathematics as a subject make this issue even more challenging. As we tried to demonstrate through this chapter, instructional design theories and strategies when combined with salient features of technology can offer pedagogically sound solutions to the abovementioned issues. However, this effort cannot be perceived as the responsibility of a specific group only. Developing mathematical literacy skills is a collaborative effort throughout middle school, high school, and college (Hughes-Hallett, 2001).

One of the common emphases across the studies we analyzed in this chapter is that the educational solutions are primarily offered as a supplementary practice or study within regular mathematics classes. This, of course, does not mean that the method of teaching in regular mathematics classes is or should only be direct instruction. However, one should note that even though the research focusing on mathematics problem solving and instructional design emphasize the importance of situating learning in context and creating opportunities in which students can solve problems socially, teaching with word problems is still a common method used in K-12 and higher education (Jonassen, 2003).

Understanding and applying mathematics in real world is practice-oriented. Conceptual understanding and procedural application of mathematical principles and rules are definitely needed to succeed in formal education. However, to realize the bigger picture (e.g., why we need mathematics or how can we use mathematics to solve problems in real life) and to become mathematically literate citizens, students need to practice such skills as reasoning, evaluating different solutions, or collaborating with others toward achieving a common goal instead of just practicing prescribed strategies to solve mathematics word problems that are well-structured and not rich in context and have defined solutions. Situating problem solving learning in context around collaborative learning activities has been found effective as demonstrated by several studies in this chapter. Furthermore, making tacit expert knowledge (i.e., teachers) visible to novices (i.e., students) is a good way of scaffolding the problem solving process, especially when learners are required to evaluate different solution options.

Finally, advancements in hardware and software technology today allow us to design learning environments that can adapt instruction, practice, and support based on individuals' learning needs or educational games that can provide engaging, challenging, and competitive learning tasks which can improve learners' motivation toward and confidence in mathematics. Although each technology can emphasize a specific way of implementation, it is educators' creativity and repertoire of pedagogical approaches what makes the difference. For example, an educational game designed for individual use might still be utilized as a collaborative learning tool.

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How Educational and Communications Technologies Play a Role in Arts and Humanities Teaching and Learning

Erica Rosenfeld Halverson, Anna Jordan-Douglass, Jessie Nixon, and Emily Schindler

While educational and communications technologies (ECTs) are typically associated with science, technology, engineering, and math (STEM) fields, the arts and the humanities have a rich tradition of using ECT to engage learners in innovative and productive approaches to teaching and learning. Progressive pedagogies that seek to reframe learning from a consumptive act to a productive one rely on ECT as crucial components of a distributed system for accessing, storing, creating, and sharing work (e.g., Barron, Gomez, Pinkard, & Martin, 2014; Ito et al., 2013). In this chapter we address the crucial topics framed by this Handbook by answering four key questions:

- What theoretical ideas guide the use of ECT in arts and humanities education?
- How do we define ECT in the arts and the humanities?
- How have ECTs been taken up in arts and humanities-based educational settings?
- Why do ECTs matter for the arts and humanities?

In answering these questions, we aim to review and synthesize relevant research on the role of ECT in arts and humanities education, provide a critical perspective on these research contributions, and discuss efforts to provide sustainable, scalable ways of taking up ECT in the context of the arts and humanities that can both lower barriers to access and reframe activitiesto take advantage of diverse repertoires of practice (Gutiérrez & Rogoff, 2008) and rich cultural folkways in order to move more students toward positions of curricular privilege in our schools.

E. R. Halverson (✉) · A. Jordan-Douglass · J. Nixon · E. Schindler
University of Wisconsin–Madison, Madison, WI, USA
e-mail: erica.halverson@wisc.edu

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What Theoretical Ideas Guide the Use of ECT in Arts and Humanities Education

Understanding the role of ECT in the arts and humanities requires a theoretical lens to orient us to the relationship between students, teachers, and tools within a learning ecology. Theoretical ideas guiding the use of ECT in the arts and humanities can be understood through three shifts in thinking over the past 50 years about the nature of learning and the role of technology. The first shift, often called the "sociocultural turn" (Krischner & Martin, 2010), takes us from an understanding of learning as autocratic, or located within individuals and their behavior, to situated within ecological systems of sociocultural and historical activity. The first theoretical shift in thinking about the role of ECT in the arts and humanities is related to the role of all tools in sensemaking. Vygotsky's 1978 essay, "Tool and Symbol in Child Development," posited that learning is not, as had been previously theorized, a matter of a one-way interaction between a learner and a tool; instead, Vygotsky theorized that learning is best viewed as activity within an ecology that includes tools and other people. The implications for this theoretical shift in the arts and humanities meant that literate behavior, previously understood as an autocratic, behavioral interaction between a learner and a sensemaking tool, like an alphabet, began to be explored as socioculturally and historically situated (c.f. Ong, 2001). Indeed, Scribner and Cole (1981) brought us an account of literate sensemaking among the Vai people, illuminating the ways productive sensemaking is necessarily situated within the cultural, historical, social situation in which it will be applied. Scribner and Cole's work, combined with other postmodern works like Bakhtin's (1981) theory of heteroglossia and the dialogic nature of discursive development, essentially destabilized the idea of learning as behavioral, as an easilyobservable interaction between a human and a tool or idea. Therefore, one's literacy would no longer be defined by one's knowledge of an alphabet, nor all the sounds of an alphabet, nor even of how to write all of the letters of that alphabet into words, sentences, paragraphs, and so on; instead, the role of tools in relationship to literacy caused the field to wonder, "Literate in what? For whom?"

The loss of alphabetic knowledge as the definition of literacy caused a productive destabilization in the arts and humanities because it opened the field to consider how one's sociocultural and historical positionality affects the way one uses discourse as a tool for learning. Gee theorized (D)discourses as tools and materials used by learners to negotiate their social identity and participation (1991). Building on the work of Gee and Bakhtin and critical theory, Gutierrez, Rymes, and Larson (1995) considered the ways that predominantly African-American and Latino students used language as a tool to develop a curricular counterscript, that is, a system of knowledge that localized sensemaking in order to strengthen belonging among their peers, and to express their opposition to the script, or the definition of "good learning" propagated by their teacher and the curricular structure he represented. This and other scholarships (e.g., Cooper, 1986; Ladson-Billings, 1994; Smitherman, 1995) repositioned sensemaking as a practice of using tools (linguistic, discursive, or otherwise) to mobilize power for agentic development and indicate belonging in social, historical, and cultural groups.

The second major shift involves the reimagination of digital tools from stable entities used for a specific purpose to objects meant for collaborative iteration. Reconceptualizing learning from a consumptive to a productive activity means understanding technologies as tools for making knowledge rather than simply accessing it. While the definition of literate sensemaking was undergoing a fundamental shift toward the sociocultural, advances in digital technology also brought about scholarship examining how powerful digital tools force us to rethink what it means to know and to learn. These two separate lines of development meet in theories of new literacies and multiliteracies (Street, 2001; Lankshear & Knobel, 2006; Cope & Kalantzis, 2000). The "under construction" nature of physical and digital tools caused theorists in the arts and humanities to again reconsider what constitutes literate sensemaking and, further, how that literate sensemaking impacts other disciplinary foci, from the expanded accessibility of new artistic mediums to new forms of civic engagement. For a comprehensive review of the literature related to turns toward multimodality, multiliteracies, and new literacies in theoretical scholarship, see Rowsell and Walsh (2011).

Whereas pre-digital tools, like the written alphabet, were theorized as stable and unchanged by the user, theoretical work on multiliteracies repositions tools as created, acted upon, acted with, and redesigned by learners. Scholarship related to mobilizing multiliteracies for learning has focused on how to design digital tools, assessments, and curricula that recognize and afford varied sensemaking, including, for example, the use of video games as learning tools (e.g., Gee, 2005; Squire, 2016) and how digital tools mediate and expand ways notions of what literacy is and can be (Beach, 2012). Overall, the field of multiliteracies has provided a space for crucial theoretical conversations related to how the activity of teaching and learning is mediated by the use of digital tools.

We are currently undergoing a third major shift in theoretical understanding of the role of ECT in the arts and humanities related to social identities and civic participation. We are moving from fixed, linear developmental notions of sociocultural and political identities to understanding identities and social participation that is both made possible and complicated by ECT (Boyd, 2017). At this moment, theory related to ECT in the arts and humanities is developing more quickly than we can document and analyze. However, one crucial and consequential line of inquiry examines the role of ECT in civic participation.

For instance, danah boyd's recent work examines the role of media literacy in the resurgence of white nationalism and hacking which influenced the 2016 election (2017). In boyd's view, the challenge before ECT now relates to how society should react when participatory cultures are in themselves democratically conducted toward nondemocratic ends. Another example of the role of tools in civic participation comes to us from the work of Everett et al. (2017) whose study of the City of Learning project seeks to understand how digital tools can connect, document, and enhance informal learning opportunities for learners throughout Chicago (Barron et al., 2014). Lastly, new theoretical stances include a desire to understand the role of digital tools in promoting, maintaining, and growing democracy (Al-Shafei & Jenkins, 2017).

This scholarship represents a shift forward in the way we theorize ECT, in that ECT, though technical progress continues apace, has moved on from a romantic theoretical position that views all digital tools as inherently useful and innovative to a more realistic position occupied by all other essential human tools: the value of ECT in the arts and humanities and, elsewhere, is dependent upon the way they are used. In this way, the long history of the arts and humanities as the seat of analytical reasoning remains necessary to ECT, and the theoretical traditions that have underpinned the arts and humanities represent the future of what we will learn about the way humanity and ECT coexist.

These three shifts in thinking cause us not only to re-examine the role of ECT in the arts and humanities but also to question how ECT breaks down the curricular silo we call "arts and humanities."

What Counts as ECT in the Arts and the Humanities?

Given the changing nature of how ECT has been theorized in education research, it seems important to define what we mean by the use of ECT in teaching and learning contexts. What do we use ECT for? How have researchers described what ECT is within the teaching and learning ecology? We take a youth-oriented lens toward defining ECT, as these tools are a part of their everyday activities both in- and out-of-school contexts (Ito et al., 2010). Youth participate in a constantly changing set of media learning ecologies where they have access to a multitude of media options toward three primary purposes: consumption, production, and collaboration and community building.

Consumption

Media consumption, such as watching video, reading, listening, playing games, and browsing the web, are a major part of a young person's day, with teenagers (ages 13–18) spending an average of 9 hours with media per day and tweens (ages 8–12) spending an average of 6 hours a day, not including time spent using media for school or homework (Rideout, 2016). Leveraging these media practices present in youth's daily lives, ECT can effectively serve as a vehicle for learning across a multitude of genres and can serve multiple functional roles in learning. Video games, for example, can serve as content providers, "bait" for preparation for future learning, vehicles for assessment, and model systems for engagement (Gee, 2005; Steinkuehler & Squire, 2014). YouTube and other online streaming platforms offer a space for learners to engage with specialized content, from listening to a particular version of a song to learning complicated chords and guitar licks. In higher education, music educators encourage effective use of technology to enhance self-exploration, collaboration, listening, and the use of visual enhancements (for a brief review, see Cayari, 2011). Blogs allow readers to leverage new affordances such as “textual connections”; hyperlinks to other sources; multimodal information from embedded photos, videos, and audio; and subscriptions (Davies & Merchant, 2007, p. 168).

These consumption practices and ECT can be leveraged as powerful instructional tools in the classroom. While classrooms are historically places that foster just-in-case learning, ECT can support just-in-time learning (Collins & Halverson, 2009). ECT can enhance instruction in a variety of ways, including customization of the learning environment, access to real-world problems, and giving students and teachers more opportunities for feedback, reflection, and critique (Bransford, Brown, & Cocking, 2000). But integrating informal consumption practices in the classroom can be challenging. The current generation of students entering and graduating from college are the first to have lived their entire lives immersed in digital technologies. Teacher education students who are fluent with ECT can bring knowledge and understanding of ways in which technology, pedagogy, and content knowledge can be combined and can “serve as collaborators in determining methods for adapting emergent social media and communications technologies to classroom use” (Bull et al., 2008, p. 105).

The use of social media platforms such as Facebook, Instagram, and YouTube can blur the lines between consumption, production, collaboration, and sharing, as users often become creators through commenting and feedback, adding their own videos, and sharing or curating media. New media has changed what media is and how it is consumed as “we are moving away from a world in which some produce and many consume media, toward one in which everyone has a more active stake in the culture that is produced” (Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006, p. 10).

Production

ECT gives youth opportunities to leverage their interest in media as a way to move from consumer to producer of creative materials such as games, animation, digital art, photography, filmmaking, and podcasting. These types of productions allow for complex forms of multimodal communication and gains in acquiring literacy practices across content/domain areas, including new media literacy, technology fluency, artistic expression, traditional computer courses, or media education (Peppler, 2010). Furthermore, creative arts production emphasizes a focus on the critical writing of texts across written texts, visual images, software programs, discussions, and other media, while encouraging design (Peppler & Kafai, 2007), to create “imaginative and expressive forms” that are driven by youth choice (Lange & Ito, 2010, p. 194) and access to tools.

Friendship-driven practices, such as sharing photos, making videos, or creating profile pages in a social media context, are driven by a desire to capture a personally meaningful moment rather than an urge to produce a creative work (Lange & Ito, 2010). However, leveraging these casual forms of production can lead to more expert forms of production, through access to tools that enable more refined practices of production and editing, as well as online sharing which allow learners to distribute their work, opening up avenues for feedback on their work. Remixing media in forms such as machinima, mashup videos, and fan fiction are common ways for youth to enter into more sophisticated forms of media production and participate in meaningful ways with interest-driven communities while they "develop new experimental genres that make use of the authoring and editing capabilities of digital media" (Lange & Ito, 2010, p. 342).

The production of creative media arts has benefits that go beyond the development of texts: "At the heart of youths' media art production lies the ability to build a more democratic society, one that fosters the inclusion of youth from marginalized communities, provides them with the capacity to participate in the 21st century, and actively re-engages them in the learning process" (Peppler, 2010, pp. 2144–45). Moreover, because this form of production is so closely tied to youth's existing interest in new media, it has the potential to serve as a tool for active learning, connecting in-school and out-of-school learning (Peppler, 2010).

Collaboration and Community Building

ECT and new media open up the possibilities of sharing artwork more widely with a distributed network than is possible with traditional media types (Peppler, 2010) and "add to the creative production process by providing opportunities to circulate work to different publics and audiences and to receive feedback and recognition from these audiences" (Lange & Ito, 2010, pp. 250–1) which further opportunities for peer-based learning and specialization. Sharing work, collaborating online, and participating in online communities provide pathways for some youth to develop commitments to this kind of work, engaging in "participatory culture" (Jenkins et al., 2006), which allows youth access to easily engage in artistic expression and further develop their craft and identity as a media creator through ongoing engagement with peers and audiences.

In some models that leverage a learner's multiple learning ecologies, across both in-school and out-of-school time, ECT also allows learners to share work across contexts. The Digital Youth Network (DYN) was created as a new model for learning environments that spans across in-school, out-of-school, online, and home contexts to teach youth how to use new media literacy tools, develop technical skills, and achieve goals using these skills (Barron et al., 2014). By leveraging all of these contexts together, "students acquired skills, developed constructive dispositions, and became practitioners within the DYN community" (Barron et al., 2014, p. 113), moving youth from "casual makers of digital artifacts to creators with a purpose" (Ibid., p. 131). To make this transition, students needed these various contexts to work within to have opportunities to not only create and pursue projects around their own interests, but reflect on their creations. Interest-driven learning across contexts, also called Connected Learning (Ito et al., 2013), occurs when youth find peers who share their interests, can access community resources to engage in peer-driven forms of learning, and attend academic institutions that recognize and leverage interest-driven learning, or the knitting together of three crucial contexts: peer-supported, interest-powered, and academically oriented (Ito et al., 2013). Engaging around shared interests with peers and friends provides a space for youth to share and give feedback to one another in their everyday social contexts. Leveraging subjects that are personally interesting allows learners to achieve greater learning outcomes. Allowing learners to connect these interests in different subjects and peer experiences to their academic studies can help learners realize their potential. Ito et al. posit that "bringing together and integrating the motivations, content, and abilities from social, interest-driven, and formal educational spheres can expand the reach of meaningful and sustained learning" (2013, p. 63) and leverages these three contexts that are traditionally disconnected or at odds with one another.

Across learning ecologies, peers play an important role in how youth develop their creative production skills and identities as creators. Through these "social processes of media production," youth are able to provide feedback and guidance to one another on the quality of their work through new channels made available through ECT (Lange & Ito, 2010). For example, members of communities such as Scratch (Fields et al., 2013, 2015) and fanfiction sites (Black, 2005; Magnifico, Curwood, & Lammer, 2015) regularly participate in organic critique and collaborative problem-solving with like-minded peers as they feel that their contributions matter (Jenkins et al., 2006).

How Have ECTs Been Taken Up in Arts and Humanities-Based Educational Settings?

With the growing recognition of the collaborative benefits of ECT, educators have also embraced the power of learning in a variety of spaces no longer limited to the classroom setting. ECTs, for example, have been embraced in a variety of spaces including, but not limited to, formal classrooms, informal classrooms, social networking sites, video games, and fan fiction sites (Black, 2005; Jocson, 2012; Steinkuehler & Squire, 2014). Each environment, from classroom settings and informal learning spaces to online learning environments, presents unique possibilities.

Classroom Spaces

In language arts classrooms, educators are faced with the difficult position of teaching ECTs while fulfilling district standards about what "officially" counts as literacy learning (Jacobs, 2012). Moreover, development of such programs as the Common

Core has created standards that promote traditional print-based literacy. Vasquez (2015) acknowledges the complexities and pressures teachers face in covering standardized curriculum, but argues that "the journey matters and what happens en route makes a difference" (p. 147). She demonstrates how a second-grade classroom not only met standards, but far surpassed the mandated curriculum in their creation of their podcast "100% Kids." The language arts curriculum mandates that youth are taught oral communication skills, how to comprehend information, and how to write stories (p. 150). While creating the podcast, students far surpassed the mandated curriculum and learned how to critique performances, research skills, and script writing.

Embracing ECTs does not mean having to abandon traditional texts, but recognizing the benefits of digital media. Kirkland (2013), for example, demonstrates how "traditional" texts can take on new domains and even offer innovative ways to revisit canonical texts. Instead of filling out a character analysis worksheet, Kirkland's students created Facebook profiles for Shakespeare's Iago, learning about his complexity and pulling on evidence from the text to support their analysis. Here, students were encouraged to use the tools and the space they use for writing to create a "new writing experience, a rewriting of a canon" (p. 45). Whether rewriting or creating one's own stories, youth also learn much about the collaborative nature of composition through digital media production. For example, Danzak (2011) demonstrates how researching family stories to compose graphic immigration stories helped ELL youth place themselves within a larger group identity. Combining individual graphic immigration stories into a larger collective of immigration stories "served as a means to affirm and reaffirm the students' own individual and group identities" (p. 188).

Vasquez, Kirkland, and Danzak's work demonstrates one of the greatest advantages of ECTs: the benefit of collective expertise (Jocson, 2012). Through ECT production, youth share collective expertise, gain skills in production, and participate in complex collaborative practices. From authoring augmented reality tools (Billinghurst & Duenser, 2012) to using Diigo or wikis to build collective knowledge (Beach, 2012), ECTs promote collaborative learning experiences in classroom and informal learning spaces.

Informal Learning Spaces

There has been an uptick in research on informal learning spaces due to the increased numbers of community-based programs with technology support and the dismantling of arts-based programs in schools caused by No Child Left Behind's focus on testing (Jocson, 2012). Many informal learning spaces, such as the Digital Youth Network (DYN), understand that youth often view schools, home, and community spaces "as separate domains that by and large do not interact with or impact each other" (Barron et al., 2014, p. 8). To shift this divide, the DYN, which helps underserved middleschool students develop technical and creative skills, works to build bridges across numerous settings, combining in-school, out-of-school, as well as an online social networking tool, Remix World, to "address the inequities for African American youth attending public schools on the South Side of Chicago" (Barron et al., 2014, p. 8). While the in-school DYN arts classes ensure that students have basic digital literacy skills, voluntary after-school DYN programs allow youth to work in areas of interest including spoken word, graphic design, digital music, digital video, digital queendom, game design, and robotics. In addition, the DYN provides numerous opportunities for youth to showcase their work, an essential part of "building environments that encourage youth to put consistent effort toward their effectiveness as digital media citizens" (Ibid., p. 34).

In many communities, informal learning spaces have become the place where youth are encouraged to embrace their cultural funds of knowledge (Ladson-Billings, 1994). From composing and transforming hip-hop lyrics into digital stories (Turner, 2011) and producing autobiographical art (Halverson, 2013) to collaboratively producing bilingual videos (Kelly, 2012), the power in such spaces rests in the collaborative nature in which knowledge is shared and where youth can "begin to reconceive who they are and what they might be able to accomplish academically and beyond" (Gutiérrez, 2008, p. 148). Mr. Soto, lead teacher of an extended-day literacy intervention program in an urban California public school, was able to encourage this important critical work through a curriculum that first taught youth to critique and analyze media and stereotypes in order to "develop and express an identity contradictory to these stereotypes" (Turner, 2011, p. 617). Through classroom discussions tied to communities and social justice, youth were better able to critique media, interpret meaning in digital texts, and produce their own critical media.

While Makerspaces are often associated with the STEM fields, scholars such as Kafai, Fields, and Searle (2014) demonstrate how the creation of arts-based projects such as electronic textiles combines the use of skills of circuit building, sewing, and coding. They argue that e-textiles give "students the opportunity to grapple with the messiness of technology"; as they experiment with technology, they begin to better understand the components and functions of technology "behind the shiny cases of their devices" (p. 536). As students become problem-solvers, "this work can disrupt the trend that puts students on the sidelines as consumers rather than producers of technology" (Kafai et al., 2014, p. 536).

Online Learning

The number of online courses has afforded youth from around the globe to access experts, visit ancient ruins, and learn mathematics from MIT professors. The field of online learning is growing exponentially as scholars recognize the impact of online learning in both formal and informal digital learning spaces.

Formal Online Courses

While online programs such as Coursera and Khan Academy have made it possible for youth to learn from professors at Yale, Stanford, and MIT, middle school and high school educators have also embraced the benefits of online learning in offering numerous online classes. Many public school online courses are housed in learning management systems such as Blackboard or Google Classroom, yet also provide opportunity to embed third-party content. Online learning allows for youth from all over the world to access digital archives such as Google's Art & Culture Project or Humanities 2.0's HyperCities (Guerlac, 2011). Google's Art & Culture Project provides youth with access to over 45,000 pieces of high-resolution artwork from over 250 institutions while also reaching beyond consumptive practices in offering experiments "at the crossroads of art and technology" (Google Arts & Culture, 2015). Now youth can go beyond learning art history in France but can virtually visit the Louvre, tour the inside and outside of the facility, and hear from artists and curators from around the world.

Online courses offer unique opportunity for participation and discussion providing for participatory learning through tools such as discussion boards and social media (Varela & Westman, 2014). Online discussions can create a community of inquiry where learners collaborate through critical thinking (Darabi et al., 2010). While early online courses were criticized for lacking the same type of spontaneous, high-level conversations found in a face-to-face classroom, teachers have improved their practices encouraging higher-order discussions with clear instruction and facilitation. Online discussion has evolved greatly to strategies such as debate and role-play which encourages more interaction and synthesis of course content (Darabi et al., 2010); co-constructing commonplace digital texts through annotations using Diigo, Reframe It, or Evernote; sharing oral annotations through VoiceThread; collaboratively constructing writing through Google Docs, Zoho Writer, and Adobe Buzzword; sharing fiction writing through sites such as Fanfiction, Inkpop, and Pulse It (Beach, 2012); and collaborative learning through platforms such as CommentPress (Davidson & Goldberg, 2009).

Informal Online Learning

Learning is not confined by physical spaces or sites that advertise their educational impact, but expands to online spaces from fanfiction sites (Black, 2009; Magnifico et al., 2015), online creative writing communities (Fields, Magnifico, Lammers, & Curwood, 2014), and Scratch programming communities (Fields et al., 2014) to networking art communities such as DeviantArt. Youth who participate benefit from engaging in artistic expression with supportive peers who also create and share work and engage in dialogue in which the most experienced members pass down information and skills to novice members (Jenkins et al., 2006). Black (2009) demonstrates how participation in a fanfiction site helped ELL youth improve their

English-language, composition, online composing, and technological skills as well. Youth benefitted from the collaborative practices, “and forms of knowledge in which authorship, teaching, and learning is distributed across community members” (Black, 2009, p. 694).

Why Do ECTs Matter for the Arts and Humanities?

As should be clear from this review, ECTs are ever-present in arts and humanities-based learning environments. Learning environments span formal and informal spaces and face-to-face and online interactions and are used for a range of purposes including consumption, production, and collaboration. Given this range of places and topics, perhaps the biggest challenge of synthesizing research on ECT in the arts and humanities is a lack of conceptual and theoretical coherence. Theoretically, the role for ECT has changed over time, settling now as potentially destabilizing tools in arts and humanities pedagogy that can promote new, production-oriented ways of learning to know and do. This destabilizing, though, has a mixed effect on learners, especially those who have historically been marginalized from mainstream teaching and learning. On the one hand, ECT have the potential to provide affordable, accessible tools for creating and sharing ideas. Critics of the maker movement, for example, argue that the ubiquitous presence of technology hides the importance of long-standing maker traditions and promotes a “hacker culture” that devalues the contributions of communities of color (Blikstein & Worsley, 2016; Vossoughi, Hooper, & Escudé, 2016). So which is it? Are ECTs liberating, as scholars like Ito and Jenkins describe? Or do they continue to reinscribe the values of middle-class, progressive education that erases long-standing traditions of creating with analog tools? Our review suggests that the meaningful inclusion of ECT can both provide additional opportunities for traditionally marginalized young people and change what counts as “good” arts and humanities work to include the processes and values of communities that have been left out of the teaching and learning conversation.

Finally, our insights are important to conversations about the role of ECT in education more broadly. Constructionist pedagogies that promote the use of ECT in formal and informal settings have largely been applied to “technical” pursuits, those situated in the fields of science, math, and engineering. A focus on the arts and humanities allows us to de-center STEM disciplines in the use of ECT for teaching and learning. A new literacies perspective on how people learn in the arts and humanities provides clear roles for ECT as opportunities for consumption of content, as tools for the production of new ideas, and as a means to share ideas. Researchers have demonstrated that ECT plays these roles across a range of learning environments including classrooms, out-of-school programs, and online learning environments.

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Vocational and Technical Learning

Brian S. Horvitz, Regina L. Garza Mitchell, Lisa R. Garcia, and Cherrelle D. Singleton

Vocational and technical education is becoming increasingly important to help meet the needs of our nation's growing and changing workforce (U.S. Department of Education, 2014). Vocational and technical education is a broad term that generally refers to a combination of academics and training intended to lead students toward obtaining a career. The terminology describing this type of education has evolved over time, but as Cohen, Brawer, and Kisker (2013) stated, "the words *terminal, vocational, technical, semiprofessional, occupational,* and *career* [emphasis in original] have all been used interchangeably or in combination" (p. 306) to describe it. Vocational pathways are offered at both the secondary and postsecondary levels, and increasingly these programs are able to transfer into baccalaureate degrees for students who wish to obtain further education (D'Amico, 2016). The goal of vocational and technical education is to equip students with the academic and technical skills necessary to participate in the workforce and be lifelong learners (Advance CTE, 2017; U.S. Department of Education, 2014). Curricular goals include technical skill proficiency, higher-order reasoning and problem-solving skills, general employability skills, and occupation-specific skills (U.S. Department of Education, 2014).

A wide spectrum of programs is included in career and technical education, which has been categorized into 16 career clusters and related pathways (Advance CTE, 2017) and encompasses everything from medical education to science, technology, engineering, and mathematics. For purposes of this chapter, we limit the focus to vocational and technical education programs and courses that primarily focus on educating technicians for high-technology programs such as manufacturing, engineering technology, automotive technology, etc. (ATE Central, n.d.). These programs tend to have a hands-on nature that relies on apprenticeship-style teaching

B. S. Horvitz (✉) · R. L. Garza Mitchell · L. R. Garcia · C. D. Singleton
Western Michigan University, Kalamazoo, MI, USA
e-mail: brian.horvitz@wmich.edu

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and learning to accustom students to working with the necessary tools and to adapt to the industry culture.

Needs and Problems in Vocational and Technical Learning

When examining educational technologies being used in vocational and technical education, it is helpful to organize them around the needs and problems in this field. As described above, the US Department of Education in its 2014 report, *National Assessment of Career and Technical Education: Final Report to Congress*, listed competencies needed by students in career and technical education. These competencies include technical skill proficiency, higher-order reasoning and problem-solving skills, general employability skills, and occupation-specific skills.

The first of these identified needs is for students to master complex technical skills. The technical skills students must learn in vocational and technical learning programs are challenging to teach. The complexity of this challenge is characterized well by the Commission on Adult Vocational Teaching and Learning (2013) who state:

> The best vocational teaching and learning combines theoretical knowledge from the underpinning disciplines (for example, math, psychology, human sciences, economics) with the occupational knowledge of practice (for example, how to cut hair, build circuit boards, administer medicines). To do this, teachers, trainers, and learners have to recontextualize theoretical and occupational knowledge to suit specific situations. Both types of knowledge are highly dynamic. So individuals need to carry on learning through being exposed to new forms of knowledge and practice in order to make real the line of sight to work. (p. 15)

The second identified need is for students to learn problem-solving skills. Today's workplaces are rapidly changing environments due to technological advances, and employers are seeking people who can overcome setbacks and failures through problem-solving (McIntosh, 2012). Lear and Hodge (2011) state that people at all levels of an organization will need to be able to think critically and solve problems. The predominantly hands-on approach used in career and technical education helps to provide students with problem-solving skills (Bernardino & Seaman, 2011). However, there is not much consensus on how to teach problem-solving in schools (van Merriënboer, 2013), because "problem solving is an extremely complex cognitive process about which little is known" (van Merriënboer, 2013, p. 153). One challenge of attempting to teach skills such as problem-solving in an online environment is that "technology can change the nature of work faster than people can change their skills" (Levy, 2010, p. 4). Also, when problem-solving is seen as a skill to be learned, it is something that develops over time as a function of practice (van Merriënboer, 2013). Vocational and technical education must be able to provide an environment where students are able to continually practice their problem-solving skills; however, that process is often time-consuming (Levy, 2010). Finally, educators need to provide opportunities for students to develop a deeper understanding of subjects that will allow them "to interpret new problem situations in more general terms, to monitor and to reflect on the quality of own performance, and to detect and correct errors" (van Merriënboer, 2013, p. 156).

The third need identified above is general employability skills, also known as *soft skills*. Technical skills alone are insufficient for obtaining and maintaining employment (Flaherty, 2014). While these skills do prepare students for the competitive workforce, it is the soft skills that separate candidates. Dutton (2012) affirmed that programs are failing to go beyond technical skills in order to cover soft, interpersonal skills. A survey conducted by the Computing Technology Industry Association found that technologically savvy employees often lack soft skills including team building, project management, problem-solving, innovation, time management, and analytical abilities. Soft, interpersonal skills are crucial in the business world, and online programs need to go beyond technical skills in order to effectively prepare students for the workforce (Dutton, 2012).

The fourth need is occupation-specific skills. These are the skills that prepare students for employment in a given occupation such as manufacturing, construction, or automotive technology. These skills include job-specific terminology or vocabulary, occupational culture (including acceptable behavior), oral and written communication practices, and other social norms that help enculturate students to acceptable and expected practices in the field. In short, occupational skills help enculturate students to particular occupational environments, norms, and expectations. These skills are usually gleaned through apprenticeships in the field and an apprenticeship-style approach to teaching and learning, such as that found in traditional vocational education classrooms (Pratt & Associates, 1998). "Students must be provided opportunities to gain these skills and learn to apply them to real-world life and work situations" (ACTE, 2010, p. 2). Obtaining occupation-specific skills is challenging in a face-to-face environment, and it becomes even more so in an online environment (Garza Mitchell, Etshim, & Dietz, 2016).

Beyond the four competencies identified by the US Department of Education (2014), another clear need in the field of vocational and technical education is addressing the challenge of the growing use of online learning. Over the past 11 years, online learning has "accounted for nearly all student enrollment growth at community colleges" (Lokken, 2016, p. 5), with 45% of all online enrollments at public institutions being at the community college level (Allen, Seaman, Poulin & Straut, 2016). Community colleges are the home to much of the technical and vocational education in the USA. While online learning is growing, instructors have concerns about its ability to effectively replace traditional hands-on instruction (Garza Mitchell, Etshim, & Dietz, 2016).

Review of the Relevant Literature

To ensure relevance of the research included here, we employed several parameters to our literature review search. We included only peer-reviewed journal articles that had been published in the last 5 years. We first searched journals that focused on vocational education, educational technology, or higher education, and then we expanded the search using keywords such as "educational technology," "online," and "technical education." The search resulted in 98 potential articles. We reviewed the articles to ensure that they met the following criteria: (1) a focus on secondary or postsecondary vocational and technical education (as defined above), (2) a focus on educational technology, and (3) a focus on an actual educational intervention. In total, 16 articles met the criteria and were reviewed for this chapter.

Technical Skills

Staklis and Klein (2010) defined technical skills as "those abilities and knowledge necessary for competent performance in carrying out responsibilities associated with the workplace" (p. 5). Thus, technical skills focus on the students' ability to competently and successfully carry out workplace procedures. This can be contrasted with conceptual understanding which takes place in the mind and is not necessarily applied through observable procedures. The following studies focused specifically on the development of technical skills.

Cattaneo, Nguyen, and Aprea (2016) investigated how hypervideo-based (or interactive video) learning can be designed to foster the acquisition of procedural knowledge in a vocational education and training context. The cases they used in their study involved a variety of professions: autobody repair, information technology, and healthcare operators. In another study, Gavota et al. (2010) examined the use of collaborative online writing about professional, technical procedures using online tools, such as blogs and wikis, in order to promote the development of professional competencies. A third study by Pu, Wu, Chiu, and Huang (2016) looked at the use of mobile tablet devices among vocational nursing students during a clinical practice course. The tablets were intended to enhance authentic learning by providing students with digital resources and giving their teachers increased opportunities to interact with and monitor their students.

These three studies each demonstrate very different approaches to the teaching of technical skills. Hypervideo-based learning primarily leverages demonstrations and modeling to show learners how to perform a skill. Collaborative online writing utilizes the learning that takes place when students reflect on and write about the technical skills they are developing. The use of mobile tablets embedded in the authentic task of practicing actual technical skills created opportunities that otherwise may not have been possible for teachers to play an integral role in students' practice of technical skills. This range of technology-rich teaching strategies hints at the wide variety of instructional approaches available to creative teachers.

Of particular interest is that only 3 of the 16 studies identified here explicitly focused on the teaching of technical skills. This is surprising given the focus of vocational and technical education on preparing students for the workplace and indicates a need for more research in this area. Considering the advancement and availability of simulation technologies that can help students learn necessary technical skills, it is surprising that more studies in this area were not available. It is unclear whether the studies are not being conducted or, if they are, not being published in refereed journals.

Problem-Solving Skills

Problem-solving is something everyone does in most if not all facets of their life. Jonassen (2004) went so far as to state "that the only legitimate goal of education and training should be problem solving" (p. 2). He described problem-solving as the creation of a mental model of a problem and its context and the active manipulation and testing of their model (Jonassen, 2004). Given the complex nature of the work for which vocational and technical education programs prepare students, developing improved problem-solving skills is clearly an important need. Three of the studies identified here clearly address approaches for addressing this need.

In their study, Yakubu, Makinde, and Joseph (2016) developed and examined computer-aided instruction (CAI) for the teaching of electrical and electronic devices. Their stated purpose was to develop tools to improve the development of basic skills and problem-solving attitudes. The CAI they developed allowed students to participate in self-paced, sequenced, online instruction. The researchers found this student-centered approach to teaching problem-solving skills more engaging and effective than traditional classroom teaching.

In another set of studies, Hämäläinen and Oksanen (2012) and Hämäläinen and Wever (2013) examined "a scripted 3D learning game to practice inter-professional knowledge construction in a vocational context"(Hämäläinen & Oksanen, 2012, p. 281). In the game, participants work together to prepare a charity concert event, ensuring customer satisfaction. Essentially, the participants work together on a set of puzzles. The researchers examined students' collaborative participation in this gaming environment and organized students into a set of primary participation categories. One of the six main categories was shared problem-solving (Hämäläinen & Oksanen, 2012). In the second study, the researchers found "joint problem-solving" to be one of the two main types of instructional activities taking place in this environment.

These studies, as with those highlighted above in the technical skills section, reflect the diversity of approaches educators can apply in using educational technologies to address instructional needs. The CAI approach studied by Yakubu et al. (2016) seems based on a more traditional behaviorist or cognitivist approach to instructional design in which students, working independently of each other, complete lessons that demonstrate and explain a predetermined set of problem-solving strategies. In contrast, Hämäläinen and colleagues (Hämäläinen & Oksanen, 2012; Hämäläinen & Wever, 2013) developed a clearly constructivist 3D, collaborative learning environment. In their approach, students have opportunities to work together to develop and try their own problem-solving strategies, and the emphasis is on a collaborative approach to solving problems in the field. Various factors may be considered in deciding between strategies that come from such different theoretical orientations such as the preferences of the teachers, the demographics of the students, the nature of the learning domain, the resources available to develop or acquire the educational technology tools, or the amount of time and teacher support that is available with the context of a larger course.

General Employability

According to the US Department of Education Office of Career, Technical, and Adult Education (2017), "Employability skills are general skills that are necessary for success in the labor market at all employment levels and in all sectors" (para. 1). In addition to applied academic and critical thinking skills, relationship and workplace skills such as communication are highlighted as key employability skills. Since applied academic and critical thinking skills seem to be covered by the Department of Education's (2014) inclusion of technical, problem-solving, and occupation-specific skills, the assumption here is that general employability skills encompass soft skills such as communication, time management, collaboration, and relationship skills.

Onorato (2014) developed and examined an instructional approach to help his microbiology students connect to the subject matter in a more personal and integrated way through reflective writing assignments using an ePortfolio system. Students were assigned to write about, research, and reflect on a disease caused by a microorganism that had impacted their lives. These reflections were made available not only to the teacher but also to the students' classmates. The researcher found that his students' learning was enhanced by connections this assignment fostered between the students, their pasts, the learning domain, and their classmates.

Two other studies that focused on students' communication skills using a computer-supported collaborative learning (CSCL) approach are the Gavota et al. (2010) study and the Hämäläinen and Oksanen (2012) study, both described above. In the Gavota et al. (2010) study, the researchers explain how students, through their blog and wiki writing activities, provided useful comments, corrections, and revisions to their classmates' written work. In the Hämäläinen and Oksanen (2012) study, the researchers also highlighted their CSCL approach as a way to support students' development of inter-professional expertise through the shared construction of new knowledge.

It is interesting that all of these studies are examples of computer-supported collaborative learning. CSCL is a "branch of the learning sciences concerned with studying how people can learn together with the help of computers" (Stahl, Koschmann, & Suthers, 2006, p. 409). In each of the studies described here, students have opportunities to collaborate on problems, provide feedback to each other, or simply share their reflections in computer-based learning environments. Given the maturity of the field of CSCL with its own academic journals and international conferences (e.g., *International Journal of Computer Supported Collaborative*

Learning, *Computer Supported Collaborative Learning in Higher Education*, *CSCL Conference*, etc.), there likely are many more opportunities for the professionals who specialize in career and technical education to borrow or be inspired by other types of innovative computer-based learning environments that support the development of such general employability skills in vocational and technical education.

Occupation-Specific Skills

The Department of Education's (2014) inclusion of *technical skills* was intended to focus on procedural learning regardless of learning domain. However, their inclusion of *occupation-specific skills* is centered on the need for educators to focus students on what they need to learn to be successful in the particular career paths they have chosen. Such occupation-specific learning may be procedural in nature or it may be knowledge-based.

In their study, Vremen-de Olde et al. (2013) explicitly concentrated on an approach to teaching students about the electricity domain of high-pass and low-pass filters. In the intervention examined, students learned in a simulation-based, inquiry learning environment. Within this environment, students were tasked with designing assignments for other imaginary students. Other studies that focused on occupation-specific skills include Yakubu et al. (2016) on the use of CAI for teaching about electrical and electronic devices, the study by Pu et al. (2016) on using mobile tablet devices to support the training of nursing practice in an authentic environment, and the study by Cattaneo et al. (2016) on the use of hypervideo to teach specific skills to students training for careers in autobody repair, information technology, and healthcare.

Mathematical skills are specific to many vocational and technical programs. While the studies above focused on using educational technology to develop occupation-specific skills, Offenholley (2014) examined the use of online tutoring as an approach to help remedial algebra students at a community college. While online, students could type their questions into a chat window and a live tutor would respond in real time. This was seen as particularly useful to students who do not have time to get to a classroom-based math lab or who get stuck on math problems while doing homework away from campus. Another such study was conducted by Wladis, Offenholley, and George (2014). They studied the implementation of a mandated set of online intervention assignments with feedback for students identified as "at-risk" at the midterm of a developmental math course at a community college. The assignments were provided automatically for identified students in the online course space and were required of all students who passed the midterm with a score of 70% or better. As a result of the intervention, passing rates improved as much as 50% higher than in semesters prior to the intervention.

It was surprising to find so few articles focused on occupation-specific skills, particularly in an age where simulation technology is available. However, the resource centers described earlier provide a myriad of information about what technologies and tools are being used to design quality learning experiences for students that focus on occupation-specific skills.

Online Learning

In addition to the needs stated by the Department of Education (2014) and explored here, another unavoidable theme among the studies identified is the proliferation of online learning in vocational and technical education. This reflects the larger, well-documented trend of an increasing and accelerating online learning presence in education at all levels and in highereducation, including 2-year colleges, in particular (Allen et al., 2016; Lokken, 2017; McFarland et al., 2017).

Ryan et al. (2016) examined the effectiveness of blended online learning courses in various content areas including statistics, biology, anatomy, and physiology at a community college. They found students enrolled in these courses performed similarly to, if not better than, students in traditional classroom settings. In another study, Capra (2014) looked at online learning from a community of inquiry (CoI) perspective. According to CoI theory, students' online educational experience is dependent on the social presence, cognitive presence, and teaching presence in students' online experience (Garrison, Anderson, & Archer, 2000). Findings from Capra's (2014) study "raise questions about the pedagogical soundness of fully online courses for community college students" (p. 108). In a third study, Liu (2013) examined an entirely online curriculum for training teachers at a vocational college. This was part of a larger accreditation process that included the work of a review panel and professors from other higher education institutions. Liu's (2013) study found that online learning was implemented successfully in this vocational education program.

In contrast to studies about online learning, one study focused on educational technology use in a traditional classroom. Sadeq et al. (2016) examined the use of interactive white boards (IWBs) in a secondary vocational school in Kuwait. The IWBs were intended to increase student engagement and participation as well as the overall effectiveness of teaching by affording students the opportunity to interact with information in a more active and sensory way. The researchers found mixed results on the use of this tool in their study and suggested they may work better in science-based subjects, rather than all subjects.

Based on the three studies examining online learning, it seems there is interest in understanding or determining the overall value of this mode of instruction for vocational and technical education. This is understandable since it is common to think about the hands-on nature of learning labs and opportunities to practice skills using various types of equipment and tools when thinking about technical education. Although vocational and technical education is characterized by its hands-on nature, students in these fields must also gain knowledge and theory as well as general employability skills such as those described above. Schools utilize a number of resources and technologies in the traditional classroom to enhance students' skills and learning, as shown by the variety of those available via resource centers. However, it is surprising that we only identified one study that is clearly focused on the use of educational technology in a traditional classroom. It seems that although technologies are being utilized, they are not being studied in depth by researchers. There is a need for future development and research on the use of educational technologies in technical and vocational education that focus on both online and traditional learning environments.

The Role of Resource Centers

Although there are few empiricallybased research articles available about educational technology usage and instructional design of vocational and technical education, a great deal of research is being conducted in this area by schools, colleges, universities, and their partners through trial and error in the classroom. In an attempt to highlight the good work being done at colleges and schools and address the shortage of published material about educational technology usage in vocational and technical programs, we (Garza Mitchell & Horvitz, 2017) edited a journal that highlighted nine federally funded projects that purposefully incorporated educational technology into technical programs. However, the most common way of sharing the tools and known results is through resource centers that are used by faculty at both secondary and postsecondary levels.

The Association for Career and Technical Education provides a variety of resources for CTE educators. These resources include online seminars that are free to members. Topics include classroom management, flipping the classroom, distance learning, problem-based learning, and more. The organization also hosts Virtual CTE Discussions that offer a venue for peersharing of resources. The resources provided here are general in nature and may include approaches to teaching and learning but do not provide actual course material.

The National Science Foundation's Advanced Technological Education (NSF-ATE) program is a key funder for partnerships between schools, colleges, universities, and industry that promote curricular development in technical education (ATE Central, n.d.). In addition to funding individual projects, NSF-ATE funds several national centers that provide access to free curriculum, modules, tools, and research conducted by grant recipients. ATE Central (http://atecentral.net) is a free online portal that highlights work being done through ATE projects and centers, and it includes a resource center with curriculum for a variety of technical subjects ranging in grade level from elementary through college and "informal education" for the general public. Resources include curricula, learning objects, podcasts, videos, and links to other resource centers. ATE centers offer even more classroom resources, from online and interactive simulations to virtual games and labs. Some of the centers focus on a single area, such as MatEdU National Resource Center for Materials Technology (http://www.materialseducation.org/) or the Nanotechnology Applications and Career Knowledge Support Center (http://nano4me.org/). Other centers, such as the Advanced Technology Environmental and Energy Center (http://ateec.org/), focus on a broader area and encompass courses or learning objects that span several programs of study. The most helpful aspect of these centers is that they gather materials for curriculum, program, and professional development from a variety of sources to provide learning tools for various levels of education. The materials are culled by knowledgeable professionals with the intent of sharing open resources to enhance teaching and learning in vocational and technical programs.

Research Approaches and Methods

The majority of the articles we found that focused on vocational and technical education applied quantitative or mixed method approaches, with only two qualitative studies. The quantitative approaches tended to be traditional experimental or quasi-experimental studies that evaluated student performance through tests or other assessments. Surveys were also used in several studies. The two qualitative studies took different approaches, a comparative case study (Cattaneo et al., 2016) and phenomenological interviews (Capra, 2014).

The qualitative aspect of the "mixed methods" studies was approached without rigor in many of the studies, with only two studies (Hämäläinen & Oksanen, 2012; Hämäläinen & Wever, 2013) indicating in-depth qualitative analysis. The remaining "mixed methods" studies included qualitative elements, such as interviews or comments, but did not provide explanations of systematic techniques for analysis or indicate how the qualitative results informed the quantitative findings. If a study is truly to take a mixed method approach, then careful consideration must be given to how each of the methods is used, what their purpose is, and how results are analyzed.

The majority of questions asked in these studies related to student learning, primarily using GPA or test scores to measure the impact of implementing a new learning technology or comparing learning with technology to traditional face-to-face methods. Other studies focused on a variety of issues associated with technology-based learning. Giani and Lee Fox (2017) examined the extent to which student enrollment in short- or very short-term programs with stackable credentials improved labor market outcomes. Sadeq et al. (2016) examined teachers' attitudes toward using interactive white boards. Few studies included student perspectives as a driving question. Capra (2014) interviewed students to gain the student perspective about the meaningfulness of their online learning experience. Ryan et al. (2016) included a student survey as part of their study; the survey collected demographic information and data about students' prior performance, study habits, time use, and familiarity of online learning – all important considerations when measuring the results of instructional efforts. Cattaneo, Nguyen, and Aprea (2016) observed classes and included both teacher interviews and student questionnaires to gain both perspectives about incorporating technology into teaching vocational courses.

There is a need for more studies about how students learn, what they learn, the factors that influence learning with technology, and the approaches to designing vocational and technical education. Studies are also needed that investigate the student perspectives on teaching and learning. Future studies should include both student and instructor perspectives about the learning process and tools and should carefully consider which methodologies are most appropriate to gain this information. Whichever approaches are chosen, they should be rigorous, relevant, and meaningful.

The studies reviewed here provided some information regarding teaching practices when incorporating educational technology into technical education, but little empirical data and no accurate methods exist by which to consistently measure instructional conditions in these settings. To scale effective instruction across all vocational and technical instructional settings, researchers and stakeholders need systematic, valid, and reliable methods to measure instruction in traditional, hybrid, and online courses. Observational instruments for classifying instructor behavior in the classroom are available to paint a comprehensive portrait of teaching practices, including the use of educational technologies, in classrooms (Hora, 2015; Piburn et al., 2000). However, despite the widespread and increasing adoption of online learning approaches (Johnson, Adams, Becker, Estrada, & Martín, 2013), there are no comprehensive instruments of teaching practices nor an objective set of descriptors necessary to classify teaching practices in online courses. Clear definitions of instructional practices are necessary in order to describe and evaluate instructional practices and, ultimately, to improve them (AAAS, 2013).

Future Research

Although the literature reviewed here provides insight into the approaches being taken to integrate educational technology into vocational and technical education, there is room for further investigation. In particular, more studies are needed that focus on how educational technology is being integrated into vocational and technical education, how online elements are being used, and how student learning is impacted. The studies reviewed for this chapter used a variety of quantitative, qualitative, and mixed method approaches. Although there are a great many resources available through NSF-ATE Centers, the Association for Career and Technical Education, and individual colleges and schools, it is not always known whether a scholarly or scientific approach was used in crafting the design of the learning objects or materials. Clearly, a need for engaging in the scholarship of teaching and learning (SoTL) in the area of vocational and technical education is necessary.

SoTL "involves systematic study of teaching and/or learning, and the public sharing and review of such work through presentations, performances, or publications" (McKinney, 2004, p. 3), and it also requires reflection about student learning (Hutchings & Shulman, 1999). Reflection on student learning should, at least in part, involve student perspectives (Merriam & Bierema, 2014). This is especially important in an online learning environment because reflective activities are one of the design and instructional strategies that appear to foster "deep" or transformative learning (Dirkx & Smith, 2009 as cited in Merriam & Bierema, 2014). Unfortunately, many of the articles we reviewed only examined learning from the perspective of those responsible for teaching but did not include students' perspectives on whether or not tools contributed to their learning. It is possible for students to learn despite the teaching approach, but this is not always considered. Future studies should incorporate consideration of the teacher, the tool, and the learner in order to gain a more complete picture of learning that is occurring.

Finally, research is needed that focuses on the sustainability of new, innovative approaches to teaching and learning in vocational and technical education. In addition to examining tools and practices that increase student learning, it is essential that we find ways to ensure that these innovations will be effective across different settings or contexts and with different types of learning content. Typically, sustainability is measured through longitudinal studies that investigate the effect of teaching and learning interventions over time. A challenge faced by researchers of educational technologies is that new technology tools are developed and adopted on a regular basis. This can make it difficult to plan long-term studies. Rather than focusing on the ever-evolving tools used in physical or virtual classrooms, it will be critical to examine the instructional strategies employed by educators as well as the types of interactions or functionality that particular tools afford. This will enable researchers to focus on the opportunities enabled by new educational technologies without getting bogged down in focusing on any one given product which may be obsolete in a matter of months or years.

Conclusion

For this chapter, we reviewed a number of studies that explored the use of educational technologies in vocational and technical education and organized those studies around the competencies that have been identified as critical for the workforce by the US Department of Education (2014): technical skill proficiency, higher-order reasoning and problem-solving skills, general employability skills, and occupation-specific skills. Though the studies we examined highlighted a diversity of approaches to the development of these necessary skills, there were few studies that focused explicitly on the teaching of technical skills or on occupation-specific skills. There were examples of computer-supported collaborative learning in some of the research, which leads us to believe that professionals who specialize in vocational and technical education could utilize innovative CSCL environments to develop general employability skills. We also examined online learning in a vocational and technical education context. While there seems to be an interest in the field of vocational and technical education in understanding its value, there was only one study that clearly focused on the use of an educational technology in a traditional classroom.

Our review of the recently published studies emphasizes the need for more research on the use of educational technologies in both online and traditional learning environments. In this chapter, we have outlined a number of potential areas for future research that should not only focus on the integration of educational technologies but also look at student learning, student perspectives, teaching, and measurement in this area. It is our hope that this future research will lead to improvements, insight, and innovation in this extremely important area of vocational and technical education.

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Section V
Understanding the Role Instructional Design/Technology Plays in Different Learning Contexts

The Digital Divide in Formal Educational Settings: The Past, Present, and Future Relevance

Albert D. Ritzhaupt, Li Cheng, Wenjing Luo, and Tina N. Hohlfeld

Introduction

The Digital Divide has become an enduring fixture in our global society with educational opportunities (e.g., integrating information and communication technology in schools, classrooms, and libraries) often being perceived as the bridge to overcome this social inequity. Understanding the impact of the Digital Divide in formal educational settings has evolved over the past 20 years to not only examining equitable student *access* to computer devices (e.g., tablets, desktops, or smartphones) and the Internet (e.g., high-speed broadband) but also how information and communication technology (ICT)) resources are used for teaching and learning, its impact on students' learning outcomes, and ultimately how ICT is used by students for their own empowerment. The Digital Divide can be manifested by a variety of demographic characteristics (dividing factors): age (e.g., generations X versus baby boomers), gender (e.g., males versus females), culture (e.g., western versus eastern), location (e.g., rural versus urban), socioeconomic status (e.g., privileged versus underprivileged), race/ethnicity (e.g., white/Caucasian versus minority or Hispanic), education (e.g., college educated versus high school dropout), disability status (e.g., visually impaired versus nonvisually impaired), literacy (e.g., English versus not speaking English), and more. Further, the Digital Divide is a multidisciplinary issue which impacts a wide range of disciplines, such as economics (Antonelli, 2003), business (Srivastava & Shainesh, 2015), psychology

A. D. Ritzhaupt (✉)
School of Teaching and Learning, College of Education, University of Florida, Gainesville, FL, USA

L. Cheng · W. Luo
University of Florida, Gainesville, FL, USA

T. N. Hohlfeld
University of South Florida, Tampa, FL, USA

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(Jackson, Ervin, Gardner, & Schmitt, 2001), sociology (Drori & Jang, 2003), computer science (Payton, 2003), political science (Milner, 2006), and information and library science (Gyamfi, 2005). This chapter attempts to acknowledge the multidisciplinary nature of the Digital Divide while focusing attention on the phenomenon in formal educational settings. The purpose of this chapter is to provide a brief history of the Digital Divide, an operational definition of the Digital Divide, a conceptual framework of the Digital Divide for formal educational settings, and a review of recent research (past 5 years) and to provide solutions to bridge the Digital Divide through formal education.

Brief History of Digital Divide

Starting in 1995, the United States (US) Commerce Department's National Telecommunications and Information Administration (NTIA) released a series of reports titled *Falling Through the Net*, which analyzed computer and online access penetration rates throughout the USA and showed a number of dividing factors like education, location (e.g., rural versus urban), age (e.g., young versus old), or income (e.g., rich versus poor) (NTIA, 1995). By the 1999 report, *Falling Through the Net: Defining the Digital Divide* showed soaring access rates to personal computers and the Internet in the USA (NTIA, 1999). However, on many demographic characteristics (dividing factors), the NTIA found that there was still a significant, and in some cases widening, Digital Divide separating "haves" and "have nots" (NTIA, 1999). The original term – Digital Divide – referred to the social inequity between those who had access to computer devices and the Internet and those who did not. By the early 2000s, the term Digital Divide had become a common slogan among policy-makers, organizations, and educators in the USA and beyond (Singleton & Mast, 2000).

The boom of the dot-com industry in the USA resulted in the Internet economy with everyone trying to get connected to the Internet (Warschauer, 2004). Over time, the Internet economy became deeper and long-lasting with ICT playing a key role (Jarboe, 2001). This information economy set itself apart from the pre-information era by its increasing reliance on science, technology, information, and management (Castells, 1993). In several developed nations, there was a major shift from noninformation commerce (e.g., manufacturing) to information-based business (e.g., health care, banking, software). The Federal Communications Commission (FCC) strongly supported the availability of broadband access, computer access, and training and technical assistance to as many households as possible (Barton, 2016). In addition, the federal government promoted activities designed to reduce the adverse economic and social consequences of those who were left behind (Kruger & Gilroy, 2013). ICT was critical during this change process which fundamentally transformed the way we interact in society, especially in education.

Moreover, the information economy led to global economic stratification not only within but also across countries (Warschauer, 2004). There was a huge gap between the richest and poorest countries in terms of wealth, exports, and Internet use (Wade, 2001). Even within developed countries, unequal distribution of ICT resulted in income inequality (Castells, 2000), while people in developing countries remained outside the global ICT revolution (Warschauer, 2004). ICT also had a huge influence on communication. Computer-mediated communication facilitated people's interaction across long distances, supporting new modes of teaching and learning. Millions of people around the world gained access to shared information (Warschauer, 2004). Therefore, ICT was critical not only for economic inclusion but also for "education, political participation, community affairs, cultural production, entertainment, and personal interaction" (Warschauer, 2004, p. 28).

Until the early to mid-2000s, access to the Internet remained highly stratified due to gaps in economics, infrastructure, politics, education, race, and culture (Warschauer, 2004). At that time, large-scale research studies reported strong correlations between Internet access with levels of economic development, education level, English popularity, and national wealth (Hargittai, 1999; Robison & Crenshaw, 2002). Countries with competitive telecommunication industries, open political policy, and high English proficiency were usually more "wired" than other countries (Hargittai, 1999). Developed countries associated socioeconomic status, culture, and race with disparities in Internet access (NTIA, 2000). In developing countries, the Internet use was largely concentrated among privileged class based in major urban areas. High rates of poverty, limited English proficiency, limited education, and rural underdevelopment limited broad use of ICT (Warschauer, 2004). Nevertheless, the unequal physical access to computers and the Internet remains a long-term concern for developed countries because (1) the development of the Internet will always leave out a small percentage of the population and (2) new forms of technological disparities will arise (Warschauer, 2004).

Operational Definition of Digital Divide

The term Digital Divide is polysemous in that it holds different meanings for individuals (Ritzhaupt, Liu, Dawson, & Barron, 2013). Parents, students, educators, administrators, legislators, and librarians account differently about how they have experienced or observed the Digital Divide in their personal and professional lives (Sparks, 2013). Researchers have used a wide array of definitions for the Digital Divide beginning with individual access to ICT and, more recently, the individual's ability to use and create knowledge and original artifacts with ICT (e.g., Warschauer, 2004). For this chapter, we will use the following definition: The Digital Divide is a social inequity due to disparate quantity and/or quality of students' access, use, and creation of original artifacts with information and communication technology (ICT) resources. There are important terms included in this definition that emphasize the perspective of this chapter. First, social inequity refers to unequal opportunities for engagement in society (e.g., social, economic, political, educational, or personal pursuits) based on different statuses or groups (e.g., culture, location, socioeconomic status, race/ethnicity, age, disability, or education level). Second, the use of the words "access," "use," and "creation" are deliberately linked to the conceptual model (*Levels of the Digital Divide in Schools*) provided in the subsequent section of this chapter. Third, the quality and quantity of students interactions with ICT bring about the multilayered phenomenon of the Digital Divide with each layer associated with a variety of problems, research methods, and an assortment of solutions. Fourth, information and communication technology (ICT) resources include both physical (e.g., computer, tablet, smartphone) and digital (e.g., software, applications, information) resources that can be utilized to create original artifacts. Finally, by "original artifacts" we refer to the many types of objects that can be created by students with ICT resources, including original artwork, digital music, written publications, open-source software, animations, videos, games, blogs, web pages, visual presentations, spreadsheets, and much more.

Digital Divide Problem and Conceptual Model

Because education is often thought to be the vehicle to close the Digital Divide in society, it is important to examine the Digital Divide in structured formal educational settings. To characterize the Digital Divide in formal educational settings, we use the *Levels of the Digital Divide in Schools* presented by Hohlfeld et al. (2008). Figure 1 provides a modified visualization of the conceptual model of the Digital Divide in this context. Notably, there are three layers to the conceptual model starting with school infrastructure and access to ICT, moving to the classroom with teacher and student use of ICT, and finally, presenting the individual empowerment of the students using ICT as the highest layer. Activities, research, problems, and

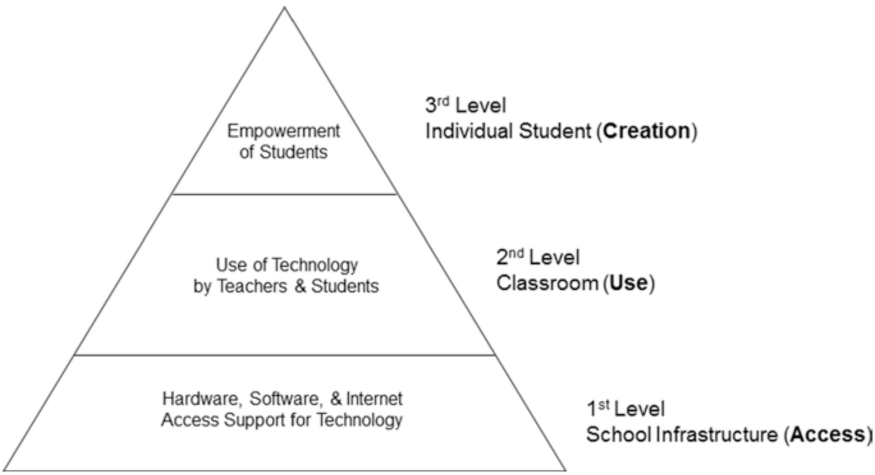

Fig. 1 Levels of the Digital Divide in Schools. (Hohlfeld et al., 2008)

solutions vary at each of these levels. From our operational definition, we use the terms "access" at level 1, "use" at level 2, and "creation" at level 3. The underlying assumption of this model is that student creation of meaningful and relevant artifacts using ICT and their ultimate empowerment with ICT is a desirable outcome for society.

Level 1: School Infrastructure and Access

The first layer of the *Levels of the Digital Divide in Schools* deals with the school infrastructure and access to appropriate ICT resources for students and teachers to integrate ICT into their daily routines. The first level is intentionally layered at the bottom of the conceptual model in that access to ICT resources is a prerequisite for teacher and student use and, ultimately, student empowerment with ICT. Further, a scan of the research literature shows that much of the early empirical research articles and reports conducted on the Digital Divide within formal educational settings has occurred at this level with researchers counting computers in schools and reporting the ratio of students to computer (e.g., Hess & Leal, 2001; Valadez & Duran, 2007). For instance, the reports published by the *National Center for Education Statistics* provide computer counts and the ratios of students to instructional computers with Internet access in formal educational settings (NCES, 2017).

There are several types of educational equity problems that occur at the first level of the Digital Divide. For example, students from lower-income homes, rural homes, ethnically diverse homes, and homes with parents with lower levels of educational attainment are less likely to have broadband Internet access (NCES, 2017). This creates a Digital Divide for these students, because they are unable to utilize online multimedia resources to complete and submit the digital homework assigned by their teachers and share their school activities with their families at home like their more advantaged peers. Although we have observed an overall decrease in the national ratio of students to instructional computers with Internet access in schools, we also have evidence that the computer devices may not have equitable software available for student and teacher use (Hohlfeld et al., 2008; Hohlfeld, Ritzhaupt, Dawson, & Wilson, 2017). In fact, providing equitable access to Internet-enabled machines at school has never guaranteed that these ICT resources would be used equitably by students and teachers (Cuban, 2009).

Level 2: Classrooms and Use

As educational researchers began to discover the limitations with "counting boxes" and attempted to answer deeper research questions about the evolving Digital Divide, some began to examine how the ICT resources were actually being used by students and teachers in their classroom environment across demographic groups (e.g., rural versus urban or High-SES versus Low-SES) (e.g., Cuban, Kirkpatrick, & Peck, 2001). The literature base includes a wide range of qualitative and quantitative empirical studies on this level of the Digital Divide, often reporting at level 1 and level 2 in the same study (e.g., Hohlfeld et al., 2008; Hohlfeld et al., 2017; Judge, Puckett, & Bell, 2006). For instance, Judge et al. (2006) found differences with ICT use based on the SES in early childhood classrooms and schools, and Hohlfeld et al. (2008) discovered that teachers and students in High- and Low-SES schools used technology for different purposes. High-SES schools had significantly greater percentages of teachers using software for both delivery of instruction and administrative purposes. Students in Low-SES schools used software more for drill-and-practice or remedial tasks, whereas their High-SES counterparts used software more for creating things, like spreadsheets or word processing documents. While this trend is decreasing, some gaps in technology use between the Low- and High-SES- schools were still detected in the most recent school years (Hohlfeld et al., 2017).

Indeed, the second level of the Digital Divide presents different types of complications and research applications for consideration. While legislators and administrators might invest heavily to integrate the hardware and software resources into schools and classrooms, if the teachers are not prepared (e.g., sufficient professional development), do not have access to adequate technology support (e.g., technology specialist in a school), and do not support the mission of the ICT program (e.g., leadership), the Digital Divide may manifest as inequitable learning experiences with ICT resources for the students. These essential conditions are outlined by the International Society for Technology in Education (ISTE) and are perceived as necessary elements to effectively leverage ICT for teaching and learning (ISTE, 2017).

Level 3: Individual Students and Creation

Level 3 requires students to have the knowledge, skills, intent, and dispositions to create original artifacts with ICT resources. Historically, far fewer studies have explicitly examined the ICT literacy skills of students. Judge et al. (2006) demonstrated connections among computer proficiency, home computer use, poverty status, and academic achievement in reading and mathematics.. Ritzhaupt et al. (2013) examined the ICT literacy skills of middle school students ($N = 5990$ from 13 school districts across the state of Florida) using a performance assessment based on the ISTE student standards. Their results showed evidence of a Digital Divide between High-SES and Low-SES, white and nonwhite, and female and male students on all the performance measures in the study. That is, High-SES, white, and female students outperformed their counterparts. Level 3 of the model requires both quantitative and qualitative or mixed-method research methods examining the student as the unit of analysis with respect to their knowledge, skills, intent, and dispositions. Barron et al. (2010); Barron, Gomez, Pinkard, and Martin (2014) conducted a 3-year longitudinal mixed-method research study examining the development of middle school students as creative producers within the context of the Digital Youth Network in Chicago public schools. During this research, case studies included observations of the activities and interviews with the students. They found the program successfully closed the Digital Divide at level 3. Students participating in this program in Low-SES schools were more engaged in empowering ICT activities than their counterparts in High-SES schools.

The ultimate goal of meaningfully integrating ICT resources into schools and classrooms is to prepare students to participate in an increasingly digital society. ICT has the potential to support, advance, and enrich opportunities and outcomes for all students. Furthermore, ICT literacy and the ability to leverage ICT for learning are essential to the future empowerment of all students across demographic conditions (dividing factors). Students with ICT literacy are at a distinct advantage in terms of learning in increasingly digital classrooms (NETP, 2010), competing in a progressively digital job market (Koenig, 2011), and participating in a digital democracy (Jenkins, 2006; p. 21, 2011). Further, students with ICT literacy have a particular advantage within the science, technology, engineering, and mathematics (STEM) disciplines, because ICT literacy is embedded within core STEM competencies (Carnevale, Smith, & Melton, 2011; NETP, 2010) and components of ICT literacy have been empirically linked to success in STEM areas (Antonenko, Toy, & Niederhauser, 2012; Kumsaikaew, Jackman, & Dark, 2006; Sonnentag & Lange, 2002). However, neither ICT literacy nor leveraging ICT for teaching and learning happens unless teachers make the decision to use ICT in their educational practice with their students (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). Thus, level 2 of the *Levels of the Digital Divide in Schools* model is a prerequisite for level 3 – the empowerment of students to use ICT resources for the betterment of their quality of lives. In the next section, we review the previous 5 years of research published about the Digital Divide in relation to formal educational settings.

Review of Recent Empirical Research

To examine the previous 5 years of research, we searched with two major peer-reviewed literature search engines, EBSCOhost and ProQuest, with all the databases in them being selected, including ERIC, Dissertations & Thesis Global, Academic Search Premier, etc. The search terms included "digital divide" or "digital equity," in combination with "education." We searched "digital divide" or "digital equity" in titles and abstracts and "education" in any field or in all text. We included the literature that is scholarly peer-reviewed, in English, from the year of 2010 to 2017, and with full text available. A total of 152 articles were extracted with these criteria. We subsequently removed the articles that were published before 2012 and that had not provided empirical data (either quantitative or qualitative) and ended up with $k = 27$ articles to carefully examine. The articles were coded in terms of a set of relevant attributes, including the location, dividing factors, education level, level of the Digital Divide addressed, educational need and problem, educational technologies and interventions employed, period of study, sample size, research methods, empirical data results, and findings.

We acknowledge a major limitation to the search strategy we used to retrieve the relevant articles for this analysis. Many studies have been published in the past 5 years that may or may not have been framed by the Digital Divide (or related term Digital Equity) terminology. For example, there have been many studies published on the topic of gender in relation to various ICT measurements from 2012 to 2017 (e.g., Aesaert & van Braak, 2015; Hohlfeld, Ritzhaupt, & Barron, 2013; Punter, Meelissen, & Glas, 2017). If these articles were not framed by the Digital Divide in relation to gender, they would not have been included in our examination. This decision was made to incorporate the literature base in which the researchers explicitly attempted to address the Digital Divide in their research context. Future research, especially meta-analytic studies of the Digital Divide, should seek to incorporate a wider net of search terms and a broader strategy to ensure all the related literature is examined. In light of this limitation to our search terms and procedures, this analysis resulted in several important findings.

Notably, only 19% of the articles examined were within the USA. The countries examined are found in all continents with the exception of Antarctica, including Albania, China, Colombia, India, New Zeeland, Norway, Romania, South Africa, Spain, Turkey, Uruguay, and the United Arab Emirates. This finding suggests that the Digital Divide may be an issue of increasing concern outside of the USA. The methodologies employed within the studies include quantitative, qualitative, and mixed-method designs with more than half of the articles making use of survey results and quantitative comparisons. We also note the disparate quality of the research procedures reported in the articles. Some studies had major methodological flaws (e.g., limited sample size, poor measures, violations of statistical assumptions, etc.). Other articles did not provide enough information to understand how the research was conducted. We present the remainder of our analysis in relation to the three layers of the *Levels of the Digital Divide in Schools* model. Table 1 provides a review of the research by dividing factors and the levels of the Digital Divide. As can be gleaned, the research on the Digital Divide in education has examined a wide range of dividing factors across the three levels. Details are reviewed in the following sections.

Level 1 Concerns

Of the 27 articles that met our criteria for inclusion, 10 studies (approximately 37%) examined issues at the first layer of the model (e.g., access to ICT resources), with a range of dividing factors, including SES, culture, geographic location, and gender (see Table 1). Some studies were executed in the context of educational programs, such as 1:1 device initiatives in formal educational settings (Pittaluga & Rivoir, 2012) or by deploying ICT resources in student homes (Lei & Zhou, 2012). There

Table 1 Research by dividing factors and levels of the Digital Divide

Dividing factor	Level 1	Level 2	Level 3
Age	–	Ballano, Uribe, & Munté-Ramos, (2014); Dornisch, (2013)	Ballano et al., (2014); Firat, (2017); Dornisch, (2013); Peral-Peral, Arenas-Gaitán, & Villarejo-Ramos, (2015); Ramalingam & Kar, (2014)
Culture	Lei & Zhou, (2012); Yuen, Park, Chen, & Cheng, (2017)	Berrío-Zapata, (2014); Hatlevik & Gudmundsdottir, 2013)	Yuen, Lau, Park, Lau, & Chan, (2016)
Education	–	Berrío-Zapata, (2014); Hatlevik & Gudmundsdottir, (2013); Naidoo & Raju, (2012)	Firat, (2017); Muresan & Gogu, (2014); Park & Lee, (2015); Ricoy, Feliz, & Couto, (2013)
Ethnicity	–	–	Ritzhaupt et al., (2013); Vigdor, Ladd, & Martinez, (2014)
Gender	Yuen et al., (2017)	Doiron, (2012); Dornisch, (2013); Eyo, (2014)	Doiron, (2012); Firat, (2017); Park & Lee, (2015); Ramalingam & Kar, (2014); Ritzhaupt et al., (2013); Yuen et al., (2016)
Geography	Pittaluga & Rivoir, (2012); Sampath, Basavaraja, & Gagendra, (2014)	–	Pittaluga & Rivoir, (2012); Ramalingam & Kar, (2014); Sampath et al., (2014)
Socioeconomic status	Hartnett, (2017); Hohlfeld et al., (2017); Pittaluga & Rivoir, (2012); Sampath et al., (2014); Starkey, Sylvester, & Johnstone, (2017)	Hatlevik & Gudmundsdottir, (2013); Hohlfeld et al., (2017); Naidoo & Raju, (2012); Starkey et al., (2017)	Firat, (2017); Mirazchiyski, (2016); Muresan & Gogu, (2014); Park & Lee, (2015); Peral-Peral et al., (2015); Pittaluga & Rivoir, (2012); Ramalingam & Kar, (2014); Ricoy et al., (2013); Ritzhaupt et al., (2013); Sampath et al., (2014); Vigdor et al., (2014); Yuen et al., (2016); Zilka, (2016)

was a wide range of outcome measures employed in the research studies, ranging from broad access to ICT resources in educational or home settings, access to various software types, access to hardware devices, Internet access, and broad ICT infrastructure measures.

Lei and Zhou (2012) found that students with parental support with ICT resources at home engaged in a wider range of online activities in school than those without parental support, showing another dividing factor – parental involvement. Starkey et al. (2017) found that the focus in schooling in New Zealand was on the access divide (level 1) for students with variation across SES conditions. From India, Sampath et al. (2014) found that infrastructural facilities varied among rural and urban schools and that the majority of urban students had access to ICT resources in their homes when compared to their rural equivalents. Yildiz and Seferoglu (2014) showed in a Turkish context that almost 50% of their $N = 979$ students from 28 cities who attended seventh and eighth grades had access to a computer at home, but far less had access to the Internet. Hohlfeld et al. (2017) reported that students within Florida schools had equitable access to both modern desktops and laptops in the most recent school years when comparing High- and Low-SES schools. These findings demonstrate that many parts of the USA may have mitigated level 1 issues of the Digital Divide, while many other developing countries continue addressing concerns at this layer of the model.

Level 2 Concerns

Analogous to the first layer, ten studies (approximately 37%) addressed concerns at the second level of the Digital Divide: student and teacher use of technology. Again, a wide range of demographic conditions operationalizing the Digital Divide were in these papers, including SES, gender, education level, culture, and age (see Table 1). Again, a wide range of outcome measures were employed at this level of the Digital Divide: barrier to the use of ICT in teaching and learning, difficulties with using ICT, use of various types of software, frequency of technology use, and frequency of Internet use.

In the context of New Zealand, Hartnett (2017) discovered that regardless of dividing factors, young people reported that the digital technology used at their schools was limited and lagging behind their educational needs, suggesting that teachers and the education system were not keeping up with the pace of ICT. Yuen et al. (2017) emphasized that the overreliance on schools by some Hong Kong parents resulted in neglecting their role in guiding their children's ethical and educational use of ICT at home. These are crucial aspects of digital equity and digital citizenship (Hollandsworth, Dowdy, & Donovan, 2011). From the United Arab Emirates, Doiron (2012) found gender differences in the types of software used by males and females. He concluded that men needed increased opportunities to practice and strengthen the use of basic applications such as word processing and presentation software, whereas females needed more learning activities that involved creating concept maps, computer programs, micro-worlds, and simulations. Meanwhile, Eyo (2014) found no differences between genders and ICT use in the context of Nigeria. From Spain, Ballano et al. (2014) examined generational divides between older and younger populations. One of their primary conclusions was that "there is no single profile of a digital native, because having been born in a digital context in no way determines a single model of appropriation and use" (Ballano et al., 2014, p. 153). This study supports previous research debunking the notion of the digital native versus immigrant debate (Bennett, Maton, & Kervin, 2008). From the US context, Hohlfeld et al. (2017) described significant differences moderated by school level (e.g., elementary, middle, and high) and SES on teacher and student use of different software types. Across the findings of these studies, we demonstrated that the Digital Divide at level 2 can be manifested on a number of dividing factors and associated outcome measures.

Level 3 Concerns

A surprising finding is that the majority ($k = 16$) or approximately 60% of the articles identified in this time period addressed to some extent the third layer of the model, which focuses on student outcomes. This is an important and inspiring finding in that it shows more interest in student outcomes or the empowerment of the student in relation to using ICT resources for creating original artifacts. We see a wide range of dividing factors studied to manifest the Digital Divide, including SES, gender, culture, geographic location, age, education level, and ethnicity (see Table 1). Both SES and gender appear to be studied most often in these level 3 articles. The student outcome measures included both perceptions and performance assessments related to ICT, such as ICT awareness, ICT literacy or mastery, ICT skills and competencies, perceived ICT competency, attitudes toward computers and the Internet, academic achievement in mathematics and reading, recognition of ICT resources, technology anxiety, and technology self-efficacy.

In Hong Kong, Yuen et al. (2016) identified differences in students' learning-related use of technology by their SES and gender. In a follow-up study, Yuen et al. (2017) found that both the culture of parent-child relationships and parents' ICT-related child-rearing practices were associated with students' effective ICT skills. That is, both parental involvement and cultural context can be dividing factors in students' effective ICT skills. Firat (2017) explained that, in Turkey, elementary school students' level of concept formation about technological artifacts was moderated by both parents' education level and the school SES. In Israel, Zilka (2016) found that although positive changes occurred in all students' computer literacy after they received a computer device (e.g., laptop or desktop), there were some differences between groups.

When explaining a generational Digital Divide in the ways that ICT resources can empower students, Ballano et al. (2014) concluded:

> Those who learned to use the tools later and have a need or an interest in including them in all aspects of their day-to-day life will no doubt use the tools in a more complex way than those who, despite facing no instrumental barriers, do not have the motivation or the necessary resources to make any significant contribution in the digital environment. (p. 152)

Using the context of online social networks, Peral-Peral et al. (2015) confirmed these findings. They examined a range of demographic and psychological variables, like technology anxiety and technology self-confidence of elderly students enrolled in a university course. This study had two major findings: (1) the researchers did not detect any differences on the "traditional" dividing factors like gender or education level, and 2) the authors reported "high heterogeneity among the elderly" (p. 62) in relation to ICT outcome measures (e.g., technology anxiety or technology self-confidence). They suggested that individual attributes are more important in producing the Digital Divide at level 3 than traditional dividing factors such as age or gender. These findings reiterate the importance for researchers to examine students' knowledge, skills, intent, and dispositions along with how they use ICT resources in complex ways for creation.

Although the number of studies that examined level 3 of the Digital Divide has been increasing (as evidenced in this chapter), few of the studies investigated the connections among the integration of ICT resources by teachers in the classroom, the influence of a supportive learning environment outside of formal school (e.g., parental guidance and support, community or after-school linkages), and the training or scaffolding techniques which support students with creating artifacts and improving their educational outcomes. An exception is the Digital Youth Network, a one-to-one laptop program examined by Barron et al. (2014), which included not only in-school but also after-school and at home components. The researchers examined the effectiveness of this program using a comprehensive set of research methods and found that students in this program were more engaged in using ICT than their counterparts in a High-SES middle school.

More research examining the dividing characteristics across a wide range of ICT-related outcome measures is warranted across both developed and developing nations. Certainly, the use of longitudinal studies would also assist in characterizing the improvements made in the Digital Divide (e.g., widening, narrowing, or no change) over time. In this next section, we provide some practical solutions to bridge the Digital Divide by use of formal educational enactments.

Bridging the Three Levels of Digital Divide

Policy-makers, administrators, researchers, and educators have sustained their efforts to address the three levels of Digital Divide by increasing access to ICT resources, providing rich and job-embedded professional development for teachers about best practices for ICT integration, and empowering individual students with ICT experiences that enhance their learning. As the educational environment and the stakeholders involved are from complex systems, we contextualize our solutions at the three system levels: (1) micro (e.g., schools, classrooms, and educational organizations such as libraries); (2) macro (e.g., state, municipal government, and school district structures), and (3) mega (e.g., national and international government and multinational organizational structures) (Richey, Klein, & Tracey, 2010).

Level 1 Solutions

To enable equitable access to ICT resources in schools, a major initiative has been the continuing development and expansion of one-to-one technology programs in K-12 schools, including urban schools (e.g., Kaufman, 2016), rural school districts (e.g., Dickinson, 2016), and schools with a high population of students from Low-SES households (e.g., Persinger, 2016). One-to-one programs have been initiated by all levels of the system (mega, macro, and micro). One-to-one technology programs address the Digital Divide by providing each student with a physical device, such as a laptop, an iPad, or other mobile devices. For instance, at the mega level, the international one laptop per child program provides a rugged, low-cost, low-power, connected laptop with access to quality educational resources to individual children within some of the poorest regions of the world (One Laptop, 2017). In some one-to-one programs, students can use the devices for all their courses and bring the devices home for learning and personal use (Penuel, 2006; Warschauer & Ames, 2010). Other programs such as the "i Learn at home" program (macro level – Hong Kong, China) (Yuen et al., 2016) assist students from low-income families, and the "Computer for Every Child project" (mega level – Israel) (Zilka, 2016) provides increased access to ICT resources. One-to-one programs, initiated at the macro level (Texas), have helped economically disadvantaged students reach the same proficiency in ICT skills as advantaged students after 3 years of participation in a laptop program (Shapley, Sheehan, Maloney, & Caranikas-Walker, 2011). Zheng, Warschauer, Hwang, and Collins (2014) found that a one-to-one laptop program, an EETT program initiated at macro level (California), significantly improved at-risk students' science test scores. When evaluating an EETT program initiated at the macro level (Florida), Dawson, Cavanaugh, and Ritzhaupt (2008) showed how a one-to-one laptop program and effective teacher professional development transformed the teaching and learning environment with increased student-centered teaching, increased tool-based teaching, and increased meaningful use of technology. Further, a recent meta-analysis on one-to-one learning environments showed positive effect sizes in a wide range of subject areas (Zheng, Warschauer, Lin, & Chang, 2016).

Providing access to computing devices is only one aspect of the complex problem of the Digital Divide at this level. Students will still need broadband Internet connectivity to exploit the access to an ICT device, complete digital online homework, and fully utilize the Internet to improve their lives and academic achievement. Government programs (e.g., E-Rate program) for providing discounts for telecommunications and Internet access costs for schools and libraries to ensure equitable access across demographic characteristics is also a requirement. These programs can be initiated at the mega and macro level of the system. Some evaluations of the E-Rate programs within the USA concluded that the program had failed to close the Digital Divide (Park, Sinha, & Chong, 2007). Even with these evaluations, by Fall of 2001, 99% of public schools in the USA had access to the Internet (NCES, 2017). Now schools are working to integrate broadband wireless network access for both students and teachers in the schools. Some schools, at the micro level, and school districts, at the macro level, have even adopted BYOD ("Bring Your Own Device") programs (Raths, 2012) where students bring their own device to connect to the school's network. Further at the mega level, partnerships between multinational public and private entities are also supporting promising ventures into addressing the Digital Divide at level 1. For instance, Google has partnered with the US government to provide Google Fiber, high-speed Internet access to low-income families, allowing children to get online and complete their digital homework (Newcomb, 2015).

Open Educational Resources (OER)) is envisioned as another important dimension for bridging the Digital Divide by increasing access to rigorous, relevant educational content and learning opportunities both inside and outside of the classroom (Olcott, 2012; Wright & Reju, 2012). OER are generally described as freely accessible, openly licensed digital assets that are useful for teaching, learning, and assessing. Educators can use OER in their classrooms and depending on the open licensing; they can reuse and remix the materials for different educational contexts. As a result of OER initiatives implemented at micro, macro, and mega levels, teachers in economically disadvantaged school districts can provide their students with high-quality educational resources without having to spend limited instructional funds on expensive traditional textbooks. For example, the Khan Academy, a global nonprofit organization (mega level), has provided free academic resources, which many K-12 students and teachers have been using to enhance their teaching and learning. WikiEducator's Learning4Content (L4C) project, funded and supported at the mega level, connects educators globally and provides training for wiki technology, which also results in the creation of new free OER (Schlicht, 2013).

Level 2 Solutions

Both ICT programs and OER initiatives may address the first level of Digital Divide by decreasing the inequity of access to ICT and quality educational resources that are associated with the dividing factors; however, these programs and initiatives do not necessarily close the second and third level of the Digital Divide. It is possible that technology integration could broaden Digital Divide (Ritzhaupt et al., 2013). It is not mere access to ICT per se that narrows Digital Divide but how ICT resources are used by students and teachers. We have years of evidence that shows merely placing ICT resources in schools does not lead to meaningful changes in important teacher or student outcomes (Cuban, 1986; Cuban, 2009). Although students had access to ICT resources, Kassam, Iding, and Hogenbirk (2013) noted that students with Low-SES primarily used technology for entertainment rather than academics. Hohlfeld et al. (2017) reported that the percent of teachers in Low-SES schools who regularly used ICT software for instructional purposes (e.g., video conferencing, web publishing, podcasting, e-mailing families and students) was significantly lower than that in High-SES schools. Teachers' perceptions toward ICT, their knowledge and skills in ICT integration, and how ICT is actually being integrated are critical factors that impact Digital Divide, which constitutes the second level of the model.

To address the second level of Digital Divide, it is imperative to provide rich job-embedded professional development opportunities for pre-service teachers and in-service teachers which help them develop their ICT skills and improve their ICT integration knowledge, skills, and dispositions (Ritzhaupt et al., 2013). In addition, schools and universities typically include instructional technologists who can provide essential instructional technology support and mentoring for teachers and professors. Students require appropriate modeling of ICT and project-based ICT learning experiences that require teachers to be effective in their ICT integration strategies. At the mega level, several professional associations (e.g., ISTE) provide ongoing professional development through conferences, workshops, webinars, and more. Further, ISTE develops technology standards for administrators, teachers, coaches, and students, which have been widely adopted in the USA and beyond. Policy-makers and administrators, at the macro and micro level, must understand that ICT is an ongoing expenditure – not a one-time investment (Ritzhaupt, Hohlfeld, Barron, & Kemker, 2008).

Evidence shows that training in the integration of ICT resources into classroom activities can be effective. For instance, pre-service teachers who received professional development for using ICT, from an initiative sponsored at the mega level (Canada), had a higher probability of using those ICT resources in their future roles as in-service teachers (Larose, Grenon, Morin, & Hasni, 2009). In the study by Kazan and ELDaou (2016), it was revealed that teachers' attitudes toward ICT and their ICT self-efficacy had significant effects on their intent to use technology in the classroom as well as on the students' performance. In this study, the researchers found that teachers who were trained were able to better define and apply ICT in their science classrooms better when compared to their peers who were not trained (Kazan & ELDaou, 2016). As part of an EETT evaluation study initiated at the macro level (Florida), Ritzhaupt, Dawson, and Cavanaugh (2012) examined 732 teachers in 17 school districts across the state of Florida and found that the frequency of teacher use of technology, classroom integration strategies, and teaching experience with technology all significantly contributed to student use of technology. We advocate for the essential conditions outlined by ISTE for preparing the teaching and learning environment for meaningful ICT use by both students and teachers (ISTE, 2017).

At the macro level, state governments and school districts determine the broad educational goals and provide directions and model plans for the implementation. In the USA, the state legislature sets the educational standards for student outcomes and requirements for teacher certification. Together, the state governments with municipal governments raise the revenue to accomplish these outcomes. The local school boards are charged with approving the educational curriculum, adopting policies for achieving the goals, and paying for the implementation. The state government, municipal government, and local school board can earmark specific revenue for special ICT programs, which are designed to overcome the Digital Divide in their communities. In the USA, state governments (macro) also control the teacher certification requirements. State governments set the course requirements, specify the curriculum for pre-service teacher education in collaboration with institutions of higher education, and administer certification assessments to assess the content knowledge of the teachers. States also set the continuing education requirements for teachers to maintain their professional certification. As a result, states have a major impact on the curriculum and teacher preparedness, which addresses the second and third levels of the Digital Divide. Recent research showed that less than 50% of the US state departments of education offered educational technology certifications for teachers (Ritzhaupt, Levene, & Dawson, 2017). At the micro and macro level, schools (micro) and school districts (macro) can support and require their teachers to participate in job-embedded and ongoing professional development to improve ICT integration strategies and practices. Also at the macro level, programs can be administered to address specific community needs (e.g., technology magnet school programs or public-private partnerships). While the use of ICT resources in classrooms is the focus of level 2, the primary focus of closing the Digital Divide is to positively impact student outcomes.

Level 3 Solutions

The third level of Digital Divide is the most challenging to tackle as it first requires the foundational levels (levels 1 and 2) of Digital Divide to be addressed. As noted, teachers play a significant role in developing a student's expertise in the use of ICT to improve the quality of their lives (Ritzhaupt et al., 2012). Teachers are the catalyst for bridging the second level of the Digital Divide to the third level by delivering educational activities that expand students' modes of using ICT for interacting with the content, their teachers, fellow students, their families, and the community (Hohlfeld, Ritzhaupt, & Barron, 2010). For example, at the second level, students can read an assignment in an OER textbook and then complete digital online homework exercises with immediate feedback. Students can research a topic online, and then they can create a digital presentation, which they can post on the class website for their peers to review and provide constructive criticism. Students can support researchers in the university setting by collecting data (e.g., take digital pictures or record interviews) in their community and uploading the data to an online database. At the final step, students perform in the third level of the Digital Divide in schools by seamlessly utilizing ICT resources and the Internet to improve their academic achievement and pursue their personal and professional interests. Although the empowerment of students has to be achieved at the micro level of the system, support and direction for programs designed for closing the Digital Divide at the third level can occur at all system levels: micro, macro, and mega.

To address the third level of Digital Divide, a well-designed program does not just provide ICT devices and resources and professional development for teachers on ICT integration in the classroom, but also it ensures adequate support and guidance for students to develop and engage in nurturing learning environments both at school and at home. Students need meaningful and relevant learning experiences that seamlessly integrate ICT into their daily lives to reach the full benefits of ICT and student empowerment. Teachers, parents, administrators, and interested community members are at the front line of these educational initiatives and are ultimately the individuals responsible for narrowing the third-level Digital Divide. Nevertheless, researchers and evaluators are necessary for documenting the effectiveness of these initiatives and disseminating best practices to the wider educational community.

Key, at the mega level, is supporting large-scale research projects, which can be used to investigate the *Levels of the Digital Divide in Schools* by the many dividing factors, and disseminating the research results [e.g., the Programme for International Student Assessment (PISA) sponsored by the Organisation for Economic Co-operation and Development (OEDC), the Trends in International Mathematics and Science Study (TIMSS) sponsored by the International Association for the Evaluation of Educational Achievement (IEA), the National Assessment of Educational Progress (NAEP) by National Center for Education Statistics (NCES), International Computer and Information Literacy Study (ICILS) by the International Association for the Evaluation of Educational Achievement (IEA)]. Another important research activity at the mega level is archiving the educational data for future Digital Divide research and making it publically accessible to educational researchers for secondary data analysis, discovery, and dissemination. Accomplishing huge research projects like these requires the coordination of many stakeholders, who are often located in different regions of the world. Closing the third level of the Digital Divide requires proactive leadership and dedication from all the stakeholders.

Closing Remarks

This chapter has provided a brief history of the Digital Divide, an operational definition of the Digital Divide, a conceptual framework of the Digital Divide for formal educational settings, a review of recent research (past 5 years), and potential solutions to bridge the Digital Divide through formal education. The terminal goal of any solution to the Digital Divide must address the third level – student empowerment of ICT. Programs and resources must create environments (ISTE essential conditions) that support both teachers and students in the meaningful use of ICT in the classroom. This chapter has shown that the research literature has mixed results across the many dividing factors associated with the Digital Divide (e.g., SES, gender, age, etc.) on a range of ICT-focused measurements that examine access, teacher and student use, and student empowerment via ICT knowledge, skills, intent, and dispositions. As noted in this chapter, there are dramatic differences between developed and developing nations on these outcome measures with many developing nations still struggling with level 1 issues (Fuchs & Horak, 2008). Future research should seek to conduct both primary data collection in virtually every country at all three levels of the Digital Divide and meta-analytic studies to examine the overall effects of each of the dividing factors on the ICT outcome measures. Further, more longitudinal studies need to examine the trends and effects of the Digital Divide, as most studies reviewed in this research were cross-sectional and only represented a single point in time with a few exceptions (e.g., Hohlfeld et al., 2008; Hohlfeld et al., 2017; Pittaluga & Rivoir, 2012; Vigdor et al., 2014). The Digital Divide remains an important and evolving social inequity that requires the careful attention of legislators, administrators, librarians, educators, students, and parents. While initiatives from all levels (mega, macro, and micro) for formal education and programming can assist in diminishing the adverse effects of the Digital Divide, the key to empowering students is to provide meaningful ICT learning experiences in classrooms. We hope this chapter has provided a useful framework for thinking about the Digital Divide and that future educational researchers can use this work to address the Digital Divide in their contexts (e.g., developing nation).

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The Role of Educational Technology in Informal Learning Environments: Making and Tinkering

Peter Wardrip and Jean Ryoo

Introduction

Informal learning environments are varied and broad. These environments have generally fit into the category of "not school" (Sefton-Green, 2012) and have been more specified by not only informal learning institutions like libraries, museums, zoos, and parks but also learning that happens at home, with friends (Ito et al., 2013), and in hobby and leisure activities (e.g., Azevedo, 2013). Despite these differences, Rogoff, Callanan, Gutiérrez, and Erickson (2016) have noted that informal learning has some similar common features across contexts, settings, and types of learners. These features include:

- Informal learning is interactive and embedded in meaningful activity.
- Guidance is available to learners and their partners through social interaction and the structure of activities.
- Talk is conversational, not didactic.
- Involvement builds on individual initiative, interest, and choice.
- Assessment occurs in support of contributing to the activity, not for external purposes.
- Participants hone their existing knowledge and skills and also innovate, developing new ideas and skills.

More and more educational technologies are playing a role in these informal learning experiences whether they are the focus of the learning, the tools in service of particular learning, or connecting learners across spaces. One prevailing problem that educational technologies address in informal learning environments, implicitly

P. Wardrip (✉)
University of Wisconsin-Madison, Madison, WI, USA

J. Ryoo
University of California-Los Angeles, Los Angeles, CA, USA

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or explicitly, is the equitable access to quality learning through or with technology. Informal learning environments have been identified as being key pieces in the overall learning ecology of communities to support learners' pathways to expertise and development (e.g., National Education Technology Plan Update, 2017).

In recent years, the making and tinkering movement has gained traction in the education community, and particularly in informal learning environments, as a vehicle for supporting learning (Peppler, Halverson, & Kafai, 2016a, 2016b). Characterized as hands-on learning experiences working on the borders of disciplines and technologies, making and tinkering involve practices that have long been part of all human cultures—spanning race/ethnicity, language, upper-class and working-class communities, dominant and indigenous cultures, etc. (see, e.g., Rose, 2005; Tofel-Grehl & Fields, 2015)—but more recently emerged as a powerful means to support learners' engagement and experiences with science, technology, engineering, and math (STEM) (Blikstein, 2013; Honey & Kanter, 2013; Martinez & Stager, 2013). Fundamentally, these experiences encompass the features of informal learning listed above.

While the definitions of making and tinkering are broad and the examples of what these experiences look like in practice are varied (Dougherty, 2016), making and tinkering embodies many of the elements of educational technologies (design, development, utilization, management, and evaluation of processes and resources for learning) and offers a perspective to view the potentials and pitfalls of educational technologies within informal learning environments. Making and tinkering also offer an interesting view into the role of educational technologies in a learning experience, more generally, because they often involve multiple forms of technologies that mix within the constructive activity.

In this chapter, we discuss the role of educational technologies in these informal learning environments through the perspective of making and tinkering. First, we define making and tinkering in informal learning contexts and how this relates to educational technologies more broadly, specifically related to the potential for equitable ambitious learning experiences for youth. Second, we review the recent research on making and tinkering in informal learning environments. This review addresses key research questions and findings in studies where technology was incorporated into making spaces in museums (e.g., Wardrip & Brahms, 2015), libraries (e.g., Halverson, Lakind, & Willett, 2017), community spaces (e.g., Litts, 2015), and afterschool programs (e.g., Bevan, Ryoo, & Shea, 2017). Third, we critically reflect on the extent to which educational technologies, as viewed through the making and tinkering perspective, are addressing the need for equitable access to high-quality learning experiences through and with technology. Finally, we discuss opportunities and gaps with respect to educational technologies and learning in informal learning environments through the lens of making and tinkering. As makerspaces and tinkering spaces expand through initiatives, such as twenty-first Century Community Learning Centers, and through funding from the Institute of Museum and Library Services, there will be a need for research to inform practice (and vice versa) as well as leverage this opportunity to deepen our understanding of learning in these informal settings.

Informal Learning and "Making and Tinkering"

Informal learning is often characterized as learning that does not take place in schools—a formal setting—and is viewed as an alternative to the formal setting (Rogoff et al., 2016). While there has been extensive deliberation about what constitutes informal learning (e.g., Burbules, 2006; Resnick, 1987), one general perspective from which to view informal learning is as an intentional learning experience done alone or with others without the direct dependence on a teacher or outside curriculum (Livingstone, 2006). In some cases, a distinction is made between formal, informal, and nonformal (Eshach, 2007). In this regard, nonformal can denote a learning experience that is not in school, but structured in some manner, thus including elements of formal and informal. A school-led field trip at a museum might fall into the category of nonformal. Nevertheless, informal learning usually contains less structure, is learner-driven, and is voluntary (Eshach, 2007). As Laurillard (2009) writes, "…there is no teacher, no defined curriculum topic or concept, and no external assessment" (p. 12).

It is important to note that informal learning environments not only have been identified as important and consequential sites for learning (e.g., Bell, Lewenstein, Shouse, & Feder, 2009) but also catalysts for learning activities beyond the particular experience of watching TV documentaries in one's free time based on prior engagement in an activity in a museum (Falk, Storksdieck, & Dierking, 2007). This builds on the understanding that learning does not happen in discrete places or moments in time, but rather across a range of contexts and experiences: learning is lifelong, life-wide, and life-deep (Banks et al., 2007). This suggests an ecological perspective of learning in one setting building upon another setting and valuing learning and experience from one setting to another (Rushby, 2012). This perspective has been referred to as connected learning (Ito et al., 2013) or a learning ecology (e.g., Barron, 2006). This view explicitly accounts for learning that happens across settings and positions informal learning settings on comparable terms with formal settings in terms of how a learner develops over time.

Making and tinkering learning experiences have been characterized by interest-driven engagement in creative production at the intersection of disciplines such as science, technology, engineering, art, and math (Honey & Kanter, 2013). Put another way, "making prioritizes students' desires and abilities to invent solutions to custom needs, debug problems that arise from their own initiative, and understand how technology works" (Dougherty, 2012, p. 535). In fact, making and tinkering has emerged as an engaging entry point and activity for STEM education (Making Meaning Report, 2013; Peppler & Bender, 2013), workforce development, and the development of innovative and entrepreneurial skills (Benton, Mullins, Shelley, & Dempsey, 2013). In these efforts, making and tinkering has developed into a recognized social, technological, and economic movement (Hatch, 2014; Honey & Kanter, 2013; Sheridan et al., 2014).

Making and tinkering fit into the field of educational technology in both theoretical and practical ways. Theoretically, making and tinkering align with many of the elements valued by educational technology. For example, concepts such as design, development, and evaluation, which have been noted to be domains of the field of educational technology, also bear heavily in making and tinkering (Seels & Richey, 2012). Whether learners are exploring the possibilities of tools and materials (Wardrip & Brahms, 2015) or engaged in a specific design challenge (Litts, 2015), the learners' engagement in making and tinkering captures a technology-rich (digital and/or analog) environment. Practically speaking, making and tinkering is a tool-rich environment where learners learn to use tools and think with tools (Salomon, Perkins, & Globerson, 1991).

Within actual informal learning contexts, researchers have characterized three different types of making: (1) assembly-style making (where youth follow step-by-step instructions, often with the use of kits, to create nearly identical final objects); (2) learners have a challenge to take on or model to replicate, but their choices about the way that project looks and behaves result in varied final objects; and (3) open-ended inquiry (most closely tied to tinkering), where youth come up with their own designs and approaches to creating what they envision (Bevan et al., 2017). Thus, learners might create anything from keychains fabricated with 3-D printing technology, but with little opportunity for complexification of skills and tools over time (Blikstein & Worsley, 2014), to a scribbling machine, to a pair of shoes for the visually impaired that vibrate when sensing objects within 10 feet of the wearer.

It is important to note that making and tinkering are not new or a new perspective on educational experiences. While the names and terms might have changed, for many years now, progressive educators and researchers have made mention of the role of making and tinkering and the production of artifacts in learning. Martinez and Stager (2013) document the deep educational roots of the maker movement that include Piagetian constructivism, the progressivism of John Dewey, and Reggio Emilia and Montessori's exploratory curriculum. This history credits Seymour Papert as a founder of the maker movement implying that constructionism is the theory of learning under which the current refocus on making, fabrication, and problem-solving rests. Papert's constructionism as a theory of how people learn, as mentioned above, is grounded in embodied, production-based experiences at the core of what it means to learn (Harel & Papert, 1991). Put another way to capture the nuance of what constructionism is:

> …the N word as opposed to the V word— shares constructivism's view of learning as "building knowledge structures" through progressive internalization of actions...It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe. (Papert & Harel, 1991, p.1, cited in Ackermann, 2001)

More fundamental than production, constructionism's roots in Deweyan notions of constructivism frame learning as the product of play, experimentation, and authentic inquiry. Furthermore, Blikstein (2013) marks how critical pedagogy has informed making and tinkering's approach to education that challenges traditional schooling's "banking education" methods that decontextualize curricula, toward support of learning that is rooted in local culture, learner's "consciousness of the real," and "consciousness of the possible" (Freire, 1974, cited in Blikstein, 2013).

It is worth mentioning that making and tinkering have been taken up in various communities across the world. As will be highlighted in this chapter, making and tinkering practices can be found for teaching engineering skills in afterschool or library programs, for example. But they have also been part of community organizations like Mexico's CASITA (Autonomous Center for the Intercultural Creation of Appropriated Technologies), where efforts to create pedal-powered blenders reflect how nondominant communities are repurposing technology for their own uses beyond what is desired by corporate interests (Vossoughi, Hooper, & Escudé, 2016). Focusing more on informal education contexts that use various educational technologies for making and tinkering purposes, in what follows, we will explore what learners' making and tinkering projects look like and what the current literature describes youth learn as a result of making and tinkering.

Educational Technology and Learning in Informal Making and Tinkering

Depending on a Makerspace's goals/purpose, the vision of its founders, location (in a school, museum, library, community space), participants' interests, etc., making environments can offer a range of different tools—from low-tech (e.g., hammers, table saws, sewing machines) to high-tech (e.g., 3-D printers, laptops, laser cutters) (Wardrip, Brahms, Reich, & Carrigan, 2016). While research has been conducted across all sorts of informal making and tinkering contexts, this review of recent literature focuses primarily on those studies involving educational technology, specifically digital and computing tools. Most commonly, this includes tools and technologies such as:

- Circuitry (such as when youth take apart battery-operated toys and repurpose their circuitry parts to create new mechanical objects or when using Squishy Circuits—insulating and conductive play dough—to build electrical circuits that can control LEDs, buzzers, motors, etc.)
- Computers (desktops and laptops)
- Computer programs (such as Scratch, a free and playful programming language with which one can design and create interactive stories, games, and animations)
- Microcomputers or microprocessors (such as Arduino, which is an open-source electronics platform that can be programmed to sense and control physical devices, or the Lilypad, which is a sewable form of Arduino)
- Makey Makey (an electronic invention tool including a circuit board, alligator clips, and a USB cable that uses closed-loop electrical signals to connect everyday objects, such as a banana, to computer programs through the keyboard or mouse)

Looking across the research on informal making and tinkering, encouraging youth to make and tinker with digital and computing technology often goes hand in hand with the goal of engaging students in STEM and computational thinking rather than focusing on just the technological tools themselves. For example, TechBridge's afterschool tinkering program for high school girls sought to increase underrepresented youth's excitement for science and engineering (Ryoo & Kekelis, 2016), but the focus of the teaching and learning was never on the technology itself. In other words, these programs and research did not focus on the goal of making youth become Arduino experts. But rather, by supporting youth in pursuing their own design ideas, various studies reveal how students would inevitably gain fluency with technological tools as well as STEM content and practices because of their personal motivation and dedication to creating unique objects (Bevan, Gutwill, Petrich, & Wilkinson, 2015). Furthermore, beyond thinking of technology as merely a tool for saving time/labor (like a dishwasher) or for entertainment/distraction (for watching movies), technology in makerspaces has been explored for their potential to encourage human creativity and expression (Buechley, Eisenberg, Catchen, & Crockett, 2008). In making and tinkering contexts, technology's role ideally moves beyond teaching youth how to use software applications, to supporting youth in actually creating new technologies and objects in the world as producers rather than consumers (Buechley, 2010; Kafai & Burke, 2013). This is because while making, youth must actively decide what and how they want to create an object, as well as problem-solve through the various challenges that arise in the design process (Kafai, Fields, & Searle, 2014).

But what does it actually look like for youth to use educational technology tools toward creating projects of their own design in informal learning environments? In the aforementioned TechBridge program, girls met on a weekly basis afterschool throughout the school year and designed/built projects to present at the flagship Maker Faire in San Mateo. Girls used laptops to program Arduino microcomputers that were incorporated into their physically built circuitry projects that included things such as (1) self-zippering jackets that would close when the temperature became colder and open when the temperature rose, specifically designed for people who had difficulty using zippers such as young children and people with disabilities; (2) backpacks for today's teens that included a solar cell phone battery charger, Bluetooth-enabled speaker to play music, and LED wire sewn throughout for visibility at night; or (3) an alarm clock that would get progressively louder and more annoying each time the user pressed the snooze button (Bevan et al., 2015; Ryoo & Kekelis, 2016). In a Michigan Boys & Girls Club that also met regularly throughout the school year, youth also focused on creating projects that could have a positive impact on their communities, using technology to create things such as (1) the anti-rape jacket, powered by solar energy, that could "yell for help if you are in trouble" and could be heard from at least one block away (Barton, Tan, & Greenberg, 2016) or (2) a light-up football that could facilitate continued play outdoors for youth living in the northeast where it gets dark at an early time in the winter (Calabrese Barton, Tan, & Shin, 2016). At an afterschool program for youth in an Oakland school, educators engaged students in a 2-day project where youth used Scratch to program lights and motors within a cardboard box and behind a mylar screen that would result in the dynamic movement of lights and shadows for viewers on the outside of the box (Gelosi, 2017). In shorter-term programs (e.g., where youth create projects during a 1-week summer program), engagement with technology might result in the creation of sewn circuit projects that use Lilypad Arduino and LEDs to decorate canvas bags (Kafai & Peppler, 2014) or to embellish a sweatshirt so that the LEDs change color according to the arm movements of its wearer (Buechley et al., 2008). In the context of a drop-in makerspace at Children's Museum of Pittsburgh (Brahms & Wardrip, 2014; Wardrip & Brahms, 2015), children are given opportunities to develop understandings of circuits by tinkering with circuit blocks—wooden blocks with battery packs, switches, and outputs such as motors, lights, and fans, joined and connected with wires—and building their own circuits (Wardrip & Brahms, 2015). This process supports their facility and knowledge of/with circuits as well as their identity as someone who can make objects with circuits (Brahms & Crowley, 2016). In these various informal learning contexts, projects were driven by the imaginations of youth makers, with technology serving as tools supporting the materialization of their creative visions.

Making and tinkering with technology can have important and lasting impacts on youth and their lives. When thinking about participation in science, technology, engineering, math (STEM) and computer science (CS), making and tinkering with technology has the potential to increase engagement and interest for youth underrepresented in these fields. For example, Buechley et al. (2008) found that through e-textiles activities—in which CS (coding with Arduino Lilypad) was incorporated into activities that girls were already engaged with (sewing)—interest in the activities of a male-dominated field (CS) could be piqued, with a desire to do and learn more with computer coding. In this way, technology served as a tool for "expanding and democratizing the range of human expression and creativity" when the educational experience was focused on connecting to activities relevant to youth culture with which the learners identified (Buechley et al., 2008, p. 423). Rather than ask, "how can we get girls and women to participate in traditional CS and support them once they are there?," the authors encourage us to ask: "How can we integrate CS with activities and communities that girls and women are already engaged in?" (Buechley et al., 2008, p. 431).

Similarly, in another e-textiles study, Buchholz, Shively, Peppler, and Wohlwend (2014) found that young women found opportunities for engagement and leadership when combining their personal interest and skills in sewing with CS practices with the Arduino Lilypad. Making and tinkering with technology in ways that rupture traditional gendered scripts around electronics can be an important means to excite interest in computing for students underrepresented in CS (Buchholz et al., 2014). E-textiles studies overall show that making and tinkering with technology that embraces the traditionally feminine practices of sewing and craft can disrupt people's perceptions of who is allowed to make with computers and what one can actually create (Fields & King, 2014; Searle, Kafai, & Fields, 2013). However, keeping this in mind, we are aware of the fact that others have noted that this approach can maintain gender stereotypes (e.g., "girls like sewing and boys shouldn't") and intensify established divides between boys and girls (Holbert, 2016; Kafai et al., 2014).

Relatedly, making and tinkering research involving informal learning environments that use technology reveals ways that youth engage in STEM practices, twenty-first-century skills (such as collaborative problem-solving and critical thinking), and persistence through intellectual and creative risk-taking when given the opportunity to connect their experiences across home, community, and school. Bevan, Ryoo, and Shea (2017) describe how youth engage in STEM-related practices while making and tinkering. These include investigative practices (e.g., asking questions, planning and carrying out investigations, etc.), sensemaking practices (e.g., developing and using models, analyzing and interpreting data, etc.), and critiquing practices (e.g., engaging in argument from evidence, etc.). This was visible, for example, when one youth hacked a pair of earbuds to figure out how the Bluetooth function could be incorporated into her making project. She engineered, tested, and troubleshot the earbuds and tested them when trying to call her friend's cell phone (Bevan et al., 2017). Similarly, Calabrese Barton, Tan, and Shin (2016) found that during key "pivot points" (when youth made in-the-moment actions to solve challenges that came up in their making projects), STEM inquiry, making, community action, and the project activities came together toward supporting new ways for youth to do and identify in STEM, making, and their communities. In the case of the youth with his light-up football project, these pivot points involved (1) using a wide range of funds of knowledge from reflection on limited street lighting, personal safety, and friendships that influenced the way he navigated coming up with an idea; (2) deepening his knowledge about energy systems, environmental, and economic impacts when figuring out power requirements for different lighting systems, designing and constructing the circuitry, and finding affordable batteries that could be environmentally friendly; and (3) gaining new identity as a STEM expert who could not only construct a light-up football but also develop fluency in the cultural repertoires of practice of both the afterschool club and his community (Gutiérrez, 2012). This was also visible in a digital fabrication workshop where a team of youth decided to make a rollercoaster. As the learners worked through challenges that arose from scaling down the project from a backyard project to a tabletop rollercoaster, they considered how to make curved tracks with uniform width, designed tracks on a vector-drawing software program, constructed these tracks with a laser cutter, and assembled everything together. Through such problem-solving processes, the youth organically engaged with key principles of physics and engineering, while pushing themselves through moments of frustration the way professional engineers have to do (Blikstein, 2013).

Youth also show a willingness to take intellectual risks and persist through challenging moments when working iteratively through their making and tinkering projects involving educational technology. As previous studies in making and tinkering describe, a making or tinkering disposition involves iteration that helps reframe "mistakes" as "drafts" that open up space for new ideas to emerge, regardless of whether they "work" (Vossoughi, Escudé, Kong, & Hooper, 2013). In the context of technology use, this was visible in an afterschool tinkering program where youth defined tinkering as "a constant process" of "chang[ing] something and then test[ing] it and then chang[ing] something again" (Ryoo, Bulalacao, Kekelis, McLeod, & Henriquez, 2015, p. 4). Having autonomy and creative authorship of projects motivated youth to work through that "constant process," which gave students a sense of ownership of the challenges that arose over time. When the program itself focused on process over product, youth took pride in working through challenging moments and even showcased their various non-working projects to audiences rather than focusing only on the working final product (Ryoo et al., 2015).

While students learn a range of important STEM, computing, twenty-first-century, and/or socioemotional skills and practices through making and tinkering with technology, research shows that there are key programmatic and pedagogical supports that are necessary to ensure such learning.

First of all, making and tinkering spaces must (1) create environments that emphasize how learning can be both purposeful and social, (2) cultivate room for play and creativity, (3) embrace broader definitions of intelligence and science that welcomes the varied perspectives that youth bring to the table, and (4) give space and time for shared activity, iteration, and the learning process (Vossoughi et al., 2013, p. 4). As such, programs must foster collaborative learning, focus on process over final products, and create multiple entry points and pathways to creating or solving problems that allow for youth to make connections across school, home, community, etc. (Bevan et al., 2017).

Yet, when engaging youth with technology that, in and of itself, may raise feelings of apprehension—for youth who lack prior experience with such technology or who have internalized sexist or racist belief systems about who should excel with technology—it is important for educators to also consider how their making and tinkering spaces address positions of privilege and power impacting the way youth experience technology, making, and tinkering. Opportunities should support engagement that is critical of structures of power and privilege, by framing youth's experiences as valued and their learning as consequential to themselves and their communities; educators must make efforts to challenge hierarchies of power between themselves and youth, as well as between youth (Barton, Tan, & Greenberg, 2016).

Finally, because technology traditionally lacks transparency (as individuals usually engage directly with the final products of computing design and engineering, but fairly little with the decisions leading up to the creation of those products), making and tinkering with technology provides youth with the opportunity to look inside that "black box" (Kafai & Peppler, 2012). Through the process of designing, building, testing, and rebuilding, making and tinkering with technology allow youth to struggle with the messiness of computers, making STEM and CS more accessible to learners (Kafai et al., 2014; Resnick, Berg, & Eisenberg, 2000). Making and tinkering with technology potentially give youth the space to "look under the hood," impacting the way youth come to see the world and, consequently, how they want to shape it (Kafai & Peppler, 2012).

Addressing Issues of Inequity in Learning with Technology

Making and tinkering provide potentially rich contexts in which youth can externalize their ideas about how things work when trying to make their designs come to life. However, different spaces engage making and tinkering differently. Depending on whether or not a space supports simple step-by-step recreation of a prototype or encourages youth to design and build based on their own vision, the outcomes of engagement with technology can be profoundly different. Research in spaces that promote youth making and tinkering that is creative and self-driven (vs. externally driven to follow step-by-step instruction) show the greatest opportunities for diverse youth to achieve high-quality experiences with and through technology that address issues of inequity in education. For example, when encouraged to build on their own interests and unique perspectives/designs with the potential of impacting their own or community's well-being, youth underrepresented in STEM and computing have opportunities to show deep engagement with STEM and computing practices (see Buechley et al., 2008 or Fields & King, 2014), make connections between their personal interests and creating with technology (see Kafai et al., 2014), or challenge the power dynamics that impact their identity and agency as scientists or successful learners and community members (see Barton, Tan, & Shin, 2016).

Yet what makes this possible? First of all, in the research studies cited above, the technology and end products are not the focus of the learning environments or communities. In these programs, technology is not the driving force for making, because educators recognize that undue emphasis on fancy machinery can actually make youth feel uncomfortable, as they may feel unwelcome to touch and play with shiny new tools in certain high-tech making labs (Barton, Tan, & Greenberg, 2016). Furthermore, if technology is the focus of making instead of the making itself, youth who have preconceived notions about their abilities with technology or who do not identify themselves as "good" with science and technology may be immediately intimidated or put-off (Nasir, 2011). Instead, technology is presented as simply another tool or means for achieving one's vision. In this way, new computing skills and STEM learning associated with the technology can be sparked by youth's interest in a specific project, while simultaneously opening the door to new interest and learning with technology.

Secondly, pedagogy matters with respect to having a rich learning experience through making and tinkering. Making pedagogies that promote social interaction and welcome youth within a space can be supportive for newcomers to engage in making and tinkering (Vossoughi et al., 2013). Simply telling youth to come up with an idea and use the technology at hand to build it is not enough to support meaningful learning. How educators engage with and teach youth with technology is consequential. This can include recognizing learners' funds of knowledge, which refers to "the historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" (Moll, Amanti, Neff, & Gonzalez, 2001, p. 133). The implication of this perspective is that the learners bring competence, knowledge, and experience to the learning experience. And it is important to ensure that all participating youth receive the opportunity to use the tools and teach each other and be experts as part of the learning experience.

Future Opportunities

Studies of making and tinkering in informal learning environments are making contributions to what we know about learning but also the role that educational technology plays in learning. In general, while we acknowledge the significant contribution of the studies mentioned in this chapter, as well as others, more research is needed on making and tinkering, specifically as it relates to engagement over time.

In general, studies of informal learning have been said to "foreground aspects of learning that are sometimes overlooked underemphasized when we study learning in other settings" (Crowley, Pierroux, & Knutson, 2014, p. 463). This provides us with an opportunity to understand learning within a context that may have different structures, cultural norms, and expectations. Just to provide one example of how this comes to bear on research, Simpson, Burris, and Maltese (2017) observed that learners' engagement in NGSS-aligned practices through making and tinkering looked differently in an informal setting compared to a formal setting.

Furthermore, informal learning often does not segment learners by age as formal learning settings do. Because of this, informal learning affords the potential for intergenerational or family learning. While some research has investigated family learning through making, such as in a children's museum (Brahms, 2014) or a community center (Roque, 2016), more research could communicate important supports, mediators, and outcomes related to the engagement of families in making and tinkering in informal learning environments.

In addition, as ecological or connected learning perspectives take hold in communities, research can understand potential learning pathways for youth, mechanisms that support those pathways, and the ways that making and tinkering interact with those pathways. This might include investigating how learners build deeper interests, skills, or identities with respect to making and tinkering, as well as how making and tinkering may connect to other ancillary experiences not directly related to making and tinkering. While the Scratch online community has connected learners globally through tinkering (e.g., Resnick, 2012; Roque, Rusk, & Resnick, 2016), little is known about connecting learners through making and tinkering within one particular community.

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Section VI
Understanding the Role Instructional Design/Technology Plays in Measuring and Communicating Learning Outcomes

Assessing Learning Outcomes

Randall Davies

Introduction

While there are a plethora of models and approaches for designing instruction (Allen, 2012; Dick & Carey, 1990; Gibbons, 2014; Merrill, 2002), there are only three basic steps in the instructional design process (Gagne, Briggs, & Wager, 1992). First, define expected learning objectives for the instructional unit. Second, determine how you will assess the anticipated learning outcomes. Third, design instructional resources and activities that will help students obtain the knowledge, skills, and abilities the course was intended to facilitate.

Granted, this is a big-picture oversimplification of the process; creating instruction is a complicated endeavor with many design decisions to be made (Gibbons, 2014). Still, most would agree that the purpose of a course in formal learning situations is defined by its learning objectives (Wiggins & McTighe, 1998). In this sense, the instructional design process has the goal of maximizing the likelihood that the intended learning outcomes for a course are achieved in an efficient and effective manner. An oft-overlooked challenge educators and instructional designers face in this process is determining the degree to which learning objectives for a specific course have been met and how to best use assessment data to improve instruction and learning. Unfortunately, assessment is often an aspect of the instructional process that educators and designers fail to do well (Fulcher, 2012; Guàrdia, Crisp, & Alsina, 2017; Hudaya, 2017; Linn, 1993; Pellegrino, 2013; Rogaten, Rienties & Whitelock, 2016; Stiggins, 1991a, 1991b; Wiggins, 1993). This chapter addresses the problem of assessing learning outcomes.

R. Davies (✉)
Instructional Psychology & Technology Department, David O McKay School of Education, Brigham Young University, Provo, UT, USA
e-mail: Randy.Davies@BYU.edu

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Terms and Definitions

An important aspect of any conversation is having a shared understanding of the meaning of terms. For example, the terms *assessment* and *evaluation* are often viewed as synonyms, yet they hold slightly different meanings. Assessment is descriptive in nature. It is intended to provide aquantitative measure of a student's achievement or ability. Assessment is value neutral. It communicates information about a student, often for the purpose of comparison. Evaluation adds to assessment in that it includes a value-based criterion that indicates whether the achievement, performance, or attitude being measured is sufficient or meets established expectations. Assessment is used for norm-referenced interpretations, while evaluation is used for criterion-referenced interpretations. While terms are often used interchangeably with little loss of meaning, some terms have precise meaning, and the communication loses clarity when terms are interchanged. The following definitions explain how specific terms are used in this chapter.

Instructional Goals

Goals are broad statements about a curriculum or a course that convey the general purpose or reason for creating instruction. Goals may include a vague intention to improve students' knowledge and ability or to develop specific desirable attitudes and dispositions. Goals often are established because we believe students will be better off (i.e., economically or socially) with specific training in that area. Course goals are often too broad to measure precisely.

Instructional Objectives and Learning Outcomes

The difference between these two terms is explained in a comparison between intended and actual outcomes. In fact, another term for *course objections* is *intended learning outcomes*. Objectives specify the intent of instruction. Outcomes are the results of instruction (intended or otherwise). We intend to accomplish instructional objectives, and we measure learning outcomes. Instructional objectives indicate what we hope to accomplish and provide specificity for instructional goals. The measurement of learning outcomes provides the evidence we require to determine whether the instructional goals have been met (Gronlund & Waugh, 2008; Mager, 1984).

Formative and Summative Assessments

These two terms differ in their timing, purpose, and structure. Formative assessment is carried out concurrently with instructions. Its purpose is to inform instructional practices by diagnosing learning challenges that need remediation and determine whether students are prepared to take summative assessments. Summative assessments typically take place at the end of a course or unit of instruction. They are typically used for accountability purposes to determine whether students have accomplished the learning goals of a course. Formative assessments are narrower in focus, are more specific in content coverage, and target specific learning objectives (Cizek, 2010; Marzano, 2009). Summative assessments typically sample the larger domain and infer or estimate from the result the degree to which a student has achieved the learning goals of a course.

Objectively Scored Assessments

An objective test is an assessment that measures characteristics independent of rater bias in that experts agree on the correct answer for each item before administering the test. When this strategy is used, scoring mechanisms can be standardized and are often scored using computer technology. Multiple-choice questions are the most often used item type in objectively scored tests. In contrasted, some items (e.g., essays) require the response to be subjectively scored. In these cases, there is no one solution, correct answer, or adequate response; someone must review of the answer to determine the degree to which the answer is correct.

Learning Objectives Background

In 1949, Ralph Tyler declared that learning objectives should drive the instructional design process and the measurement of learning outcomes, but the idea of using instructional objectives in education began much earlier (see Bobbitt, 1918, 1934; West, 1937). A decade after Tyler's declaration, Mager (1962) challenged educators to explore the feasibility and value of creating and using behavioral objectives for instructional purposes. In 1992, Gagne, Briggs, and Wager stated that the best way to design instruction was to work backward from the expected learning outcomes. Later, this idea was relabeled *backward design* and, borrowing from Covey's (1989) *Seven Habits of Highly Effective People*, made memorable by the phrase "begin with the end in mind" (Wiggins & McTighe, 1998). Yet, educators and instructional designers still struggle with this expectation. They typically start with broad course goals but not specific learning objectives (Borrego & Cutler, 2010; Wilson & Floden, 2001). Often, the learning objectives are established after the instruction is developed. Measuring learning outcomes is often an afterthought.

There are many ways to write learning objectives. Early methods for writing learning objectives focused on behavioral objectives (i.e., you must be able to observe the behavior as evidence that learning has occurred). Instructions for creating behavioral objectives prescribed that specific components be included. For example, behavioral objectives were to include a description of the students, a description of the task the students must complete, the conditions under which the task was to be completed, and the performance criteria for judging the quality of the effort (Ebel, 1970; Gagne, 1970; Mager, 1962; Popham, 1969). Opponents of this approach most often recognized the value of identifying instructional objectives but opposed the use of behavioral objectives in that they were difficult to develop and difficult to operationalize (Eisner, 1967; Hogben, 1972; McDonald-Ross, 1973). Further criticism of behavioral objectives included the belief that they typically only addressed lower-level learning and that the required specificity of behavioral objectives led to the creation of an overwhelming number of targeted learning objectives that became impossible to manage (Popham, 2008; Resnick & Resnick, 1992). More recently, approaches for creating learning objectives attempt to balance the use of vague learning goals and super-specific instructional objectives. For example, Gronlund and Waugh (2008) advocate pairing *general instructional objectives* (i.e., instructional goals) with a list of *specific learning outcomes* that provide educators with some guidance as to what evidence might indicate that the learning goals for the course have been met (Gronlund & Brookhardt, 2009). With the standard-based movement that began in the 1980s in the United States, curricular standards often provided the general learning goals for the curriculum (American Federation of Teachers, 1997; Wilson & Floden, 2001). Initial attempts to mainstream the use of curriculum guides and content standards were not without challenges. Curriculum standards describe well enough what should be taught in a specific course (i.e., curricular content) but not specifically what students should learn (Miller, Linn, & Gronlund, 2013). They often provided a basic overview of the instructional goals for a course; educators and instructional designers were then expected to write more detailed learning objectives for the various units covered in a course. Typically, the learning objectives for a course did not specify the knowledge components or precise learning outcomes to be measured. They also failed to describe how well students should be able to do what was expected (i.e., they did not provide evaluation criterion or performance standards). The challenge for those attempting to assess learning outcomes is to create instruments that test the important aspects of a course and provide results that can be used by teachers to diagnose and remediate students' misconceptions, knowledge gaps, or lack of skill.

Problems Associated with Assessing Learning Outcomes

The quality of an assessment is normally expressed in terms of reliability, validity, and utility. Reliability refers to the consistency of the result. Validity is a unitary concept (Messick, 1989) that depends on evidence that the test adequately covers the content (i.e., content validity evidence), that the test addresses the intended construct (i.e., construct validity evidence), that the test provides results that adequately predict future success (i.e., assessment-criterion relationship evidence), and that the results are interpreted and used appropriately (i.e., consequential validity evidence). Assessments are typically only valid for a specific purpose (Miller et al., 2013). In addition to reliability and validity, utility can be a concern. Assessments must be relatively easy to administer, and the results must be reasonably easy to interpret. Utility includes the cost of test administration, both time and money. Problems with assessment usually are the result of issues with one or more of these test quality characteristics.

Difficulty in Assessing Higher-Level Learning

This is an issue associated with construct validity. Bloom's *Taxonomy of Educational Objectives* is often used as a basis for understanding learning outcomes and defining learning objectives (Anderson & Krathwohl, 2000), but it is difficult to write clear, measurable learning objectives, especially when the intended learning outcome is at a higher level of the cognitive domain or in the affective domain (Resnick & Resnick, 1992). A common criticism of many assessments is that the learning objectives too often focus (intentionally or otherwise) on lower-level learning objectives (i.e., remembering and understanding) and fail to address important higher-level learning objectives (i.e., applying, analyzing, evaluating, and creating). For example, the Accreditation Board for Engineering and Technology (ABET) established an expectation for engineering programs to focus on 11 intentionally vague engineering goals as a necessary step in the accreditation process. Their framework is based on Bloom's *Taxonomy* for the cognitive domain but adds an objective from the affective domain, valuation. Using this framework, engineering faculty are expected to establish measurable learning objectives that can be used in the assessment and feedback process (Besterfield-Sacre et al., 2000). Learning objectives that require engineering students to gain and apply knowledge (e.g., understand a specific principle, analyze and interpret data, or design and conduct an experiment) are easy enough to define and measure. However, the expectation that students value, appreciate, or develop a specific attitudinal disposition can be a challenge to assess. Certainly, expecting a student to appreciate and value the need to be a lifelong learner may be a worthy endeavor, but it constitutes a formidable assessment challenge. Students may be able to articulate the arguments for such an attitude (i.e., knowledge and understanding), but educators may find it challenging to determine how strongly a student holds a specific opinion (i.e., disposition and valuation). Likewise, it is easy to test a student's understanding of ethical principles and professional codes of conduct but difficult to determine whether a student personally values these standards and will demonstrate moral and ethical behavior once they are working in the profession. An example of this issue is the capstone project (a problem-based learning task) often used to assess higher-level learning outcomes. Students' grades are often based on the students' ability to follow appropriate procedures (application), not on the quality of the solution, the ability to think critically, nor whether the students can work effectively as members of a team (Dutson, Todd, Magleby, & Sorensen, 1997). The learning pedagogy is sound, but the assessment of specific higher-level learning outcomes is often faulty (i.e., lacking evidence of construct validity).

Assessing higher-level cognitive abilities is difficult, because these abilities require a foundational knowledge base and an understanding of principles, but the satisfactory completion of a complex learning task can typically be accomplished in a variety of ways (i.e., creative and innovative ways with no one solution that might be deemed adequate or correct). Often, the constructs being measured are not directly observable, are poorly understood and defined, are not valued by all (i.e., experts do not agree on their importance), or must be assessed contextually in an authentic situation (i.e., an issue of assessment utility). These factors make it difficult to measure certain learning outcomes.

Using Instrument that Do Not Align with the Test Purpose or Learning Objectives

Assessing learning outcomes is made more challenging by the various purposes of assessment. When the results of an assessment are used inappropriately (i.e., a purpose for which they were not intended), the assessment is not valid (i.e., an issue of consequential validity). Creating assessments for a specific purpose often places restrictive parameters on the implementation and appropriate use of an assessment instrument. Political and usability restriction can also affect the development and implementation of assessments. While summative assessments are often used for accountability purposes, formative assessment are typically more useful to educators when they attempt to personalize instruction, diagnose knowledge gaps, and remediate student learning problems (Marzano, 2009). An instrument developed as a summative assessment does not function well as a formative assessment. For example, a common criticism of the accountability movement in US education is the overuse of summative assessments and the misuse (or misinterpretation) of the results (Hursh, 2013; Ravitch, 2010).

Using Inappropriate Types of Assessment

Another issue affecting the assessment of learning is the overuse of objectively scored assessment instruments—more specifically, the overuse of items that can be scored quickly and efficiently (i.e., multiple-choice questions). For example, language assessment is particularly susceptible to the problem of using the wrong type of assessment, leading to invalid results and interpretations. For convenience, many language tests use objectively scored assessments to test students' ability to communicate orally in a specific language. While multiple-choice items might test vocabulary or reading comprehension well enough, a performance assessment is needed to assess speaking ability (i.e., a construct validity issue). While the Oral Proficiency Interview (OPI) is the gold standard for assessing an individual's ability to speak a language, its use is prohibitive due to the need to train interviewers as well as the time it takes to administer individual examinations (i.e., utility issues).

Writing Quality Test Items

It is easy to write bad test items! Test writing is a challenging activity (Stiggins, 1991b), and the field of assessment literacy is a growing area of interest for educators (Gotch & French, 2014; Stiggins, 2014). Many teachers are underprepared to accurately assess student learning (Lam, 2014); even fewer educators are willing to put in the time and effort it takes to validate and revise the assessments they use (Mertler, 2016; Stiggins, 2014). The validity of all tests depends on the quality of the items used (Miller et al., 2013); as such, the development and selection of test items play a central role in the assessment process (El-Alfy & Abdel-Aal, 2008). While an in-depth discussion of item creation and test validation is beyond the scope of this chapter, the lack of quality test items and validated tests remains an assessment problem that needs to be addressed. We often assume a test is valid (i.e., face validity) when it is not.

Solving the Assessment Problem

The problems associated with assessing learning outcomes are many. This section of the chapter presents examples and discussion regarding ways in which individuals are attempting to solve assessment problems. Few of the problems have been adequately addressed, but progress is being made in many instances.

Alternative Assessment: A Pedagogical Solution

Presently in the United States, there is considerable dissatisfaction with current education policies that are fixated on testing (some would say over testing) for the purpose of holding educators accountable for student learning (Fulcher, 2010; Hursh, 2013; Popham, 2008; Ravitch, 2010; Zumbo & Hubley, 2016). As a result, considerable attention is presently being placed on alternative, qualitative forms of assessment in schools (Anderson, 1998; Borrego & Cutler, 2010; Hodgson, Varsavsky, & Matthews, 2014; Jacoby, Heugh, Bax, & Branford-White, 2014; López-Lozano, Solís, & Azcárate, 2016; Marzano, 2009; Pellegrino, 2010; Smith, Johnson, Johnson, & Sheppard, 2005). Typically, these alternative assessments refer to anything other than objectively scored tests (Miller et al., 2013) and represent a pedagogical solution to the assessment problem. The main focus of these assessments is to improve student learning not necessarily to accurately and precisely assess specific learning outcomes. Alternative assessments are often described as formative assessments rather than summative assessments (Black & Wiliam, 1998). And while there are hundreds of research articles that use the term *alternative assessment* in the title, few, if any, describe an approach to assessment that has not been tried in the past (Ewing, 1998). Many of these educational ideas and practices have simply been rediscovered, revised slightly, relabeled, and reintroduced as an educational reform or movement. In practice, current assessment initiatives associated with alternative assessments are a renewal process more than an innovative reform (Fox, 2017).

Alternative assessments are typically used in student-centered, activity-based instructional settings that require a performance of some type (Gordon & Rajagopalan, 2016). In student-centered instructional settings (e.g., *problem-based learning*), students are presented with an *authentic* tasks or problem that would require individuals to utilize higher-level cognitive abilities in order to complete the assignment satisfactorily (Barrows & Hmelo-Silver, 2006; Broadbear, 2012; Lesh & Lamon, 2013). In theory, satisfactory completion of the task provides evidence that, to some degree, the individual has the cognitive ability identified by the intended learning objectives for the course (Gulikers, Bastiaens, & Kirschner, 2004). Still, while the tasks used are designed to improve learning, the skills students purportedly gain need to be assessed.

Various Qualitative Assessment Alternatives Common types of alternative assessments include the following: *portfolios* (Fox, 2017; Gaide, 2006; Pegrum & Oakley, 2017), *infographics* (Cifci, 2016; Gover, 2017), *concept maps* (Davies, 2011), *self-assessments* (Boud, 2013; Bruce & Ross, 2008), *peer reviews* (Boud, Cohen, & Sampson, 2009), *expert reviews*, and *observations* (McMillan, Myran, & Workman, 2002; Papay, 2012). For each of these testing approaches, the assessment is bound in the problem that students must solve or the task students are asked to accomplish. The approach used is foremost a learning activity (Drake, 2001; López-Lozano et al., 2016; Pellegrino, 2010). The assessment is usually secondary to the pedagogy (Smith et al., 2005; Taras, 2002).

Each of these methods of assessment suffers from a variety of test quality challenges (Ewing, 1998). Reliability is an issue in that, by nature, all must be rated somewhat subjectively. Validity is an issue in that these tests produce indirect measures that may or may not get at the construct being targeted, neither do they provide a precise measure of any specific outcome. The utility of using alternative assessments is, simply put, a tremendous problem for both students and teachers in terms of the time and effort required. However, what alternative assessment practices lack in specificity of measuring learning outcomes (Zumbo & Hubley, 2016) they make up for in the increased likelihood that students will develop higher-level cognitive skills and abilities (Jacoby et al., 2014; Lesh & Lamon, 2013).

Rubrics An essential aspect of alternative assessment is the development and use of rubrics. Alternative assessment techniques are highly susceptible to several threats to validity, including rater bias, self-report issues, floating criteria, and irrelevant factor interactions (Miller et al., 2013). These threats to validity are alleviated somewhat when raters are trained to use rubrics (Fulcher, 2012; Mertler, 2001). Assessment reliability is improved when raters follow the assessment rubric. The validity of the assessment is enhanced if the rubric addresses all the important components of the performance and aligns with the specific outcomes being measured.

Technology-Enabled Assessment Solutions

While technology is often used when assessing student learning, in the case of technology-enabled assessments, technology is an essential enabling aspect, not just a tool to improve the efficiency or utility of the process. For example, the alternative assessments mentioned previously can be, and often are, completed without the use of technology. When technology is used, it is most often used for efficiency to help educators organize, record, and report assessment data. Unlike technology use in alternative assessments, technology-enabled assessment solutions require technology and often sophisticated assessment algorithms. These solutions typically cannot be created (and sometime even implemented) by a regular classroom teacher; however, educators can benefit from the collaboration of specialists who create technology-enabled assessment solutions. Like alternative assessment practices, many of these solutions use assessment data to drive instruction and remediation (i.e., are formative assessments), but they are also used for summative assessment purposes. Unlike alternative assessment approaches, these technology-enabled assessment solutions are quantitative in nature. They also tend to focus on learning objectives that measure lower-level cognitive abilities and skills, and they are reported as student master of specific skills (Chung et al., 2016; Melis et al., 2001; Mitrovic, Ohlsson, & Barrow, 2013).

Learning Hierarchies An essential component of most technology-enabled assessment solutions is the use of learning hierarchies or frameworks that categorize requisite knowledge components and define relationships between knowledge components and test items (Drasgow, 2015; Rupp & Leighton, 2016; Templin & Bradshaw, 2014). Foundational to this activity is the need to understand threshold concepts (Cousin, 2006) and an analysis of what specific skills need to be acquired by students in order to master the desired learning outlined by the course objectives (Liu, Xu, & Ying, 2013).

The process of mapping requisite knowledge components (i.e., latent attributes) with assessment items is a challenging activity (de la Torre & Chiu, 2016). The mapping process is based on a theoretical understanding of the curriculum domain, the content, the context, the assessment purpose, and the psychometric properties of the data. It typically requires a collaborative effort of educational specialists and psychometricians. The process of tagging assessment problems with knowledge components goes by various labels, including *Q-matrix* (Birenbaum, Kelly, & Tatsuoka, 1993), *diagnostic classification model* (Rupp, Templin, & Henson, 2010), *transfer model* (Feng & Heffernan, 2006), *cognitive model* (Feng & Heffernan, 2006), *learning ontology* (Melis et al., 2001), *domain model* (Sottilare & LaViola, 2016), and other derivations of these terms. Each of these labels carries with it particular connotations that represent aspects of the learning hierarchy it describes. These methods of classification are not exactly the same; however, they each represent an attempt to define the knowledge and skills required to answer specific assessment questions (i.e., the item-attribute relationship). The resulting framework can then be used to analyze test results and identify which concepts and skills a student has mastered and which still need to be learned. A variation on a Q-matrix concept involves tying incorrect responses and mistakes to possible knowledge gaps and misconceptions a student may have (Bradshaw, Izsak, Templin, & Jacobson, 2014; Lemley, Sudweeks, Howell, Laws, & Sawyer, 2007; Nyland, Davies, Chapman, & Allen, 2016). This type of analysis is key to providing feedback and remediation (Leibold & Schwarz, 2015). Many researchers in a variety of areas are exploring ways to utilize learning hierarchies.

Personalizing Instructions Through Assessment Most educators attempt to personalize instruction for their students, which generally means identifying the needs and capabilities of individual students; providing flexibility in scheduling, assignments, and pacing; and making instruction relevant and meaningful for the individual learners (Keefe, 2007). Personalizing instruction is typically the goal in classrooms, and often computer-assisted instruction (CAI) is expected to be adaptive (i.e., personalized) to some degree as well (Watson & Watson, 2016). Personalized instruction in the context of adaptive CAI is also called *adaptive instruction* or *adaptive learning* (Sottilare & LaViola, 2016; Yildirim Biten, 2017), *artificial intelligence* (du Boulay, 2016; Underwood & Luckin, 2011), or, most often, *intelligent tutoring* (Burns & Capps, 1988; Graesser, Conley, & Olney, 2012; Murray, 2003). There are many types of intelligent tutors, but not all adapt based on an analysis of assessment data. Some CAI systems are simply technology-facilitated content delivery systems based on passive learning models of instruction (Chung, 2014; Robson & McElroy, 2008). In essence, these systems are simply electronic page turners following a didactic approach to instruction (Fairweather & Gibbons, 2000; Robson, 2013). The assessment in these systems is typically summative. Other CAI systems limit the way they personalize instruction to changes based on information about the learner and their personal preferences (Watson & Watson, 2016). A few CAI systems can be described as adaptive intelligent tutors in that the instruction they provide is personalized using assessment results that are based on carefully designed learning hierarchies (Fletcher & Sottilare, 2017; Sottilare et al., 2016).

There are several examples of intelligent tutors that use assessment data to adapt instruction, including *ActiveMath* (Melis et al., 2001), *Khans Academy* (Khan, 2012), and *Carnegie Learning's Cognitive Tutor* (Cabalo, Ma, & Jaciw, 2007). These are all computer-based, adaptive learning tools that assess student competencies and provide instruction, problems, and hints designed to optimize individual student learning. Reported results on the effectiveness of these instructional tools have been mixed (Kulik & Fletcher, 2016) but are likely confounded by variables outside the control of the intelligent tutor (Davies, 2009). These examples tend to assess mastery learning within the first three levels of Bloom's *Taxonomy*: knowledge recall, comprehension, and application (Melis et al., 2001). Each of these examples adapts the scope and sequence of the instruction based on students successfully completing tasks (i.e., assessments). The process is designed around a specific learning hierarchy and uses sophisticated algorithms to decide which specific adaptations to make. Intelligent tutors claim to be effective at improving learning (Ash, 2013; Pane, Griffin, McCaffrey, & Karam, 2014; Ritter, Joshi, Fancsali, & Nixon, 2013). Still, more research needs to be done, especially in the area of psychometric models and the predictive algorithms being used.

Learning Analytics and Educational Data Mining Using assessment data to enhance education is not a new concept (Skinner, 1968; Tyler, 1949). However, current discussions about data use have taken on new dimensions with advances in technology that facilitate our ability to acquire copious amounts of educational data through technology-enhanced instructional systems. In fact, the fundamental problem we currently face in education regarding data use is the volume of data we are now able to acquire and our apparent inability to identify useful data (Davies et al., 2017). DiCerbo and Behrens (2012) describe the problem as drowning in a digital ocean of data. Considerable research is being done regarding what data to collect and how to use it (Van Horne, Russell, & Schuh, 2015).

Learning analytics and its sister field educational data mining (EDM) have had a huge impact on adaptive learning (Baker & Inventado, 2014; Papamitsiou & Economides, 2014). Research in these fields is immense, diverse, and growing. Researchers are looking at measuring learning outcomes, and they are also looking at using process-level data, which helps educators better understand how students go about learning (Chung, 2014). Many educators use EDM to identify patterns and trends in data that help them predict student success and flag at-risk students (Brinton & Chiang, 2015; Saqr, Fors, & Tedre, 2017; Wolff, Zdrahal, Nikolov, & Pantucek, 2013). Researchers are also working on ways to measure higher-level cognitive ability through an analysis of process-level data (Brasiel et al., 2017; Fidalgo-Blanco, Sein-Echaluce, García-Peñalvo, & Conde, 2015; Hu, 2017). In many cases, these adaptive systems do not just assess learning outcomes; they also attempt to monitor student learning gains during a course by continually analyzing process-level data obtained through learning analytics procedures (Chung, 2014; Fu, Shimada, Ogata, Taniguchi, & Suehiro, 2017; Kavitha & Raj, 2017). The goal is to provide real-time actionable information to educators and students (Davies et al., 2017; Johnson et al., 2016). These applications of learning analytics often utilize Q-matrix frameworks and sophisticated psychometric algorithms to identify specific skills a student has acquired and also to identify knowledge gaps and misconceptions that a teacher might need to remediate (Bradshaw & Templin, 2014; Nyland et al., 2016). Learninganalytic and EDM processes often require psychometric expertise, considerable data storage, and computing power (all issues of utility). A weakness of this approach is that the assessment items used must be carefully crafted and entered into a Q-matrix for use (a time-consuming and difficult task).

Computer Adaptive Testing Computer adaptive testing (CAT) is largely based in *item response theory* (Wang, Zheng, & Chang, 2014; Weiss, 2014). It is a quantitative approach to testing that requires advanced statistical methods; Rausch modeling is a common statistical approach used for CAT (Lange, 2017). CAT started in the1970s and has become increasingly more popular in educational settings, largely due to improvements in computer technology (both in access and power) and the fact that CAT is particularly appropriate for large-scale testing situations (Chang, 2015). CAT exams have been created for a number of different purposes and content areas (Clemens et al., 2015; De Beurs, de Vries, de Groot, de Keijser, & Kerkhof, 2014; Foorman, Espinosa, Wood, & Wu, 2016; González Romero, 2016; Liu, You, Wang, Ding, & Chang, 2013). Much of the early research in this area was done using computer simulations (Weiss, 2014). Current work tends to focus on the development of new tests (e.g., Foorman et al., 2016; Liu, You, et al., 2013) as well as improving item-selection algorithms and methods, for example, using item-stratification grouping rather than single-item branching (Hsu & Wang, 2015; Huebner, Wang, Quinlan, & Seubert, 2015; Kaplan, de la Torre, & Barrada, 2015; Templin & Hoffman, 2013; Wang et al., 2014; Yutong, Zhaosheng, & Rui, 2015).

Although CAT is seen as a good way of estimating learning ability (i.e., trait levels), such assessments do not always provide specific measures of learning outcomes and are more suitable for summative assessment than formative assessment (Chang, 2015). Critics of CAT also point out that testing is stressful and that CAT assessments add an additional level of stress: they are designed to challenge students' ability through an adaptive-convergence process that presents the student with an increasingly harder question each time he or she gets an item correct (Kimura, 2017; Sampayo-Vargas, Cope, He, & Byrne, 2013; Weiss, 2014).

In addition, even though CAT is an efficient way to test, it requires an extensive test bank of items. As the measurement accuracy (i.e., assessment validity) of all tests depends on the quality of the items they include, item creation and selection procedures play an important role in the CAT assessment process (El-Alfy & Abdel-Aal, 2008). Thus, creating quality items to use and being able to select appropriate items are fundamental challenges for CAT.

Diagnostic Measurement Diagnostic measurement in education is the psychometric process of analyzing data from carefully designed assessments for the purpose of making classification-based decisions about a learner's cognitive achievement (Li, Cohen, Bottge, & Templin, 2016; Rupp et al., 2010). Whereas item response theory and classical (i.e., traditional) test theory assume unidimensionality in terms of the construct test's attempt to measure, diagnostic measurement is intentionally multidimensional (Bradshaw et al., 2014; Park & Lee, 2014). Like other testing approaches, selection of items is key to this process (El-Alfy & Abdel-Aal, 2008) as well as the development and validation of the Q-matrix to be used (Basokey, 2014; de la Torre & Chiu, 2016; DeCarlo, 2012; Li & Suen, 2013; Rupp & Templin, 2008). Much of the research in this area is related to item response theory and Bayesian statistical modeling (Bradshaw & Templin, 2014; Hanson, Cai, & Monroe, 2014; Hoijtink, Beland, & Vermeulen, 2014). While these processes tend to work better for well-defined content areas at lowerlevels of Bloom's *Taxonomy* (Basokey, 2014; Bradshaw et al., 2014; DiBello, Henson, & Stout, 2015; Rupp & Templin, 2008), some attempts have been made to measure higher-order thinking and cognitive abilities (Daniel & Embretson, 2010). These assessments do not usually provide a precise measure of specific learning outcomes but instead intentionally and simultaneously attempt to estimate (using a few items) the probability that a student has mastered a variety of cognitive constructs (Bradshaw et al., 2014; Embretson, 2016; Wang, 2013).

Computer-Assisted Language Testing

Language instruction is another area where technology is being used to both facilitate and enable assessment. The field of computer-assisted language testing (CALT) is an area of great interest and considerable research (Chapelle & Voss, 2017). Natural-language processing technology used in this field has many purposes, includingtext and speech translation, second languagetraining practice, and assessing language proficiency (Winke & Isbell, 2017). A particularly troublesome challenge for researchers however is the fact that language processors used for assessment do not perceive meaning well (Bowman, Angeli, Potts, & Manning, 2015). Still, although the task of assessing communication quality is daunting (Kamp & Reyle, 2013), there are many applications of natural-language processingthat attempt to assess various forms of human communication.

Writing Assessments Computerized assessment of writing is an area of great interest in schools, primarily for utility and efficiency reasons. It is a well-known fact that teachers often struggle to assess and provide feedback to students regarding their writing. It is an issue of not only time but also ability (Stiggins, 2014). Efforts to obtain valid computer-scored assessments of writing have had mixed results (Correnti, Matsumura, Hamilton, & Wang, 2013; Deane, Williams, Weng, & Trapani, 2013; Elliot & Klobucar, 2013; Lavolette, Polio, & Kahng, 2015). Though assessment researchers find moderate to high correlations between the results of computer-scored and human-scored writing tests (Elliot & Klobucar, 2013; Ranalli, Link, & Chukharev-Hudilainen, 2017), critics have described serious flaws in the process, including the fact that human ratings are themselves often flawed (Attali, Lewis, & Steier, 2013; Davies & West, 2014; Lam, 2014). Writing software that uses computer scoring can be programmed to identify language patterns, basic writing conventions, and sentence structure fairly well (Holland, 2013; Ranalli et al., 2017). Language processors cannot, however, read for meaning, creativity, or logical argument, which are often important learning objectives in writing courses (Attali et al., 2013; Bowman et al., 2015; Rahimi & Litman, 2016). Using language analytic processes, some studies have had success predicting human-scored assessments of writing quality based on linguistic indices related to lexical diversity, word frequency, and syntactic complexity measures. These, however, are indirect measures and not particularly good evidence of writing cohesion, rhetorical prowess, writing clarity, or ease of reading (McNamara, Crossley, & Roscoe, 2013). Another challenge is that writing itself in many ways is an ill-defined, dynamically changing domain (Drouin, 2014). Regrettably, experts often do not all agree on what constitutes good writing (Cecire, 2015; Snow et al., 2016).

Although computerized assessments of writing do pretty well at assessing basic writing skills (Deane et al., 2013; Lavolette et al., 2015), work still needs to be done in educational areas that attempt to measure how well students understand concepts, how well they can provide content-based explanations, and whether they can logically support a position with relevant evidence (Attali et al., 2013; Liu et al., 2014). In many cases, researchers conclude that while computer-based assessment can provide somewhat reliable evidence of basic writing prowess, it should serve as only a complement to human scoring in a low-stakes classroom setting (Correnti et al., 2013; Lavolette et al., 2015; Liu et al., 2014; Ranalli et al., 2017).

Writing-assessment research is being conducted in a variety of areas, including improving assessment reliability (e.g., Attali et al., 2013; Rahimi, Litman, Correnti, Wang, & Matsumura, 2017), using assessment results for remediation (e.g., Lallé, Mostow, Luengo, & Guin, 2013; Lavolette et al., 2015; Ranalli et al., 2017), targeting ill-defined higher-level learning skills (e.g., Correnti et al., 2013; Rahimi et al., 2017), and improving language processing algorithms (e.g., Latham, Crockett, & McLean, 2014; Snow et al., 2016).

Oral Proficiency Assessments Assessing someone's ability to speak a language requires a performance assessment. And while it is unfortunately a far-too-frequent practice, you cannot use a multiple-choice exam to assess speaking ability (Stiggins, 1991b). Currently, best practice requires that speaking ability be assessed by human raters, preferably raters trained to administer an oralproficiency exam (Xiong et al., 2016). Regrettably, many teachers are underprepared to assess language skills well, and the subjective nature of the rating process is inevitably affected by issues of rater bias (Kim, 2015; Lam, 2014; Sandlund, Sundqvist, & Nyroos, 2016). Assessing levels of speaking proficiency can be accomplished using natural-language processors, but the issue of what constitutes proficiency is problematic (De Jong, Groenhout, Schoonen, & Hulstijn, 2015; Segalowitz, 2016). Not everyone speaks their native language well, yet individuals are usually assumed to be proficient in their own native language (De Jong, 2016).

One way researchers have attempted to estimate oral proficiency using computers is through a practice called *elicited imitation* (EI) (Cox, Bown, & Burdis, 2015). This practice uses fluency indices (e.g., number of silent pauses, number of syllables used, or length of utterance) to estimate an individual's speaking fluency (De Jong & Bosker, 2013). Although some successful applications of EI have been reported in low-stakes educational settings, like literacyplacement screening (Huang & Konold, 2014; Risdiani, 2016), using EI to measure specific learning outcomes has its limitations (Suzuki & DeKeyser, 2015). Natural-language programs must learn how to listen. Though they do fairly well recognizing words they have learned, attempting to capture words in an unrestricted utterance is a concern. A speaker's accent, gender, age, use of acceptable pronunciation differences (e.g., tomato vs. tomauto), use of semantic similarities (i.e., alternative words), and use of colloquial phrases or slang can cause problems for a language processor when it is trying to detect distinct words. EI asks individuals to listen to and then repeat a phrase. In order to function effectively, EI restricts the utterances' vocabulary, number of syllables, and length (Campfield, 2017). These restrictions allow the natural-language programs to more accurately capture the words being repeated but also help predict ability. While EI returns a measure of fluency, the indices used often need to be normalized based on the speech patterns of each individual in their native language to account for the speaking fluency, as measured by these indices, which varies naturally for individuals.

Critics of EI, and the use of natural-language processors for CALTin general, argue that although EI may measure fluency in a limited way, it does not measure listening comprehension, usable vocabulary, nor the ability to construct an intelligent response—all of which are essential skills needed for conversational speech (Baker-Smemoe, Dewey, Bown, & Martinsen, 2014). In general, natural-language processors are challenged when attempting to evaluate the degree to which a statement makes sense (i.e., intelligent speech), whether the arguments being made are logical, or whether the arguments are adequately supported by evidence (Attali et al., 2013; Suzuki & DeKeyser, 2015).

Research in this area focuses on improving techniques (e.g., Cox et al., 2015; Spada, Shiu, & Tomita, 2015), validating instruments for specific languages (e.g., Gaillard, 2014; Wu & Ortega, 2013), researching contextual aspects of assessments and how they might best be used (e.g., Huang, 2016; Segalowitz, 2016; van Compernolle & Zhang, 2014), and defining and categorizing elements of language to enable CALT applications (e.g., Harispe, Ranwez, Janaqi, & Montmain, 2015).

Reporting Assessment Data

Two topics that warrant mention are the growing field of *data visualization* (Evergreen, 2016) and the novel practice of *digital badges* (Gibson, Ostashewski, Flintoff, Grant, & Knight, 2015). Both these topics relate to reporting assessment data. The data they report is assumed to be valid.

Data Visualization Given the current state of educational technology, students expect real-time information about their progress in the courses they are taking. Largely due to the increased use of learning analytics, reporting information about student progress in a course can be rather sophisticated (Bodily & Verbert, 2017; Johnson et al., 2016). Assessment data is often reported in a learning management system; more recently, this means reporting student progressusing digital dashboards (Verbert, Duval, Klerkx, Govaerts, & Santos, 2013; Williamson, 2016).

Most technology-facilitated courses report assessment data in a rather rudimentary fashion. They indicate progress and predict success as a function of whether students handed in assignments and whether their current cumulative grade is at or above some established level (Arnold & Pistilli, 2012). Several improvements to early dashboard systems have been made. For instance, some digital dashboards are now reporting the degree to which specific learning objectives have been mastered (e.g., Marbouti, Diefes-Dux, & Madhavan, 2017). Additionally, recommender systems consider where students are spending their time and make suggestions or provide feedback based on assessment results (Einhardt, Tavares, & Cechinel, 2016; Thomas, Reinders, & Gelan, 2017). Still, other dashboard systems attempt to analyze students' learning patterns and assessment results and then help students set goals to better engage them in the required learning (Buckingham Shum & Crick, 2016; Sedrakyan, Järvelä, & Kirschner, 2016). Research is also being conducted to solve issues of big data, including developing tools needed to analyze and report these data (Keim, Qu, & Ma, 2013; Sin & Muthu, 2015; Slater, Joksimović, Kovanovic, Baker, & Gasevic, 2017).

Digital Badging and Micro-credentials A research area aimed at solving the problem of reporting assessment results is that of digital badging. This idea is only beginning to gain traction in education, and much of the research on this topic addresses stakeholder perceptions and possible implications (e.g., Ahn, Pellicone, & Butler, 2014; Davis & Singh, 2015; Lemoine & Richardson, 2015). The basic idea of this innovation is to provide an alternative way to recognize student mastery of specific skills and abilities (Fedock, Kebritchi, Sanders, & Holland, 2016). The idea has prompted considerable discussion, but rigor and implementation issues are a concern for many (Davies, Randall, & West, 2015; Fanfarelli & McDaniel, 2017; West & Randall, 2016).

Conclusions

Teachers have been struggling with assessing learning outcomes for decades, and while we're still struggling to do it well, the need to assess and evaluate learning outcomes has only increased (Ravitch, 2010; Stiggins, 1991b). To be fair, educators seem to be quite capable of adequately assessing low-level learning outcomes in well-defined domains. However, the assessment and evaluation of higher-level learning outcomes (especially in subjects with dynamic, ill-defined domains) has been, and continues to be, a challenge. Alternative assessments, touted by many as "new approaches" to testing, are not new at all, and as in the past, they suffer in terms of reliability, validity, and utility (Ewing, 1998). They represent pedagogical solutions to the assessment problem and are more concerned with providing students with an effective learning opportunity than with measuring specific learning outcomes. What alternative assessment practices lack in quality they attempt to make up for in the increased likelihood that students will develop higher-level cognitive skills and abilities.

Innovative advances have been made as the result of technology-facilitated and technology-enabled assessments. However, while technology has improved our ability to assess efficiently and effectively in some ways, technology has also added complexity and additional challenges that must be overcome. Technology-enabled assessment solutions tend to focus on improving the quality of assessments, but they require expertise in creating and using sophisticated computer algorithms to capture and analyze data. They also tend to focus on creating better measures of low-level learning in well-defined domains than creating good measures of higher-level learning.

With the increase in adaptive online courses (i.e., intelligent tutors), there has been an increased need to create valid online assessments. Intelligent tutors often require the use of learning analytics, which considers assessment data (i.e., what students learned) and voluminous amounts of learningactivity data (i.e., how students went about learning). Coinciding with this increase in adaptive online learning is the need for better data visualization. Data visualization is an emergent area of research that focuses on analyzing both assessment and activitytrace data and then presenting actionable information to educators and students in the form of real-time digital dashboards.

In summary, assessment remains a challenge for educators. Some seem to have given up trying to accurately measure higher-level learning and have opted for a pedagogical solution to assessment (i.e., using alternative assessments). These educators focus on providing learning opportunities that will likely require students to develop and practice important higher-level skills. Others have leveraged sophisticated technology-enabled solutions in an attempt to solve the assessment problem. However, creating these solutions tends to require skills beyond what most regular classroom teachers have, as creating them requires teams of experts in education, technology, and psychometrics. In addition to this, the fields of learning analytics and data visualization are emerging areas of interest for many data scientists and assessment experts.

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Competencies in Context: New Approaches to Capturing, Recognizing, and Endorsing Learning

Daniel T. Hickey, Suraj L. Uttamchandani, and Grant T. Chartrand

As highlighted across the many chapters in this volume, educational technologies are continuing to evolve rapidly. New technologies are giving rise to entirely new models of educational practice. The co-evolutions of technology and practice are particularly obvious in virtual schools, MOOCs, and open learning. These new educational settings have been widely discussed by researchers and have gained the attention of the broader news media and policy makers. Given that some of these new educational settings are supporting new forms of learning, they have also revealed the need for new approaches to educational measurement, credentialing, and accreditation. This chapter discusses current efforts to develop such approaches, with a focus on efforts associated with the introduction of open digital badges and other digital microcredentials, starting around 2012. While these developments are primarily discussed in the context of post-secondary education and learning, they are relevant to K-12 contexts.

Definition of the Problem

The problem addressed by this chapter is rooted in prevailing practices for measuring achievement, credentialing individuals, and accrediting schools. College transcripts, for example, emerged alongside related practices for teaching students, advancing graduates, and hiring employees. These practices co- evolved gradually over the last century (Brown, 2001). Partly because of this, current practices for testing, accrediting, and credentialing are quite opaque for many stakeholders. For example, most students and many employers are utterly unaware of how particular

D. T. Hickey (✉) · S. L. Uttamchandani · G. T. Chartrand
Indiana University, Bloomington, IN, USA
e-mail: dthickey@indiana.edu

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schools are accredited (Powell, 2013). Because these practices interact with each other in complex ways, they can lead to "wicked" problems (Borko, Whitcomb, & Liston, 2009) that obstruct progress. For example, the presumed expectations of external accreditors have discouraged some schools from expanding into online courses (e.g., Parker, 2008) and discouraged others from allowing students to transfer in credits from courses taken online (AACRAO, 2017; Schrock, 2010). In a similar vein, the presumed expectations of hiring managers have discouraged many schools from embracing new evidence-rich digital badges and micro-credentials (Fong, Janzow, & Peck, 2016). Meanwhile, recent school closures and controversies have placed the entire process by which schools are accredited under new scrutiny (Flood & Roberts, 2017). These and other problems created by the lack of transparency in credentialing are nicely summarized by Grant (2014) and Gallagher (2016, particularly in chap. 2, entitled *Behind the Curtain*).

In addition to being opaque, prevailing practices for testing, credentialing, and accrediting are relatively analog or have only embraced technology as proxies for analog practices. For example, while educational tests are increasingly administered online, most still employ the same assumptions about learning and measurement as tests used decades ago (Timmis, Broadfoot, Sutherland, & Oldfield, 2016). Likewise, while admissions officers or hiring managers are now more likely to use email rather than telephone when digging beyond a transcript or resume, such individualized non-networked communication is still quite laborious. Meanwhile, the networked developments in this regard that have occurred (such as online job postings) appear to have made matters worse (by streamlining the application process and massively increasing the number of applications for a given job). This difficulty in finding qualified employees is expensive. Recent estimates suggest that US employers spend around \$150B a year in recruitment (Cappelli, 2015) and around \$70B for corporate training (Bersin, 2014).

Technically speaking, educational *credentials* include diplomas, degrees, and certificates, which attest to the completion of an educational or training program; in most contexts, *certification* refers to industry-sponsored or professional recognition, which may or may not include an educational program. In most credentialing contexts, grades earned from completing classes and degrees or certificates earned from completing programs are recorded on a *transcript*. The limitations of traditional credentials are well known and are partly rooted in concerns over security and fraud. This is not surprising given the value of degrees. While most K-12 systems have moved to digital transcripts, that transition has been much slower for colleges and universities. Despite concerted efforts by college registrars towards digitizing transcripts starting in the 1990s (Harris, Hannah, Stones, & Morley, 2011), the wholesale shift to digital transcripts did not really get underway until around 2013–2014 when the National Student Clearinghouse centralized these efforts and when a host of commercial enterprises got involved (Fain, 2014).

The credentialing expert Paul Gaston (2017) elaborated on how the problems summarized above impact all stakeholders in the educational system:

> *Learners* seeking programs corresponding to their interests and priorities hardly know where to start…. *Counselors* lack tools that should enable them to navigate the muddled assortment of credentials in order to provide informed and up-to-date guidance…. *Employers* often have little in the way of knowing what an applicant's credential means in terms of job-related competencies…. The *public* at large lacks a coherent understanding of what educational opportunities are available, what they require in time and expense, and what they mean in terms of opportunities for employment and further education. (p. 58)

Gaston's concerns are not new and have been discussed in scholarly and general media. These concerns have typically been raised within the context of broader critiques of educational systems and concerns over graduation rates and career readiness (e.g., the 1983 *A Nation at Risk* report from the US Department of Education and the 2006 report by Margaret Spelling's Commission on the Future of Higher Education). Arguably, these entrenched practices also obstruct efforts to overcome the inequities that plague contemporary education in the United States and most countries (e.g., Bowen & Bok, 1998; Carnoy, 2005; but see Olneck, 2015). In short, these problems have been developing for many years. There appears to be wide consensus that these problems are very real. But there appears to be less agreement about the most appropriate response. This chapter briefly summarizes some relatively comprehensive responses to these problems and then delves more deeply into one more specific response that might help many educational technology innovators address these problems in more specific contexts.

Comprehensive Responses to this Problem

Perhaps the most comprehensive response to the challenges summarized above is the efforts of the Lumina Foundation for Education. The foundation was established in 2004 with a goal of expanding post-secondary access and success. Lumina's *Project 2025* aims to boost the proportion of Americans holding post-secondary degrees (i.e., 2-year associate or 4-year bachelor) or high-quality certificates (i.e., sub-degree certificates that lead to gainful employment that include opportunity for career advancement). Specifically, Lumina aims to increase this proportion from around 45% to 60% by 2025 (Lumina Foundation, 2017b). This singular focus was motivated by a $780M endowment generated by the sale of the largest private student loan company in the United States (Lumina Foundation, 2007).

To help reach this goal, Lumina has led the development of the *Credential Engine* program, which is organized around an ambitious platform known as the *Credential Registry*. This platform aims to "continuously capture, connect, archive and share metadata about credentials, credentialing organizations, quality assurance organizations and competency frameworks, and additional metadata as needed to support an open applications marketplace" (Credential Engine). According to Gaston (2017), the Credential Engine will:

> allow students to locate, learn about and compare educational offerings. Counselors will have a convenient and reliable means of guiding their clients, and employers will gain a

> database that supports rigorous but equitable evaluation of applicants. The fully developed registry will finally make it possible to consider and compare not simply degrees and certificates, for example, but other credentials offered by both traditional and non-traditional providers. (p. 57)

The formal launch of the Credential Engine in December 2017 attracted significant media coverage (e.g., Fain, 2017; Johnson, 2017; Trumka & Dimon, 2017). The Credential Engine project has garnered additional support from several high-profile partners (e.g., JPMorgan Chase, Microsoft, The US Chamber of Commerce Foundation, and the AFL-CIO) and had nearly 400 participants as of December 2019 (Credential Engine, 2019). Of course, this effort faces a daunting challenge in the vast and ever-expanding pool of credentials. The organization had identified over 330,000 accredited credentials in the United States (Credential Engine, 2018). While it was reported to had only included 2,200 credentials in their *Credential Finder* application as of July 2018 (McKenzie, 2018a).

Competency-based education (CBE) is another response to the problem of measuring, credentialing, and accrediting achievement. CBE is nearly as comprehensive as the Credential Engine, but it has been around much longer. CBE has long been touted as a solution to the challenges of opaque and inflexible credentials. CBE follows rather directly from Bloom's early *mastery learning* model (Bloom, 1974). In CBE, learning outcomes are clearly established, usually in directly assessable terms, and those outcomes are then directly assessed. The important feature is that learners are given as much time as they need to meet those outcomes. Hence, CBE is usually "self-paced" and is often characterized as "personalized" learning. As summarized by Nodine (2016), CBE has been expanding "briskly" in the United States, with dozens of colleges and universities already employing it in some programs and hundreds more reportedly considering it. The most notable example is Western Governors University (WGU), which reported that it has awarded over 100,000 undergraduate and graduate degrees since 2001 and now enrolls nearly 100,000 students (Western Governors University, 2017). In a major innovation, WGU students pay a flat tuition fee per term and can complete as many courses as they wish during that time. A related, more radical response is *direct assessment.* This is where the entire course structure is abandoned and instead students progress through competencies based entirely on completing assessments (e.g., Klein-Collins, 2013).

Another relatively comprehensive response to the problems of measuring, credentialing, and accrediting achievement are *ePortfolios* (Eynon & Gambino, 2017). ePortfolio leader Trent Batson (2011) summarized the potential of this response in the inaugural issue of the *International Journal of ePortfolio*:

> The very technology that we have used to rupture the equilibrium of the educational enterprise is also well suited to *manage* the transformation of institutions to be consonant with the new structures we now live within. For example, learning occurring at all times in all situations, because it is beyond the reach of the teacher, cannot be captured and assessed well by traditional testing technologies, but *can be* captured, shared, revised, assessed, presented, reassessed, reflected upon, and integrated using electronic portfolios and the technologies that feed data to the portfolios. (p. 109)

Recent advances in learning analytics are making such functions more automated and less laborious for all stakeholders (e.g., van der Schaaf et al., 2017). Recent developments among commercial ePortfolio platforms are offering promising new ways to help connect students, counselors, educators, and employers around digital artifacts and evidence (e.g., from firms like Portfolium and Chalk & Wire).

Other relatively comprehensive responses include those using blockchain technology (e.g., the public ledgers behind Bitcoin currency; Hope, 2018; Badgechain, 2018), commercial efforts to digitize and centralize credentialing (e.g., from Parchment.com), and efforts by institutions to offer "extended" digital transcripts that contain hyperlinks to completed student work and other artifacts (e.g., Black, Leuba, Owczarek, Parks, & Shandy, 2016; Light, Chen, & Ittelson, 2012; Matthews-DeNatale, Blevins-Bohanan, Rothwell, & Wehlburg, 2017). It is also worth noting the various efforts to offer "stackable" credentials that can be more readily assembled (Ganzglass, 2014) and "connected" credentials (Ganzglass, Everhart, Hickey, Casilli, & Muramatsu, 2016) that have more in common with the more specific solution will be described next.

A Relatively Specific Response to this Problem: *Open Digital Badges*

For many members of the Association for Educational Communications and Technology and readers of this volume, connecting their efforts to the more comprehensive solutions described above probably feels daunting. This chapter aims to offer readers a more specific solution to the problems described. It is hoped that most educational technology innovators might be able to employ this solution quite readily while also defining a trajectory that is consistent with broader solutions. This more specific solution is known as *open digital badges*. While this solution is related to the more comprehensive responses above, open digital badges are a more specific technology that is organized around a relatively small number of standards.

As leading authority Sheryl Grant opened W*hat Counts as Learning* (2014), an open digital badge is "an image file embedded with information" (p. 1). The information contained in that image file is organized according to established standards, which increases the meaningfulness and value of this information. And because this information is web-enabled, it can include links to additional evidence (e.g., student writing) and information about how that evidence was obtained. Most importantly, the evidence and information in these new digital credentials can circulate in digital social networks where the evidence and information they contain can take on additional social value.

Open digital badges were introduced in 2011 in a major initiative of the John D. and Catherine T. MacArthur Foundation. These new credentials were introduced in part to offer new models for capturing and presenting evidence of the new forms of learning supported by MacArthur's *Digital Media and Learning* initiative. The

2011 launch of MacArthur's *Badges for Lifelong Learning* competition featured a speech by then Secretary of Education Arne Duncan, and the initiative was reported broadly in the popular media (e.g., Carey, 2012) and educational media (e.g., Young, 2012). The competition ultimately funded 29 groundbreaking efforts to develop digital badge systems across a diverse set of educational programs. MacArthur also funded teams at several non- profit and for-profit organizations to develop the *Open Badges Specifications*. These are the standards for the metadata (i.e., data about data) needed to ensure that these new credentials are *interoperable* (i.e., able to function on any platform that is compliant with those standards) and *extensible* (i.e., can function on any future platform as the standards are further refined to support additional functionality). The Open Badge Specifications 1.0 were initiated and revised within the Mozilla Foundation and were transferred as version 1.1 to the newly formed Open Badges Alliance in 2014. On January 1, 2017, the Open Badges Specifications 2.0 were released. Concurrently, Open Badges Alliance was dissolved in January 2017, and leadership of the specifications was transferred to the IMS Global Learning Consortium, the primary standard-setting organization for educational technologies.

Readers should note that while some have opted to use the term *microcredential*, there are some "digital badge" systems in operation outside of Open Badges Specifications. The label *Open Badges* specifically refers to digital credentials that adhere to the metadata standards that emerged from this initiative and are continuing to be refined. Many writings and this chapter use the labels Open Badges and digital badges interchangeably.

While it is not yet clear that digital badges will prevail over other specific solutions to the problems described above, digital badges have captured much of the attention of stakeholders seeking the address these problems. Arguably, digital badges represent a "transitional technology" (Bull, 2017) for whatever shape digital credentials ultimately take. It is notable that the Lumina Foundation has directly referenced digital badges in its discussion of "high-quality certificates" and that Lumina's venture capital subsidiary made a substantial investment into Credly, the leading commercial provider of digital badges (McNeal, 2016). Alongside the launch of the Credential Engine, Credly announced that the company was formally adopting the Credential Engine's Credential Transparency Description Language (CTDL; Kelly, 2017). In addition to Credly, digital badges have captured the attention and investment of other high-profile commercial entities (e.g., IBM, Pearson), leading educational technology innovators (e.g., Concentric Sky), badge-oriented startups (e.g., Discendium and BadgeList), and badge-oriented non-profits (e.g., DigitalMe and We Are Open CoOp). As of January 2020, there were at least 24 badge platforms that were committed to the Open Badges Specifications (Badge Wiki, n.d.).

To illustrate some of the potential of digital badges, discuss recent developments, and speculate about the future, this chapter will primarily draw on examples from a single badge system. This badge system was designed within an open online course on educational assessment that was offered from 2013 to 2016. It was designed to take advantage of key features of Open Badges while exploiting the potential synergy between badges and digital portfolios. This course and badge system were explicitly designed using contemporary sociocultural theories of knowing, learning, and motivation that provided significant impetus for the broader Digital Media and Learning initiative (Chaplin, 2014a, 2014b; Yowell & Smylie, 1999).

This chapter is organized around the three categories of badge functions introduced above: capturing, recognizing, and endorsing learning. These three categories overlap with the four categories of functions used to organize the prior study of the 30 Open Badge systems funded by MacArthur in 2012: *recognizing*, *assessing*, *motivating*, and *studying* learning (Hickey & Chartrand, 2019; Hickey & Willis, 2017; Hickey, Willis, & Quick, 2015); Hickey and Schenke (2019) provide an extended discussion of the motivational functions of digital badges, and these functions are only briefly considered in this chapter. Moreover, while exemplifying and exploring these three badge functions, this chapter will highlight relevant research and articles that have emerged from the Open Badges movement. This includes articles from a special issue (Ahn & Erickson, 2016) and two recent edited volumes (Ifenthaler, Bellin-Mularski, & Mah, 2016; Muilenburg & Berge, 2016). This chapter will also reference some of the many articles from mainstream media that have discussed digital badges, as well as several blog posts that have been widely read and cited. Readers should note that this chapter is not intended to serve as a comprehensive review of research on digital badges. Interested readers may wish to consult existing reviews, including West (2020), Grant and Shawgo (2013), Liyanagunawardena, Scalzavara, and Williams (2017), and Motheeram, Herselman, and Botha (2018).

Open Digital Badges in the Assessment BOOC

The digital badges used to illustrate the claims in this chapter were issued in an open online course offered by the first author from 2013 to 2016, with the assistance of the second author, and which the third author completed as a credentialed student in 2016. This open online course was based on an existing three-credit graduate-level course called *Assessment in Schools*. With the support of a grant from Google, a new open version of the course using Google's *CourseBuilder* platform was initiated. Because the approach and the technology were so new, and because some features were to be refined as the course was underway, the course was intended for hundreds of learners rather than the thousands of learners served by typical MOOCs. Hence, the course was called a *big* (rather than *massive*) *open online course* (BOOC), and registration in the first offering was capped at 600 participants.

The original Assessment in Schools course and the Assessment BOOC were both designed using an approach to learning and assessment that is based on contemporary situative theories of knowing, learning, and transfer (i.e., Greeno et al., 1998). This approach also draws on Engle and Conant's (2002) principles for *productive disciplinary engagement*; Engle, Nguyen, and Mendelson's (2011) principles for *expansive framing*; and Hickey and Zuiker's (2012) *multi- level assessment* framework. While a full articulation of these principles is beyond the scope of this chapter (but see Hickey, Andrews, & Chartrand, in review; Hickey & Rehak, 2013; Hickey, 2016), it is important to note what this means for the example badges discussed in this chapter. Embracing these principles meant that the Assessment BOOC focused primarily on engagement in relevant disciplinary *discourse* while focusing secondarily on more conventional competencies. While this distinction may be nuanced for some readers, it is important in appreciating the full potential of digital badges. As illustrated below, the contextualized nature of the evidence contained in digital badges makes it possible to offer badge viewers detailed information about the disciplinary discourse that the earner participated in while gaining conventional competencies. This gives the badge viewer crucial evidence regarding the settings (e.g., other courses, workplace settings, assessments) in which the earner should be able to use those competencies. With direct relevance for capturing elusive "twenty-first-century" competencies like collaboration and communication, this evidence can inform judgments about whether represented competencies are likely to transfer to new and different contexts relative to the contexts in which they were gained.

Examples Badges from the Assessment BOOC

Figure 1 presents the *Educational Assessment Expert* badge that was issued to a student named Len Adams who consented to sharing his credentials. The badge was earned for completing all three modules in the Assessment BOOC and scoring at least 80% on the final exam. Figure 2 displays the *Assessment Principles Expertise* badge that Len Adams earned for completing the first module in Assessment BOOC and scoring at least 80% on the module exam. Features from the badges in Figs. 1 and 2 will be used to illustrate and exemplify each of the three categories of badge functions in the sections that follow.

Mr. Adams was a graduate student at Indiana University and was in one of the small annual cohorts of students who completed the Assessment BOOC as a three-credit graduate course. Using the technical language associated with Open Badges Specifications, the Educational Assessment Expert *BadgeClass* (i.e., the generic version of the badge before it was issued) was created by adding code to the CourseBuilder program used to deliver the course. This code generated the content that was then inserted into the metadata fields each time an *Assertion* of that BadgeClass was issued to an individual (cf. Mozilla, n.d.-a). These metadata fields include *Badge Name* ("Educational Assessment Expert"), *Badge Earner* ("Len Adams"), *Badge Description* ("earned this badge by participating in…"), *Issuer* ("Educational Assessment BOOC," which was hyperlinked to the course homepage), *Criteria* ("The owner of this badge has demonstrated…"), and the *Evidence link* (the URL that links to information in the shaded box on the bottom half of the badge).

When the badge in Fig. 1 was issued by the Assessment BOOC (i.e., when this Assertion of this BadgeClass was generated), the information in each of these meta-

Fig. 1 Meta-badge earned for completing the Assessment BOOC

data fields was embedded in the image displayed in the upper right (a 400 × 400-pixel file in the PNG format). This process is called “baking” and takes advantage of the unique nature of the Java Script Object Notation (JSON) language (cf. Mozilla, n.d.-b). Any software platform that is consistent with the Open Badges Specifications can extract the data from the metadata fields and parse it accordingly. The most obvious parsing of the badge data concerns the way a website displays this information. But many other functions are already available that make badges searchable and shareable.

Fig. 2 Badge earned for completing one of three modules in the Assessment BOOC

Technically speaking, only the information in the top half of the badge in Fig. 1 is baked into the badge image. The information in the evidence fields (the bottom of the badge in Fig. 1) is generated from the evidence link each time the badges is displayed. While the information baked into these badges exists independently of the Assessment BOOC, the BOOC website and the information it contains must be maintained for the information that is displayed via the evidence URL.

From Measuring Achievement to Capturing Learning

The first set of potentially transformative functions associated with digital badges concerns *assessment*. Digital badges are not in and of themselves assessments, though they are sometimes characterized that way (e.g., Battista, 2014; Fanfarelli & McDaniel, 2017; Gibson, Coleman, & Irving, 2016; Põldoja & Laanpere, 2014; Reid, Paster, & Abramovich, 2015). Such characterizations of digital badges represent a broader and more colloquial use of the term "assessment" than is typical among assessment and measurement specialists. This terminology highlights the fact that digital badges are intended to display web-enabled evidence. While this is widely understood as evidence of *learning*, the term *learning* is also used with broad meaning among innovators and educators in the digital badges communities. In fact, digital badges can be and have been awarded for quite a range of things. Although badges are most commonly used to display evidence of proficiency or competency, they can be awarded for any accomplishment or activity, such as the completion of courses or programs, and for presenting at or attending professional events.[1]

When used as evidence of competence or proficiency, the practices for capturing the corresponding evidence are typically referred to as "educational assessments." This evidence can include scores on quizzes and tests, as well as essays, portfolios, completed student work, and other sorts of activities that have long been used by teachers for assigning grades. While this can also include more formal standardized achievement tests, such uses seem ill-conceived. This is because the scores on such tests typically "speak for themselves." It is worth noting that learner artifacts such as essays and portfolios can also "speak for themselves." But such artifacts have traditionally needed to be scored or graded by teachers or experts to be considered as evidence of competence or proficiency.

It is worth noting that some observers have conflated the use of digital badges with two other somewhat controversial trends in education. The first trend that some writers have conflated with digital badges is with CBE (e.g., Blackburn, Porto, & Thompson, 2016; Duncan, 2011; Olneck, 2015). As described above, CBE typically organizes learning around self-paced mastery of specific competencies and is often presented as an alternative to traditional expository lectures and a focus on "seat-time." Digital badges were quickly embraced by proponents of these approaches (which include the Lumina Foundation). The second trend to be conflated with badges is "gamification" of education via the use of competition, points, and leaderboards. Proponents of gamification were also quick to embrace digital badges (e.g., Buckingham, 2014; Mallon, 2013); some of the most influential critiques of

[1] It is worth noting that one common use of digital badges is for simply attending professional conferences. This is unfortunate as such badges almost never contain any evidence of learning. It is particularly unfortunate that such badges are often derisively labeled "participation" badges rather than "attendance" badges. This seems to have diminished the appreciation of evidence-rich badges in some professional communities and obscured the usefulness of badges as evidence of more meaningful participation in disciplinary practices such as those illustrated in this chapter.

digital badges focus on gamification badges (e.g., Jenkins, 2012; Resnick, 2012). It is beyond the scope of this chapter to discuss the full implications of these two trends. But the concern that many observers have raised with CBE and gamification (e.g., Bogost, 2015; Olneck, 2018; Silva, White, & Toch, 2015) is that they narrow education and learning to very specific measurable outcomes and undermine intrinsic motivation and learner autonomy. As argued in Hickey and Schenke (2019), badges need not be used in such a fashion, but even if they are used in such a manner, the wealth of information contained in well-designed badges is likely to counter some of the potential negative motivational consequences. More importantly, as described next, badges make it possible to capture broader forms of evidence of even broader types of "competency" than was previously possible.

Capturing Richer Evidence of Learning Contexts

As stated in the introduction, one of the novel functions of digital badges is capturing evidence regarding the context in which learning occurred. In the Assessment Practices badge in Fig. 2, the evidence field includes links for each of the four assignments that made up the Assessment Practices Module. Clicking on each of these links opens a "wikifolio" (student-generated ePortfolios; Hickey & Rehak, 2013) that the learner completed for each assignment. As shown in Figs. 3 and 4, this means that earners who choose to include this information in their badge can include their completed work from each assignment inside of their badge (in the form of layers of hyperlinks). This also means that viewers can "drill down" into the badge without getting lost; the information in the badge and the annotations on the hyperlinks help viewers know what they are clicking on and how it relates to the competencies asserted in the criteria of the badge.

For the interested viewer, even more information about the learning context for the badge in Fig. 2 can be accessed. A viewer can watch the YouTube videos that were included in the lessons and read a student's response to a unique "ranking" activity (Fig. 4) used to engage students with the ideas introduced in that video and elaborated in the course text.[2] The completed wikifolios in the badges also contain the actual instructions in the assignment that the learner was responding to (in black, revealed or hidden by clicking on the gray headers). The badge also includes a hyperlink to a course homepage, which offers additional information about the course. All of this offers the viewer of the badge immediate access to information about the context in which the learner completed their work. While this is ultimately a great deal of information, it is hyperlinked and annotated in ways that makes it available to those who want it without overwhelming others who do not need this information.

[2] Other assignments included extensive links to external open educational resources. This same approach is being used in other contexts that only rely on open educational resources. But the existing course was based on a textbook; university policy required that the Assessment BOOC be comparable if students were to be able to enroll in the same course for formal credit.

Fig. 3 First page of a completed "wikifolio" assignment in the Assessment BOOC

One of the widely acknowledged concerns about ePortfolios and extended credentials is that employers and admissions officials simply do not have time to sift through such information and make sense of it (Gallagher, 2016, pp. 114–116). While these are also valid concerns for digital badges, they are likely to be mitigated by several factors in the coming years. One such factor is simply novelty. Just as hiring and admissions officials are likely to dig more deeply when encountering potentially qualified applicants with credentials from unfamiliar institutions, these same officials are naturally going to have to dig deeper when encountering unfamiliar credentials. The difference with digital badges is that such investigation is likely to

Apply Types of Validity

Rank the three Types of Validity in order of relevance within your role and context (see Table 4.1, Popham, p. 102).

Add brief justifications for the Types of Validity that you chose as **most** relevant, **second most** relevant, and the **least** relevant, keeping in mind your role and context.

Content-related
Critereon-related
Construct-related

For many of my contexts the combination of experience level of staff and the amount of time we had with the learners make **content-related** most relevant. I could make the case that there were aspects of the projects that might involve other parts of validity, but in the end I think Content-related validity would still come out as the major player. It would be fun to consider what type of project with residents would allow us to consider Criterion-related or Construct-related as a larger part of our assessment. I think if we were to do something like a citizen-science project with residents that we might be able to get a better handle on their attitudes or other constructs around environmental stewardship. Such a program would have us meeting with the same residents over a period of time, and provide us opportunity to take a look at their behaviors to limit their impact upon water quality, or to consider their feelings about their own personal responsibility to keeping the waters of nearby bays clean.

The least relevant for us is **Criterion-related** validity. I think there has been some work for us to be able to begin comparing how participation in a citizen science project might predict their performance on an existing unrelated assessment, though I don't know of any other existing assessments or performance measures we could use to see how their scores correalate.

Big Ideas

Review the chapter, assignment, and your peers' wikifolios. Also, read the *Chapter Summary* and *What Teachers Need to Know*. **Come up with three big ideas about validity.** Number the ideas (1, 2, 3) and list them in order of importance to you, keeping in mind your role and context. Write a brief summary/explanation of each idea where you make it clear why they are relevant to you. These are the BIG ideas of the chapter not the more specific concepts listed above. You should refer to the *What Teachers Need to Know....* section and the summary at the end of the chapter. Try to insert your experience and academic domain into this discussion.

1) Validity describes the crucial step of making the best educational decisions based on inferences that come out of assessments. I previously assumed that what I now understand to be validity, was incorporated into reliability of assessment, and didn't realize I'd been making this assumption until reading this chapter. I think this goes to highlight for me how much biased reading can influence my understanding, and how difficult it can be to catch my own bias by myself.

2) Some people are inclined to compartmentalize educational assessment to be free of considering consequences. I could see this if we were designing hand tools, we would focus on creating the most appealing, balanced, effective hammer we could. And whether carpenters used the hammers on nails, or screws or hinge pins would be up to them to suit their needs. I think it's nearsighted to ignore the consequences of your work.

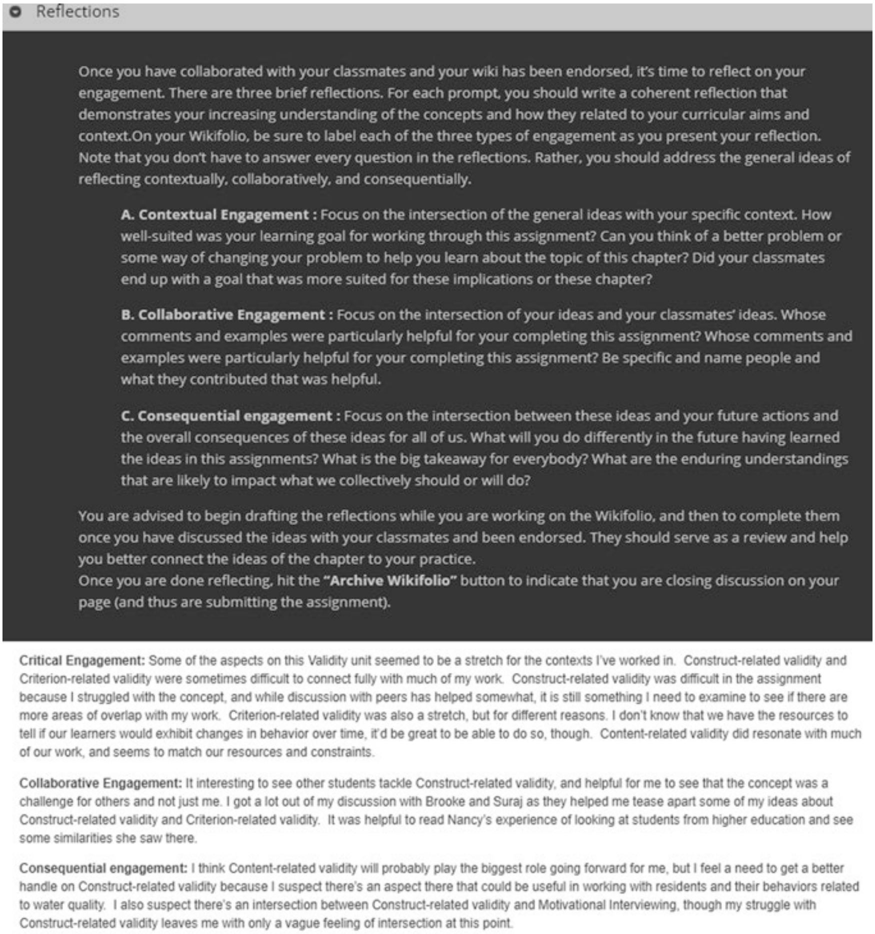
3) I feel like I need to do more reading about Construct-related validity, I struggled with describing it to my wife. I struggled with describing it here. Well, I struggled when getting to the nuts and bolts. The idea of considering how well an assessment matches up to a complex construction of knowledge makes sense. I struggle when trying to pin down how to recognize a constructed concept, and further how one might determine how an assessment might determine how well the scope of an assessment matches the construct. I also struggle in trying to see when a topic can be considered a constructed concept.

Fig. 4 Two completed engagement activities in a wikifolio assignment in the Assessment BOOC

be much easier thanks to the standardized format of Open Badges. A second factor is the more comprehensive set of solutions described in the introduction of this chapter. The meaningfulness of contextual information contained in badges or other microcredentials seems likely to find useful synergy when paired with information in competency management systems such Credential Engine and Parchment. Two additional factors are *learning pathways* and *endorsements*, both of which are described below.

Capturing Broader Evidence of Individual Learning

In addition to capturing rich information about the context of learning, digital badges are able to capture much broader evidence of individual competency than is otherwise practical. For example, Fig. 5 shows the reflection prompt and one example response. These were used to award credit for completing each assignment to the tuition-paying students who enrolled for course credit. To knowledgeable viewers, these reflections provide quite compelling evidence of disciplinary engagement, building on the notion of *consequential engagement* (Gresalfi, Barab, Siyahhan, & Christensen, 2009). In short, it is quite difficult to draft a coherent response to the reflection prompts without having meaningfully connected the disciplinary knowledge of the assignment with one's own disciplinary practices.



Reflections

Once you have collaborated with your classmates and your wiki has been endorsed, it's time to reflect on your engagement. There are three brief reflections. For each prompt, you should write a coherent reflection that demonstrates your increasing understanding of the concepts and how they related to your curricular aims and context.On your Wikifolio, be sure to label each of the three types of engagement as you present your reflection. Note that you don't have to answer every question in the reflections. Rather, you should address the general ideas of reflecting contextually, collaboratively, and consequentially.

A. Contextual Engagement : Focus on the intersection of the general ideas with your specific context. How well-suited was your learning goal for working through this assignment? Can you think of a better problem or some way of changing your problem to help you learn about the topic of this chapter? Did your classmates end up with a goal that was more suited for these implications or these chapter?

B. Collaborative Engagement : Focus on the intersection of your ideas and your classmates' ideas. Whose comments and examples were particularly helpful for your completing this assignment? Whose comments and examples were particularly helpful for your completing this assignment? Be specific and name people and what they contributed that was helpful.

C. Consequential engagement : Focus on the intersection between these ideas and your future actions and the overall consequences of these ideas for all of us. What will you do differently in the future having learned the ideas in this assignments? What is the big takeaway for everybody? What are the enduring understandings that are likely to impact what we collectively should or will do?

You are advised to begin drafting the reflections while you are working on the Wikifolio, and then to complete them once you have discussed the ideas with your classmates and been endorsed. They should serve as a review and help you better connect the ideas of the chapter to your practice.
Once you are done reflecting, hit the **"Archive Wikifolio"** button to indicate that you are closing discussion on your page (and thus are submitting the assignment).

Critical Engagement: Some of the aspects on this Validity unit seemed to be a stretch for the contexts I've worked in. Construct-related validity and Criterion-related validity were sometimes difficult to connect fully with much of my work. Construct-related validity was difficult in the assignment because I struggled with the concept, and while discussion with peers has helped somewhat, it is still something I need to examine to see if there are more areas of overlap with my work. Criterion-related validity was also a stretch, but for different reasons. I don't know that we have the resources to tell if our learners would exhibit changes in behavior over time, it'd be great to be able to do so, though. Content-related validity did resonate with much of our work, and seems to match our resources and constraints.

Collaborative Engagement: It interesting to see other students tackle Construct-related validity, and helpful for me to see that the concept was a challenge for others and not just me. I got a lot out of my discussion with Brooke and Suraj as they helped me tease apart some of my ideas about Construct-related validity and Criterion-related validity. It was helpful to read Nancy's experience of looking at students from higher education and see some similarities she saw there.

Consequential engagement: I think Content-related validity will probably play the biggest role going forward for me, but I feel a need to get a better handle on Construct-related validity because I suspect there's an aspect there that could be useful in working with residents and their behaviors related to water quality. I also suspect there's an intersection between Construct-related validity and Motivational Interviewing, though my struggle with Construct-related validity leaves me with only a vague feeling of intersection at this point.

Fig. 5 Reflections used to summatively assess engagement

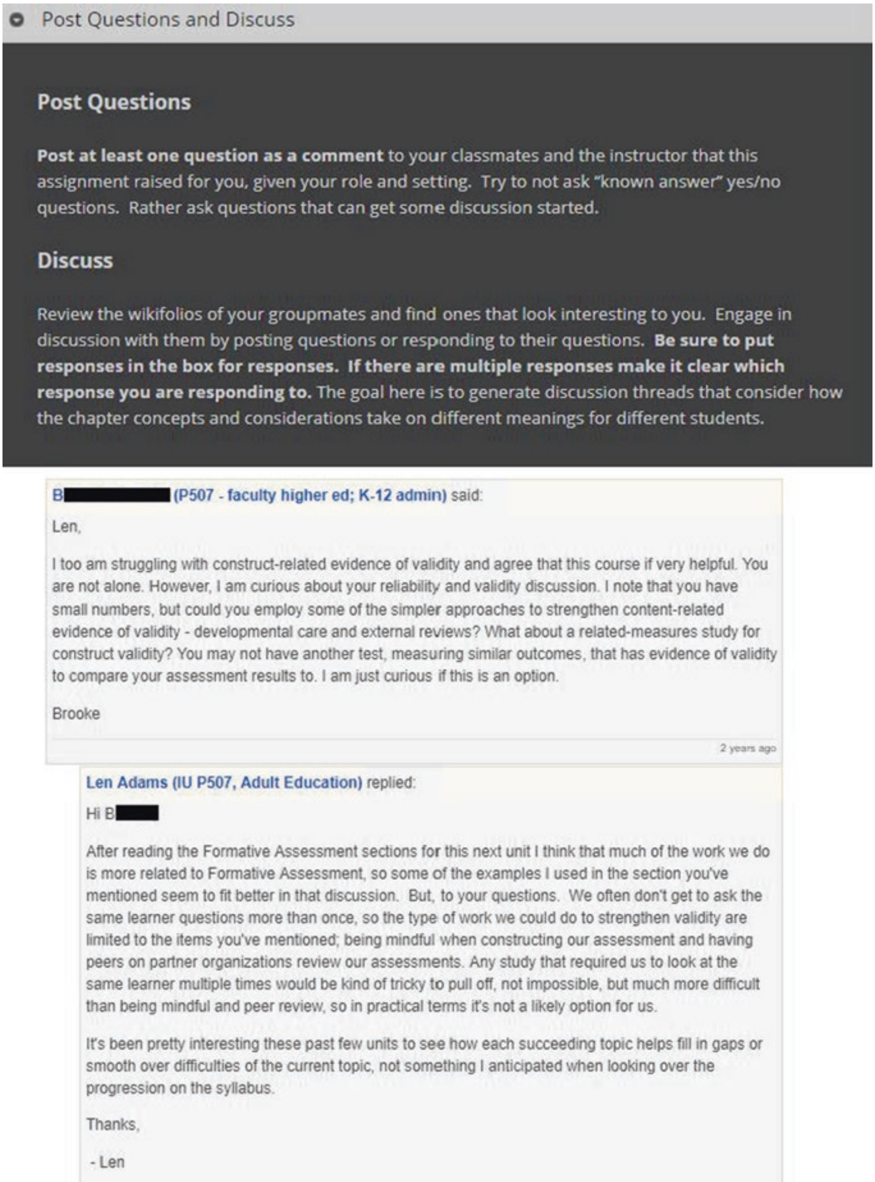
But it is also worth noting the badge in Fig. 1 indicates that the earner scored over 80% on the module exam, while the badge in Fig. 2 states that the earner scored over 80% on the final exam. These were rigorous exams that were also time-limited and featured many “best answer” items that were difficult to look up in the allocated time. The expectation here was that the instructions in the assignments, student responses to the assignments, the reflections, and the exam scores together provide compelling evidence of proficiency. Arguably, this wealth of information provides an effective response to the problem of CAMEO cheating (*Copying Answers from Multiple Existences Online*; described by Northcutt, Ho, & Chuang, 2016) that plagues MOOCs. Such widespread cheating can undermines the validity of claims based only on test scores in settings where learners have the option of logging on to the course with multiple accounts or accessing videos or other resources while taking tests.

In the case of the Assessment BOOC, earners who took the exam but failed to score at least 80% earn a badge that only indicated that the exam was *submitted* but would not reveal the sub-criterion score that was earned. In situations where the stakes or the marketplace value of the badge were very high, such nuanced information could be quite meaningful. Because the earners choose to claim and share badges as they wish, this approach offers a balance between open sharing and the genuine concerns over learner’s privacy. As elaborated below, this seemingly- subtle nuance presents badge designers with important decisions. The ability to issue badges that do *not* include a potential form of evidence further broadens the potential range of proficiency that can be captured.

Capturing Evidence of Social Learning

One of the biggest shortcomings of conventional individual assessments and tests is that they are ill-suited for capturing evidence of what many characterize as “social” learning and what learning scientists typically characterize as productive forms of disciplinary discourse (Greeno & Gresalfi, 2008). An important function of digital badges that seems to have been overlooked by some early adopters is the ability to capture evidence of what Greeno et al. (1998) labeled *engaged participation*. As introduced above, the prior Assessment in Schools course had been refined extensively to support these forms of learning. These refinements resulted in a number of course features for helping students publicly (within the course) engage with and discuss complex course concepts with professional peers (described in Hickey & Rehak, 2013; Hickey & Uttamchandani, 2017). Significant effort was invested in designing and refining the BOOC and its badges to automate some of these features and capture evidence of this learning.

This focus on engaged participation in the Assessment BOOC is partly captured by the collaboration prompt and example reflection shown in Fig. 4. Other significant features in this regard are (a) that the first competency listed on both of the badges in Figs. 1 and 2 is *Productively discuss___ with professional peers*, (b) that the badges assert that this claim is *Evidenced by the number and nature of comments on the individual wikifolios*, (c) that the number of comments on each wikifolio is summarized on the badge in Fig. 2, and (d) that the actual threaded comments posted to each wikifolio are still attached to each wikifolio when accessed via the evidence link in the badges (Figs. 6 and 7). A careful read of the discussion threads



Post Questions and Discuss

Post Questions

Post at least one question as a comment to your classmates and the instructor that this assignment raised for you, given your role and setting. Try to not ask "known answer" yes/no questions. Rather ask questions that can get some discussion started.

Discuss

Review the wikifolios of your groupmates and find ones that look interesting to you. Engage in discussion with them by posting questions or responding to their questions. **Be sure to put responses in the box for responses. If there are multiple responses make it clear which response you are responding to.** The goal here is to generate discussion threads that consider how the chapter concepts and considerations take on different meanings for different students.

B[redacted] (P507 - faculty higher ed; K-12 admin) said:

Len,

I too am struggling with construct-related evidence of validity and agree that this course if very helpful. You are not alone. However, I am curious about your reliability and validity discussion. I note that you have small numbers, but could you employ some of the simpler approaches to strengthen content-related evidence of validity - developmental care and external reviews? What about a related-measures study for construct validity? You may not have another test, measuring similar outcomes, that has evidence of validity to compare your assessment results to. I am just curious if this is an option.

Brooke

2 years ago

Len Adams (IU P507, Adult Education) replied:

Hi B[redacted]

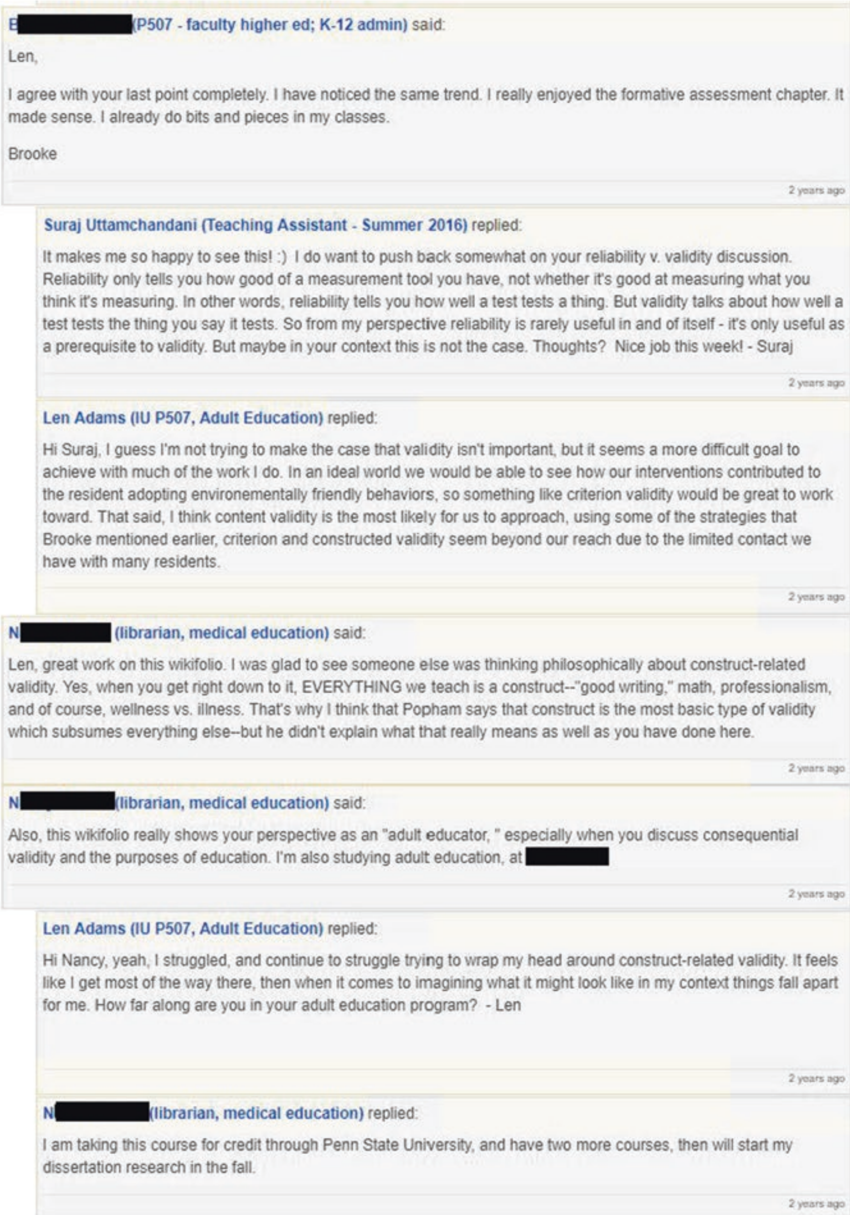
After reading the Formative Assessment sections for this next unit I think that much of the work we do is more related to Formative Assessment, so some of the examples I used in the section you've mentioned seem to fit better in that discussion. But, to your questions. We often don't get to ask the same learner questions more than once, so the type of work we could do to strengthen validity are limited to the items you've mentioned; being mindful when constructing our assessment and having peers on partner organizations review our assessments. Any study that required us to look at the same learner multiple times would be kind of tricky to pull off, not impossible, but much more difficult than being mindful and peer review, so in practical terms it's not a likely option for us.

It's been pretty interesting these past few units to see how each succeeding topic helps fill in gaps or smooth over difficulties of the current topic, not something I anticipated when looking over the progression on the syllabus.

Thanks,

- Len

Fig. 6 Instructions and initial exchange for discussing wikifolio with peers



B[redacted](P507 - faculty higher ed; K-12 admin) said:

Len,

I agree with your last point completely. I have noticed the same trend. I really enjoyed the formative assessment chapter. It made sense. I already do bits and pieces in my classes.

Brooke

2 years ago

Suraj Uttamchandani (Teaching Assistant - Summer 2016) replied:

It makes me so happy to see this! :) I do want to push back somewhat on your reliability v. validity discussion. Reliability only tells you how good of a measurement tool you have, not whether it's good at measuring what you think it's measuring. In other words, reliability tells you how well a test tests a thing. But validity talks about how well a test tests the thing you say it tests. So from my perspective reliability is rarely useful in and of itself - it's only useful as a prerequisite to validity. But maybe in your context this is not the case. Thoughts? Nice job this week! - Suraj

2 years ago

Len Adams (IU P507, Adult Education) replied:

Hi Suraj, I guess I'm not trying to make the case that validity isn't important, but it seems a more difficult goal to achieve with much of the work I do. In an ideal world we would be able to see how our interventions contributed to the resident adopting environementally friendly behaviors, so something like criterion validity would be great to work toward. That said, I think content validity is the most likely for us to approach, using some of the strategies that Brooke mentioned earlier, criterion and constructed validity seem beyond our reach due to the limited contact we have with many residents.

2 years ago

N[redacted] (librarian, medical education) said:

Len, great work on this wikifolio. I was glad to see someone else was thinking philosophically about construct-related validity. Yes, when you get right down to it, EVERYTHING we teach is a construct--"good writing," math, professionalism, and of course, wellness vs. illness. That's why I think that Popham says that construct is the most basic type of validity which subsumes everything else--but he didn't explain what that really means as well as you have done here.

2 years ago

N[redacted](librarian, medical education) said:

Also, this wikifolio really shows your perspective as an "adult educator, " especially when you discuss consequential validity and the purposes of education. I'm also studying adult education, at [redacted]

2 years ago

Len Adams (IU P507, Adult Education) replied:

Hi Nancy, yeah, I struggled, and continue to struggle trying to wrap my head around construct-related validity. It feels like I get most of the way there, then when it comes to imagining what it might look like in my context things fall apart for me. How far along are you in your adult education program? - Len

2 years ago

N[redacted](librarian, medical education) replied:

I am taking this course for credit through Penn State University, and have two more courses, then will start my dissertation research in the fall.

2 years ago

Fig. 7 Remainder of discussion thread in Figs. 6 and 7 reveals compelling evidence that Len Adams did indeed participate in a very productive discussion of a particularly complex topic (i.e., validity) and did so with professional peers and the teaching assistant. The threads present multiple connections to prior and future contexts of practice, with a subsequent chapter in the textbook, and between other BOOC participants who were engaging in similar disciplinary practices. By capturing and highlighting this engagement, the BOOC badges encouraged and rewarded learners for making numerous connections to multiple contexts of practice. Such *intercontextuality* is the hallmark of what Engle and colleagues (2011) labeled *expansive framing*. Expansive framing pushes students to connect course knowledge with learning and practice contexts beyond both the assignment and the course. This positions students as authors who hold each other accountable for what they say. Empirical studies have shown that expansive framing supports generative forms of learning that are likely to transfer readily to subsequent learning and practice contexts (Engle, 2006; Engle et al., 2011; Engle & Faux, 2006). This function of digital badges offers educators a more promising means of holding students accountable for engaged participation, compared to problematic methods such as grading posts in discussion forums (as described in Pollak, 2017).

It is worth noting that while the BOOC assignments instructed learners to post at least one question to their peers and to comment on the work of at least three peers, doing so was not technically required, and there was no accountability for choosing not to do so. While students were informed that discussing concepts with peers would help prepare them for exams, it seems likely that that ability to display evidence of this engagement in their badges was a significant motivator for doing so. Only a handful of students did not engage in discussions at all, though logfiles revealed evidence that most of these students still examined the work of their peers while working on their posts.

A relevant source of empirical evidence concerning this function of digital badges comes from the aforementioned study of the digital badge development efforts funded in 2012 (Hickey & Chartrand, 2019; Hickey & Willis, 2017). Of the 29 proposed badge systems, the subset of efforts that were most likely to have an established badge-based learning ecosystem three years later focused on “participation” badges awarded for more social forms of learning. Two particularly successful efforts, *Supporter to Reporter* from DigitalMe and *Student Reporting Lab* badges from the *News Hour* show from the Public Broadcasting Service, awarded badges for digital media productions by youth, which lent themselves particularly well to such engagement and learning. The other proposed systems that focused more directly on individual learning were less successful. More specifically, none of the proposals to develop competency-based badge systems (i.e., awarded for demonstration of specific competencies) and only a few of the proposals to develop “completion-based” badge systems (i.e., for completing projects or investigations) resulted in ecosystems that were thriving three years later. Highlighting the value of the peer-supported “crowdsourced” assessment of participation described above, the primary challenge that thwarted these other projects was implementing ambitious plans for having teachers and/or outside experts assess learners’ portfolios and projects for evidence of competency and/or completeness. Further discussion of this issue is presented below in the context of endorsement of learning.

Capturing Evidence from Learning Pathways

Another function of digital badges is that they can be used to define and then capture evidence from learning *pathways*. The three module badges contained in the badge in Fig. 1 provide an example of such a pathway. While the idea of learning pathways has been discussed outside of the context of badges (e.g., Bell, Bricker, Reeve, Zimmerman, & Tzou, 2013), the idea takes on new meaning when the pathways are defined by badges that can contain additional web-enabled evidence of learning, and such badges can then be embedded in a larger "meta-badge."

As elaborated by Gibson et al. (2016), such learning pathways serve important new educational functions. For example, when earners share such badges over social networks, they offer pathways *into* learning by helping other potential learners readily envision what the course entails. Arrays of badges can also form useful pathways *during* learning, by capturing evidence of accomplishment of smaller goals that are nonetheless meaningful. Such pathways can motivate continued engagement and can provide recognition of these smaller goals. As in most MOOCs, most of the open learners did not complete the entire Assessment BOOC. While the completion rates were better than typical for MOOCs, the assignments were more time-intensive than in a typical MOOC. Significantly, most of the open learners who completed the first assignment went on to complete the four assignments needed to earn the Assessment Practices badge. Many of these learners were practicing educators who were looking for immediately useful learning in their own classrooms while also earning the continuing education credits needed to maintain licensure. Several of these teachers reported that the evidence in their badge was indeed adequate evidence for their supervisors of the actual hours that they had invested (reportedly around 20 hours).

Broader functions of badge pathways are nicely illustrated in a sophisticated badge system funded by the National Science Foundation at Seattle's Pacific Science Center (Davis, 2015). This system features a *Career Ladder* pathway organized around badges for interns ("youth science entrepreneurs") taking on increasingly sophisticated professional roles during paid internships at the center. As articulated by Nate Otto (2017; who designed the *Badgr* platform used to implement this other badge pathway), this pathway functions to support *wayfinding* where the interns see what they have done and what they need to do next, *understanding progress* where learners and educators can see the progress of other students in the program, and engage in *sharing achievement*. This latter achievement sharing function serves "not as a flat list of badge awards … but as a view of their progress embedded in the story of their progress through four levels of career ladders and three levels of each customer service skill" (Otto, 2017, Case Study section, para. 7).

The Pacific Science Center's badge system highlights one of the most far-reaching implications of learning pathways for capturing evidence of learning.

Interns were able to customize parts of the pathway by choosing which badges they wanted to earn at various points along the pathway. Proponents envision such larger badge pathways as allowing multiple routes to success, the inclusion of self-selected evidence, and capturing learning over longer timescales. Gibson et al. (2016) characterized such "lifelong pathways of learning" as a "signpost of engagement, learning, and achievement continues as the learner's journey moves past formal education into lifelong learning" (p. 123).

From Credentialing Graduates to Recognizing Learning

While closely related to the capturing functions described above, digital badges also serve distinct functions associated with the *recognition* of learning. Whereas capturing refers to obtaining evidence of learning, recognition functions correspond more directly to credentialing practices associated with giving grades for completing assignments and courses and awarding certificates and degrees for completing programs of study. As described in a crucial foundational document for digital badges from Peer 2 Peer University:

> *Recognition* is the acknowledgment of achievements and conveys approval by the person, group, or organization doing the recognizing. Recognition can be implicit (for example, use of the original work by another author/citation) or explicit (for example, in the form of gradually increasing responsibilities within a community, by attribution of contributions, or via a badge or other tangible form that communicates recognition). Recognition can be provided by members of a community itself, or by outsiders (Schmidt, Geith, Håklev, & Thierstein, 2009, p. 2).

These functions are particularly relevant when considering the potential of digital badges to catalyze broader transformations of educational ecosystems. This is because of the broader social and cultural function that credentials serve. The sociologist David Bills (2003) summarized seven different theories that have been advanced to explain the functions of credentials and the recognition of learning, including *human capital*, *screening & filtering*, *signaling*, *control*, *cultural capital*, *institutional*, and *credentialism*. It is beyond the scope of the present chapter to explore the implications of digital badges from each of the theories. However, it appears that the following recognition functions can be considered apart from the capturing functions described above and the endorsement functions described later, making it possible to more systematically consider their interactions with each other.

Recognizing Learning Openly

While conventional transcripts are generally private documents, a great deal of the effort associated with transcripts concerns *security*. This makes sense given the value of degrees and the potential consequences of documented success and failure in school. Not surprisingly then, some of the criticisms and concerns about digital badges have concerned their open approach to recognition and the corresponding lack of traditional methods for securing credentials (e.g., Geisel, 2015; Mathews, 2016). Because of this and because open recognition is still emerging, its transformative potential is not readily obvious to many observers.

Part of the transformative potential of open recognition is implicitly rooted in the corresponding potential of open learning more broadly. For example, Bonk (2009) points out that:

> While learning is being opened up to masses of people that previously did not have access, it is also opening up in new forms to those who already did. Learners of all ages are increasingly engaged in formal as well as informal learning, which is highly mobile and often ubiquitous. (2009, p. 49; see also Wiley & Gurrell, 2009)

The transformative potential of open recognition of learning was explicitly recognized in the 2016 *Bologna Open Recognition Declaration*. Included in this declaration was the statement that:

> Open Badges, the open standard for the recognition of learning achievements has proved the power of a simple, affordable, resilient and trustworthy technology to create an open recognition ecosystem working across countries, educational sectors, work, social environments and technologies. Open Badges have demonstrated that we have the means and the opportunity to put an end to the disparities of the recognition landscape. Connecting and informing competency frameworks, they become the building blocks of an open architecture for the recognition of lifelong and life wide learning achievements. They create the conditions for individuals to be in control of their own recognition, to establish their identity and agency, whether formally (within institutions) or informally (across communities). (Open Recognition Alliance, 2016)

The title of this declaration reflects the relevance of badges to an ambitious effort to standardize higher education credentials across Europe known as the *Bologna Process* (the resolution was introduced at a conference in Bologna, Italy). While the success of the Bologna Process was widely debated (e.g., Keeling, 2006), its reliance on conventional credentials resulted in a massive and complex new bureaucracy for formally recognizing educational credentials across European borders (Kettunen & Kantola, 2006). The Bologna Declaration and the Open Recognition Alliance envision a future where open recognition via digital badges supplements and eventually supplants a significant part of this existing bureaucracy. Doing so is expected to support broader transformations towards more open models of learning and education advanced by pioneers associated with Peer 2 Peer University, Mozilla, and the MacArthur Foundation's Digital Media and Learning initiative (Ravet, 2014).

The anthropological notion of *boundary objects* is helpful for understanding open recognition of learning. Boundary objects are produced in one context but are used in other contexts by other people, sometimes for very different purposes. This is because they are:

> both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use and become strongly structured in individual-site use. They may be abstract or concrete. They have different meanings in different social worlds, but their structure is common enough to more than one world to make them recognizable, a means of

> translation. The creation and management of boundary objects is key in developing and maintaining coherence across intersecting social worlds. (Star & Griesemer, 1989, p. 412)

Several authors who have already used boundary objects consider the potential of open recognition of learning with digital badges (Davis & Singh, 2015; Elkordy, 2016; Rughinis, 2013); Halavais (2012) characterized digital badges as an "almost ideal" boundary object because of their potential for "translating practices and social capital of one community to another dissimilar community" (p. 368).

Consider, for example, that the same badges that an instructor might issue in a course can also be shared by the earner on their Facebook or LinkedIn account. The instructor might "stack" that badge into a learning management system (by recording the URL of the badge) and associate it with a grade and private feedback (information which must be assigned strict privacy protections). But that exact same badge might also circulate widely and publicly in social networks where it gains "likes" and comments, which give the badge further and different meanings. As elaborated below, a badge issuer might make it possible or even necessary for a badge to be endorsed by a qualified third party who confirms that the information in the badge is valid evidence of the claims made by the badge.

Of course, conventional grades and transcripts also function as boundary objects. Some assessment researchers have used this notion to consider how evidence from conventional assessments travel (or fail to travel) across contexts (Hickey, Honeyford, Clinton, & McWilliams, 2010; Moss, Girard, & Greeno, 2008; Moss, Girard, & Haniford, 2006; Nolen, Horn, Ward, & Childers, 2011). But the web-enabled nature of badges and the additional information about the context in which badge evidence was obtained allows badges to traverse context more readily *and* meaningfully. In *What Counts as Learning*, Grant (2014) pointed out that:

> In our current system, a limited number of people see the criteria or evidence for how grades and degrees were earned. Badges, however, are transparent and information-rich. Everything is bundled into one click, allowing us to see what someone did to earn the credential, including a link to the evidence behind the learning, maybe a testimonial from the instructor, comments from peers, or even an endorsement from an expert. (p. 7)

The Assessment BOOC provides a nice illustration of the contrast between traditional credentials and open recognition using digital badges. To reiterate, each offering of the BOOC included a small cohort of students who completed the course as part of their graduate degrees at Indiana University. On each weekly wikifolio, the credential students were all required to complete several additional activities and the reflection described above (all of which were presented as *Optional Expertise Elements* to the non-credit open learners). In addition to open public feedback (in the form of comments) from the instructor or teaching assistant on each activity, these credential students were also assigned points towards their grade each week and provided private feedback via the grade book in a conventional learning management system. Additionally, the credential students' scores on the module exams and final exam were copied over from the Course Builder site to the LMS where they were used to calculate final grades in the course. The course grade made its way onto each student's program of studies document used to track course completion with the requirements of the degree program and into the Student Information System at the registrar's office. To share the information on their transcript, the student must go to the registrar's website and pay $10 to request a secure PDF that can be digitally verified for 45 days or pay $15 to have a watermarked copy mailed to an address. Each of these additional activities consumed some fraction of the tuition each student paid (roughly $1,500 for the three-credit course). Nonetheless, the only information that appeared on the transcript was the name of the course, the semester completed, the grade earned, and the number of credits.

In contrast, those badges in the Assessment BOOC required far less effort and infrastructure. As elaborated below, most of the value of the formal grade in the Assessment BOOC and the degree it contributed to concerned reputation: Indiana University's Instructional Systems Technology program where Len Adams was enrolled is one of the most highly regarded programs in the world. Nonetheless, the effort and cost associated with the information-poor conventional credentials stand in sharp contrast to the information-rich badge displayed in Figs. 1 and 2.

Notably, several graduate students at other universities completed the Assessment BOOC while enrolling for independent study credits at their home institutions. In these cases, the Educational Assessment Expertise badges were reportedly accepted as adequate evidence for awarding those credits. In other words, the open recognition of learning in the Assessment BOOC allowed these other students to bypass the entire transcript-sending process. In this case, the course homepage, which was linked to the badge, clearly displayed the different expectations for the credential students than for the non-credential students, allowing a reviewer of this "high-stakes" instance of the badge to readily determine whether the earner did in fact complete the equivalent of the for-credit course.

Recognizing a Broader Range of Competencies

Whereas the transformative potential of open recognition is still emerging, the ability to recognize a broader range of competencies is a more obvious transformative potential for digital badges. One of the foundational documents of the MacArthur initiative asserted that:

> Badges can play a critical role in the connected learning ecology by acting as a bridge between contexts and making these alternative learning channels and types of learning more viable, portable and impactful. Badges can be awarded for a potentially limitless set of individual skills regardless of where each skill is developed, and the collection of badges can serve as a virtual resume of competencies and qualities for key stakeholders such as peers, schools or potential employers. (Peer 2 Peer University and the Mozilla Foundation, 2011, p. 4)

That paper went on to describe the range of ways in which the newly-envisioned open digital badges could provide entirely new ways of signaling a broader range of competencies. As many others have subsequently observed, this broader range includes the so-called "twenty-first-century" competencies associated with networked digital learning environments (as described in Brown & Adler, 2008). While competencies in collaboration, communication, and critical thinking are increasingly crucial in contemporary schools and workplaces, they are notoriously difficult to assess and even harder to measure in standardized ways (Stiggins, 1995). This is because these competencies are highly contextual. In contrast to more easily measured disciplinary *knowledge* (what disciplinary experts "know" independent of context), such competencies are better understood as disciplinary *practices* (what experts "do" in specific disciplinary contexts, where their expertise is typically recognized). Because badges are well-suited for displaying information about what an individual did to earn the badge and the context in which it was done, they have obvious potential for recognizing these elusive-but-important competencies.

Of course, the ability to recognize broader competencies has previously been ascribed to ePortfolios (e.g., Gibson & Barrett, 2002) and well before that within the expansion of portfolio assessment in the early 1990s (e.g., Paulson, Paulson, & Meyer, 1991). Unfortunately, objective studies have shown that portfolio-based assessment can fail to accomplish these functions (Delandshere & Petrosky, 1998; Lam, 2017; Stecher, 1998). As pointed out by measurement theorists (i.e., Haertel, 1999; Messick, 1995), moving away from standardized tests to recognizing learning with portfolios of work (or extended performance tasks) represents a fundamental shift away from *construct-driven* assessment and towards *task-driven* assessment. This is crucial because it impacts the generalizability of evidence:

> With construct-driven assessment, it is assumed that the items given are a sample from some larger domain of items that could have been chosen instead. This assumption warrants the statistical inference from an examinee's performance on the test to predicted performance across the hypothetical item domain the test represents. With portfolios, however, students participate in selecting the work samples presented. Each portfolio entry may be a worthy demonstration of proficiency, but any statistical inference to a larger domain of potential portfolio entries is problematical. (Haertel, 1999, p. 664)

In other words, from a conventional measurement perspective, moving away from objective assessments of constructs (typically using tests) and towards more subjective assessment of tasks (using performances or portfolios) may *narrow* the range of competencies that can be recognized. Observers argue that failure to recognize this challenge for task-driven assessment (along with related challenges of increased cost and decreased reliability) led to the collapse of performance-based and portfolio-based K-12 assessment reforms in the United States in the mid-1990s (e.g., Koretz, 1998; Koretz, Stecher, Klein, & McCaffrey, 1994). These same issues contribute to continued resistance to ePortfolios on many college campus (Meyer & Latham, 2008; Swan, 2009).

In *The Future of University Credentials*, Sean Gallagher (2016) summarizes the evidence that ePortfolios have yet to significantly impact the practices of most admissions and hiring officials. He asserted such recognition practices must "align with the realities—including the limitations—of employers' existing business practices, systems, and cultures" and that "unless it is streamlined or parsed in some form, an ePortfolio is just more extraneous information for employers to cognitively process—and technologically process in their application system" (p. 115). Notably, Gallagher is only slightly more optimistic about the potential impact of digital badges, as indicated by the subtitle of that section of his book: *Interesting Potential* *but Little Evidence of Uptake or Impact*. After reviewing some of the most promising examples and the evidence of limited impact, Gallagher (2016) concludes that:

> Badges can certainly be useful add-ons to degrees, particularly as part of competency-based education frameworks, but no evidence yet exists that badges will be able to replace or truly complete with degrees in job attainment in the ways that many advocates of badging claim. (p. 147)

The obvious question here with whether the combination of ePortfolios and digital badges has the potential to overcome the challenges associated with recognizing a broader range of competencies.

The potential for combining ePortfolios and badges to recognize broader forms of learning has indeed been explored by badge proponents and designers (e.g., Gibson, Ostashewski, Flintoff, Grant, & Knight, 2015; Hickey & Chartrand, 2019; Kehoe & Goudzwaard, 2015). At minimum, digital badges are more interoperable and extensible than typical (i.e., proprietary) ePortfolios platforms. Technologically at least, this allows badges (and the links to ePortfolios that they contain) to travel more readily and meaningfully across contexts than the portfolios themselves. A particularly noteworthy recent development is the formal introduction of open digital badges *and* competency frameworks into leading ePortfolio platforms (including *Portfolium* and *Chalk & Wire*). When combined with ePortfolios, digital badges become the boundary objects that make it easier to interpret the evidence they contain while simultaneously allowing that evidence to travel more readily and meaningfully. The recent acquisition of Portfolium Inc. by Instructure Inc. (publisher of the popular Canvas LMS) is a noteworthy development in this regard.

The synergy between ePortfolios and badges is particularly well-suited for recognizing elusive twenty-first-century competencies. For example, as introduced above, the Assessment BOOC allowed badge earners to include the threaded discussions that they engaged in during their weekly assignments, and much of the course was organized around fostering productive forms of disciplinary engagement around those discussions. This made it possible to include *productively discuss* as one of the competencies that the badges recognized. Additionally, this made it plausible that the badges would be received, shared, and perceived as valid evidence of these more discursive and contextualized competencies. Arguably, gathering such evidence would have otherwise required more laborious interpretive methods that yield evidence that requires disciplinary and methodological expertise to interpret and evaluate. This is just one example of the many ways that the synergy between badges and ePortfolios can allow recognition of broader competencies that have mostly eluded traditional credentialing practices.

Recognizing a Broader Range of Proficiency of a Competency

Traditional credentials are hard-pressed to recognize the range of proficiency for a given set of competencies beyond grades, grade point averages, and honors achievements. For the same reasons that badges can recognize a broader range of competencies, badges can also recognize a broader range of proficiency for a specific competency. In considering this function, Gallagher (2016) suggests that the ability to recognize a broader range of competency is currently constraining the uptake of digital badges:

> There is also the question of when a given amount of learning or skill rises to the level of a badge, or when a badges or series of badges graduates to a certificate or something else. With badges issued for everything from attending an event to completing a single hourlong class, many organizations issuing badges are careful to note that the efforts or platforms focus on resume-worthy accomplishments, *and where that line lies is an open question and very important in the potential utility of badges as a signal or screening device in the employer hiring process*. (p. 147, emphasis added)

West and Randall (2016) explore this issue further in their arguments against issuing what they describe as "lightweight" badges in favor of "heavyweight" badges that are based on rigorous assessments of relatively high levels of proficiency. While this position seems to overlook the potential of the learning pathways described above, it is certainly an issue that badge designers and the larger Open Badges community need to discuss (see also Casilli, 2014).

Returning to the BOOC example, the module badges and the learning pathways discussed above provide an illustration of how digital badges facilitate the recognition of a broader range of competency. This function was also exemplified by way that earning a passing score on the final exam transformed the *Educational Assessment* badge into the *Educational Assessment Expertise* badge. It is also worth noting that some of the most successful badge systems uncovered in the 30 projects funded in the 2012 Badges for Lifelong Learning initiative offered a lightweight introductory badge that introduced learners to their programs and "unlocked" the subsequent heavyweight badges (Hickey & Willis, 2017).

This potential of digital badges is particularly relevant when recognizing contextual twenty-first-century competencies. This is because an individual's level of proficiency with these competencies is ultimately recognized in terms of the nature and number of contexts in which such competencies are demonstrated. Consider, for example, the competency *productively discuss classroom assessment principles with professional peers* recognized by the Assessment Principles Expertise badge in Fig. 2. Highlighting the subjective nature of any evidence of such a competency, the badge criteria indicate that this competency is *evidenced by the number and nature of comments on the individual wikifolios*.

Some viewers of the badge in Fig. 2 would presumably find the number of comments on each wikifolio sufficient evidence of this competency; others might explore those discussions by clicking on the adjacent link. A measurement expert might be particularly interested in the discussion of validity shown in Figs. 6 and 7 because they know that it is a particularly challenging topic that takes on different meaning in different measurement contexts. In retrospect, the evidence contained in these BOOC badges made it possible to have "variable criterion" for earning the badges by using the criterion: *to the extent that the evidence linked below contains threaded discussions with professional peers, this badge is evidence of the earner's proficiency at doing so*. While such a criterion might seem ponderous given the concerns that Gallagher (2016) raised about digital badges, the criterion takes on special significance in the context of the endorsement functions described below.

Recognizing Opportunities for Learning

Another important function of digital badges is helping *potential* learners recognize opportunities to learn. This function is nicely highlighted in the MacArthur-funded *Chicago Summer of Learning* in 2013, the subsequent nationwide *Cities of Leaning* initiative, and the ongoing *Project LRNG*. These initiatives all used digital badges to recognize learning by urban youth in a diverse range of settings, including libraries, parks, museums, and science centers, and including both online and physical settings. The websites associated with each initiative featured nicely organized displays of the badges that could be earned by participating youth, which linked directly to the opportunity to accomplish the activities necessary to earn the badge (called *Learning Experiences* or *XPs*). More importantly, earners were encouraged and expected to share the badges they earned as widely as possible over social networks so that their friends and peers might also learn about and take up those opportunities.

In the case of the Assessment BOOC, badge earners were strongly encouraged to share their badges over Facebook, LinkedIn, Twitter, and any relevant interest-driven professional networks. As shown in Figs. 1 and 2, the BOOC badges invited viewers of the badges to submit their email addresses and place themselves on the distribution list. Additionally, clicking on the course URL in the first line of each badge took the viewer to the course homepage, which included a link that allowed new learners to enroll in the course. While most of the open learners indicated in the end of course survey that they had learned about the BOOC via a paid targeted advertisement on Facebook, a handful of them indicated that they had learned about it via a badge posted by a friend in their social network.

Recognizing Evidence to Motivate Learning

It is well beyond the scope of this chapter to explore the many complex ways in which the recognition of learning in digital badges has potential to motivate learning. The analysis of the 29 badge systems funded in 2012 uncovered 17 different principles for using digital badges to motivate learning (Hickey & Willis, 2017). Motivational functions have proven to be the most controversial functions of digital badges. As introduced above, influential figures within the community supported by MacArthur Digital Media and Learning initiative expressed widely-cited concerns that badges would be used as “extrinsic incentives,” which have been shown in numerous studies to undermine intrinsically motivated inquiry-oriented learning (i.e., Jenkins, 2012; Resnick, 2012). This issue is further complicated because the potential of any innovation to motivate learning depends on one's assumptions about the nature of learning.

Digital badges have reignited the debate over extrinsic rewards and learning that has endured since the 1970s. Indeed, some innovators have used digital badges as information-poor tokens in gamified learning systems (such as the *BuzzMath* system created by one of the 2012 MacArthur awardees). So far, only a few empirical studies of badges and motivation have made their way through the peer review process (e.g., Abramovich, Schunn, & Higashi, 2013; Filsecker & Hickey, 2014).

This debate over extrinsic incentives in the context of digital badges is discussed at length in a new handbook chapter (Hickey & Schenke, 2019). That chapter makes several arguments about the potential motivational impact of open recognition with digital badges. These include (1) digital badges are inherently more meaningful than grades and other credentials, which minimizes the likelihood that they will be issued or perceived as arbitrary and "exogenous" (Rieber, 1996); (2) circulation in digital networks makes Open Badges particularly meaningful, which make them more likely to support intrinsically motivated learning; (3) digital badges are particularly consequential credentials; (4) the negative consequences of extrinsic rewards are likely overstated; and (5) consideration of motivation and badges should focus primarily on social activity and only secondarily on individual behavior and cognition. Given that digital badges contain actual evidence of engagement and learning, it seems like the time is right to explore these questions by experimentally manipulating badge characteristics in this regard to study these questions.

From Accrediting Schools to Endorsing Learning

The third set of potentially transformative functions associated with digital badges is perhaps the least understood. These functions are traditionally associated with *accreditation.* This is where external "third parties" review and verify the quality of schools and educational programs and the achievement represented by the degrees and credentials conferred. Outside of the United States, accreditation is commonly carried out by government agencies and ministries, whereas in the United States, it is carried out by independent accrediting organizations. These US organizations expanded in the 1950s when the federal government moved to position accrediting organizations as arbiters of increasingly important federal funding (Gallagher, 2016, p. 29).

There are four types of accrediting organizations in the United States (summarized in Eaton, 2006). The first type of accrediting organization is the voluntary regional and national organizations formed by the many public and private (mostly non-profit) educational institutions that belong to them. There were six regional accreditors and five national accreditors as of 2018. The second type is faith-based accreditors that serve religious institutions that are mostly non-profit and degree-granting. The third type serves private vocational schools that are mostly for-profit "single purpose" institutions that grant degrees as well as non-degree certificates.

The fourth type is programmatic accreditors that serve discipline-specific programs and schools (e.g., law schools, health programs). These accrediting organizations are funded by annual dues paid by member institutions, and schools must renew their accreditation every few years. While these organizations are primarily responsible for accreditation, the federal government and state agencies still maintain a significant role in the process and oversee the broader accreditation field. In most cases, that actual accreditation process is quite involved and requires substantial investment on the part of institutions to gather necessary information, meet with external visitors, and respond to concerns. The process serves to ensure the quality of schools and programs, allow access to federal funds, engender confidence in employers, and ease the transfer of credits across schools. Not surprisingly, the process by which schools and programs gain accreditation is quite opaque to most observers and resistant to change.

Many readers likely doubt that digital badges will supplant existing accreditation practices in the foreseeable future. Four developments may cause this to happen sooner than might otherwise be expected. The first development is the broader shift towards open and online learning, while the second is the expanded interest in sub-degree certificates and credentials (discussed briefly in the introduction of this chapter and at length in Gallagher, 2016). Both developments challenge the dominant models of accreditation, which have traditionally emphasized degree programs and conventional schools. The third development is new concern over the integrity of the accreditation process and the calls by some for new alternatives. Particularly in the United States and particularly in the for-profit sector, the rapid collapse of several large for-profit colleges that depended mostly on federally subsidized grants and loans has drawn new scrutiny to the entire accreditation process (e.g., Flores, 2017).

One noteworthy response to all three of these developments was the US Department of Education's *EQUIP* (Educational Quality through Innovative Partnerships) program launched in 2015. This experiment was designed to explore whether a new class of accreditors known as "quality assurance entities" (QAEs) might be better suited to endorse credentials issued by non-traditional educational programs such as coding "bootcamps." Offering a somewhat more specific function than traditional accreditors, these new QAEs were expected to "strengthen approaches for outcomes-based quality assurance processes that focus on student learning and other outcomes" (U.S. Department of Education, n.d.). The QAEs ranged from the relatively conventional American Council on Education (who have long managed GED and CLEP testing) to the HackerRank.com website that offers competitive challenges to coders and screens candidates for potential employers. While project EQUIP has not been without critics or problems (described in Fain, 2016; McKenzie, 2018b), it is widely recognized as a significant step away from traditional models of accreditation.

The fourth development that may help digital badges supplant formal accreditation is specific to Open Badges. This development is the inclusion of standards for *third-party endorsement* in the Open Badges 2.0 Specifications released in 2017. In the prior specifications, badges were tacitly endorsed by whoever issued them. In technical terms, this refers to the entity or organization whose URL was included in the *issuer* metadata field of the BadgeClass.[3]This means that this issuer information will be displayed in the badge; the credibility of the claims made within the badge is partly endorsed by the perceived credibility of the issuer, according to this information. One issue with this open approach to endorsement is that there was nothing to stop people from issuing badges to themselves (i.e., by creating an actual or fake issuer profile; Bull, 2015). Such concerns have fueled skeptics who question the potential validity of digital badges as high-stakes credentials (Raish & Rimland, 2016).

The endorsement features included in the Open Badges 2.0 Specifications that respond directly to these concerns are the culmination of extensive prior efforts by leaders of the Open Badges community. Carla Casilli, the initial Open Badges project manager at the Mozilla Foundation, pointed out in an early blog post that Open Badges were expected to change the very nature of the discussion. She specifically argued that badges would move the discussion away from traditional notions of validity and towards the notion of *credibility*:

> Credibility inspires belief and is derived from perceptions of trustworthiness and expertise. These things can be assessed through personal means but quite often are accepted tacitly. How so? Through the cultural shorthand of pre-existing standards. We countenance many sociocultural values with little to no deep consideration, i.e., everyone was doing it, I just followed the crowd, etc. Let's consider some ways that we might be able to classify what we mean when we talk about credibility (Casilli, 2012, Credibility section, para. 1).

Casilli went on the argue that traditional validity frameworks might need to be replaced by newer frameworks such as those that consider the persuasiveness of information on the Internet (e.g., the distinction between *presumed*, *surfaced*, *reputed*, and *earned* credibility in Fogg, 2003). This and related issues about measurement validity are elaborated in Casilli and Hickey (2016). Notably, a recent interview study of college admissions officers and tech-industry recruiters (Pitt, Bell, Strickman, & Davis, 2018) found that using badges to establish the credibility of a learner's accomplishments was the most frequently stated *opportunity* associated with digital badges; the credibility of that information was also the most frequently stated *challenge* associated with digital badges.

One of the first working groups established by the Badge Alliance in 2014 was the Endorsement Working Group. As stated on their home page, endorsement is a "game changer for how badges are used, understood and trusted." They stated that:

> It [endorsement] allows third-party organizations to publicly indicate which badges are aligned with their values — those that are the most meaningful and useful to them. It adds a new metadata component to the Open Badges standard and defines the structure for rich, well-defined endorsement information and criteria such as alignment with standards, uses for the badge in the context of the endorsing organization, description of evidence of learning and assessment techniques the organization values, etc. (Badge Alliance, 2014).

[3] The issuer URL should point to an *Issuer Profile* on the web that contains the name, a description, contact address, and other information about the issuer.

This vision was elaborated on in a subsequent chapter led by Deb Everhart, a central member of the Endorsement Working Group. The chapter featured several scenarios illustrating how badge endorsements might supplant traditional accreditation and pointed to the transformative potential of "open" endorsement:

> The intentionally open structure of badges provides opportunities for a variety of different types of endorses, including community organizations, employers, standards bodies, and groups that are re-envisioning how the value of learning is defined. (Everhart, Derryberry, Knight, & Lee, 2016, p. 232)

While the various badge platforms are still building out the technologies needed to implement the new Endorsement 2.0 standards, the standards themselves provide a clear picture of what is now possible in Open Badges platforms and what will soon be available to badge issuers. Central to this process are endorser *profiles* and endorsing *statements*. Endorser profiles give third parties the permission to endorse badges and display the information in each of the profile fields in the badge. Endorsing statements are where the endorser can indicate the nature of the endorsement. Profiles and statements are "inside" the badges. More specifically, because viewers can readily access this information in the context of the credential, this information is presumably more accessible and meaningful than conventional accreditation information.

With these new specifications, issuers will be able to have third parties endorse a badge before it is issued (the BadgeClass), which then appears in every Assertion of that BadgeClass, along with the profile (or link to the profile) and the endorsing statement. Issuers can also approve third parties to add more specific endorsements to each Assertion of the BadgeClass (elaborated in IMS Global Learning Consortium, 2018). In practical terms, this means that an educational program might have an employer organization endorse its badges and then allow representatives of that organization to add an additional individualized endorsement and endorsing statements after examining the evidence in the specific badge considering the claims made by the badge. Importantly, issuers would have the option of including an endorsement field where it would be apparent if a badge assertion had yet to obtain endorsement where such an endorsement was expected. In the e-commerce context discussed below, this might be akin to the way that e-shoppers are now unlikely to select a product that has no reviews.

In addition to the new endorsement features, the Open Badges 2.0 Specifications include a range of other new features that should further enhance the potential validity and credibility of badges. These include version control, the ability to bake information (including criteria for earning, evidence, and issuer profiles) directly in the badge (rather than inserting hyperlinks), and the ability to reference multiple competency frameworks or standards (see Belshaw, 2017).

Most of the major Open Badges platforms are currently making their systems compliant with these new specifications; as of June 2018, there were still no operational badge systems using them. Given the potential of these various new features to enhance the credibility of badges, it seems inevitable that badges will begin disrupting the existing educational credentialing ecosystem in the years to come. To provide several concrete examples of existing endorsement functions, this chapter now turns to several features of the badges from the Educational Assessment BOOC.

Endorsing Learning with Peer Endorsement

To encourage informal peer-review and crowdsource-review of wikifolios, a *peer endorsement* feature was added to each assignment in the Assessment BOOC. As shown in Fig. 8, participants were instructed to endorse at least three of their classmates' wikifolios for being "complete." Specifically, participants were instructed to click one button if they felt their peers had completed all the required elements and to click a different button if their peer had completed both the required and the optional elements (to reiterate, the optional elements were required for the degree-seeking participants). As shown in Fig. 8, Len Adams' validity wikifolio earned three such endorsements from his peers. The CourseBuilder site was programmed to aggregate these endorsements and display them alongside the link to the wikifolio inside of the module badge (shown in Fig. 2). CourseBuilder was also programmed to verify that a wikifolio had at least one such endorsement before counting that wikifolio towards earning the module badge.

In practice, peer endorsements were quite common in the Assessment BOOC even though there was no formal mechanism for tracking whether each participant awarded them. It was clear that the endorsements gave participants a means of indicating that they had reviewed peer work without having to leave a comment. Systematic analyses of a random sample of endorsements uncovered very few examples of endorsed wikifolios with incomplete elements; conversely, just a handful of complete posts did not earn at least one peer endorsement (typically because they were completed late by participants who choose to not interact with other students). In these cases, the participants were instructed to request the teaching assistant to review and provide an endorsement.

While there is no direct analog for these peer endorsement features in the Open Badges Specifications, there are some more specific comparisons that can be made. For example, the fact that only participants in the BOOC were able to make peer endorsements is akin to the way issuers of badges will be able determine who is able to endorse a given badge. In this case, BOOC participants were aware of the rigor of the course and the corresponding investment necessary for one's work to be deemed exemplary. Additionally, the aggregation of endorsements from wikifolios to module badges and the use of wikifolio endorsements to automatically trigger other events such as issuing the badge illustrate how endorsement information can be aggregated and used in badge systems.

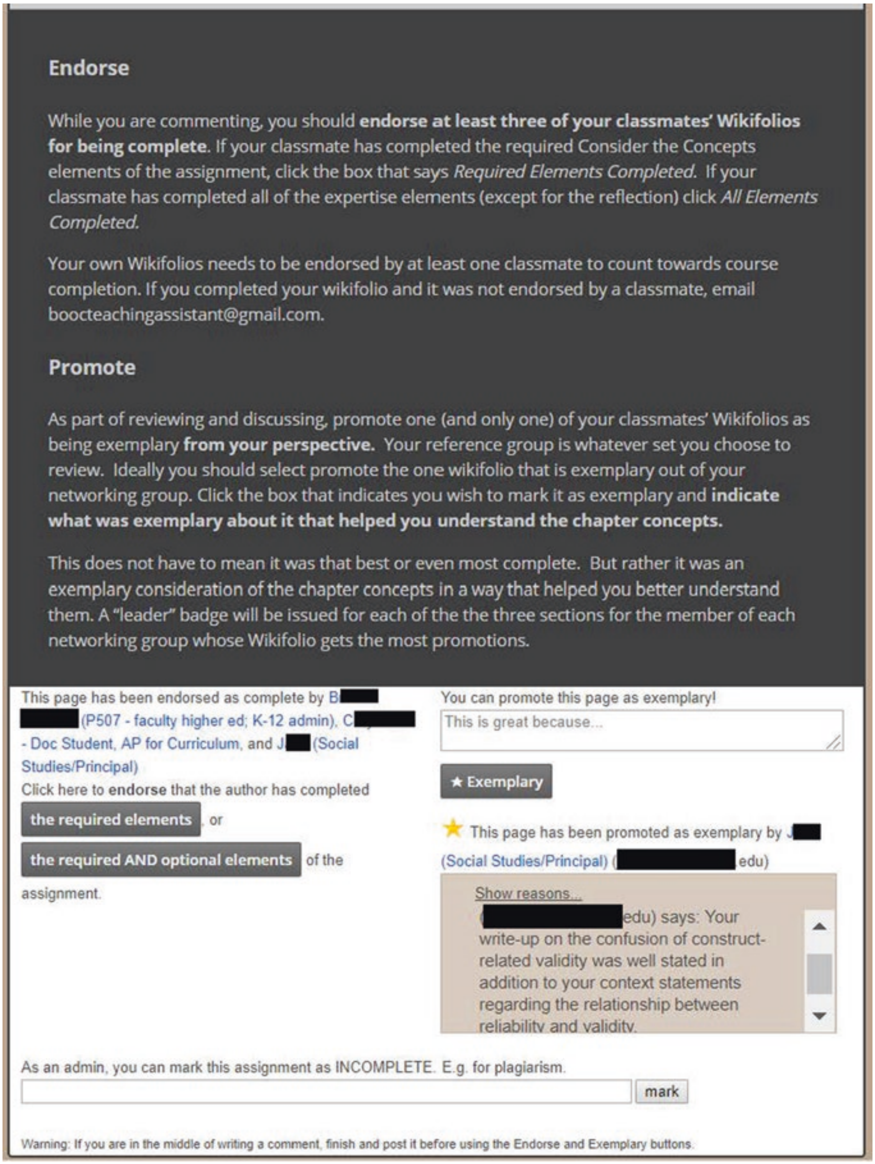


Fig. 8 Instructions and interface for peer endorsement and promotion in the BOOC

Endorsing Learning with Peer Promotion

A second endorsement feature explored in the Assessment BOOC was *peer promotion*. As shown in Fig. 8, each wikifolio assignment instructed students to promote one (and only one) of their peers' wikifolio each week for being "exemplary."

Unlike the peer endorsement feature, students were required to provide an endorsing statement describing what was exemplary about the post (in the "this is great because…" box). The CourseBuilder platform was programmed so that promotions could not be posted without an endorsing statement and so that each student could only post one promotion each week. Figure 2 shows how the promotion of the wikifolio was summarized inside of the badge, while Fig. 3 shows how the peer endorsement and endorsing statement were posted at the top of completed wikifolio.

While participants were technically not required to post a peer endorsement each week, cohorts consistently saw that over 80% of the students who completed a wikifolio provided a peer endorsement each week. Students appeared to value the endorsements strongly and complained when course practices made it harder for them to earn endorsements (such as "early posters announcements" that put some students who could not post early at a disadvantage for earning peer endorsements). These peer endorsements illustrate how a relatively competitive approach to endorsement might enhance the value of badges that had earned relatively scarce endorsements.

The representation of endorsements across assignments and module badges, and ultimately to the course badges, further illustrates how endorsement information can be aggregated across different levels for different purposes. This information can also be indexed and made readily searchable in interesting ways. For example, participants in the Assessment BOOC were able to readily locate the most widely promoted peer work and to even do so for peers with similar professional roles.

Discussion and Future Directions

To summarize, this chapter reviewed how digital badges can be used to support the transformation of educational practices from measuring, credentialing, and accrediting *achievement* towards capturing, recognizing, and endorsing *learning*. To reiterate, it is not certain that open digital badges will prevail over (or perhaps within) other solutions to the problems of measuring, credentialing, and accrediting achievement. Indeed, of the 30 digital badge systems funded by MacArthur in 2012, only 11 of those systems had established a "thriving" open badge ecosystem by 2015 (Hickey & Chartrand, 2019; Hickey & Willis, 2017). But as shown here, badges certainly provide a promising transitional technology for considering how web-enabled digital credentials will help support the transformation towards capturing, recognizing, and endorsing learning. Several factors suggest that digital badges may indeed prevail. The most obvious factor is the continued expansion of the Open Badges ecosystem. Also notable is the continued growth of Credly, Inc. (including Credly's acquisition of Pearson's *Acclaim* badging system); the expanded use of badging platforms like of *Badgr.io*, *Open Badge Factory*, and *Open Badge Academy*; and the integration of Open Badges into leading ePortfolio platforms including *Chalk & Wire* and *Portfolium*.

Other factors suggesting continued expansion of Open Badges are the 2017 acquisition of the Open Badges Specifications by the IMS Global Learning Consortium and the introduction of endorsements and other features in the Open Badges 2.0 Specifications. As argued in Hickey (2017), there are important historical and technological parallels between (a) the way consumer reviews allowed e-commerce to begin supplanting traditional retailing after 2000 and (b) the way that new endorsement features might lead digital badges to begin supplanting traditional credentials around 2020. It seems worth noting that the badge system described in this chapter was just one part of a larger educational experiment that was funded with a relatively modest ($50,000) grant from Google. Thanks to the Open Badges Specifications (along with Google *AppEngine* and *CourseBuilder*), an experienced programmer was able to create a sophisticated system of digital badges that were evidence-rich, searchable, sharable, and interoperable with other open badge systems, along with an entire innovative structure for the lager course.

Another factor suggesting expanded use is that digital badges continue to be the subject of robust exploration, innovation, and publication. As was the case between 2012 and 2016, most peer-reviewed publications since 2017 appear to be either descriptive case studies (e.g., Hensiek et al., 2017; Hrastinski, Cleveland-Innes, & Stenbom, 2018; Robles, Thrash, Walker, & Brush, 2017) or studies of the perceptions of badges (e.g., Dyjur & Lindstrom, 2017; Fajiculay, Parikh, Wright, & Sheehan, 2017; Jones, Hope, & Adams, 2018). Unfortunately, it appears that there are still no published empirical studies that examine the impact of placing actual evidence of learning inside of digital badges. Given that gathering valid evidence of learning is often one of the biggest challenges facing educational researchers, it seems that the evidence contained in a well-designed badge system could be readily used in a wide range of empirical studies.

Perhaps the most important future direction to consider is whether this turn towards learning and the use of digital badges might advance goals of educational equity and social justice. In the United States, continued increases in outsourcing and automation are expected to further expand the growing wage disparity between less credentialed and more credentialed individuals and between underrepresented racial minorities and racial majorities (Goldin & Katz, 2008). The broader trend towards learning promises to make education and educational credentials less expensive and more readily available, with obvious implications for access to higher education. Lumina's *Equity Imperative* (2017a) outlines the foundation's commitment to both equity and excellence. The foundation asserts that:

> While we know that educational attainment is at the center of civic, social and economic success, the current system prevents an increasing number of students from realizing that success — particularly those who have been historically excluded from and served the least by the existing structure. The system must be redesigned in a way that values the diverse pathways by which students obtain the knowledge, skills and abilities they need to succeed in the workplace and in life. (p. 2)

Indeed, this commitment to equity is prominently featured throughout Lumina's *Strategic Plan* (2017b), and the foundation is aggressively prioritizing underrepresented minorities and disadvantaged populations in its efforts to expand access to education.

More specifically with digital badges, many high-value digital badges can be earned with no enrollment costs of any sort. Badges also offer a way of validating learning in spaces like libraries and museums, which is particularly important for young people when limited school resources and accountability pressures preclude offering deep experiences beyond mandated curriculum. In this way, badges *should* allow learners who are unserved by traditional education to gain and display their experiences and talents and in turn access educative and career opportunities. Several recent developments demonstrate initial progress using digital badges to expand access to education in this manner. The most impactful is Collective Shift's *Project LRNG* initiative, which is coordinating more than a dozen city-wide efforts to offer badged learning opportunities to thousands of (mostly) low-income youth. Concerns with equity were central at the *2018 Badge Summit*, including the event subtitled, *An Exploration of Micro-credentials, Access, and Equity* (Badge Summit, 2018); Samuel Dyson's keynote address, *Achieving the Dream of Digital Badges: Closing Gaps in Engagement and Opportunity* (EduTechGuys, 2018); and other sessions. A particularly promising program of research in this regard is supporting STEM identity and participation among underserved youth, a project being carried out in the context of Davis's (2015) aforementioned after-school program at the Pacific Science Center. In this context, Pitt and Davis (2017) provide a compelling example of using participatory design to help support equity when creating digital badge systems, while Bell and Davis (2016) provide helpful details about the actual design process; the recent interview study by Pitt et al. (2018) found that supporting equity was one of the five most frequently mentioned opportunities offered by digital badges (though it was the fifth of the five and was mentioned by college admission officials and not by employment officials).

As Cuban (1986) pointed out, proponents of every successive wave of educational technology (including radio!) have argued that the innovation would make education more equitable. While such claims were common around the explosion of interest in open learning and MOOCs (e.g., Bonk, 2009; Irvine, Code, & Richards, 2013; Kelly & Carey, 2013), findings from multiple studies reveal that MOOC participants are overwhelmingly well- educated and economically privileged and that the format presents significant barriers for underprivileged learners (e.g., Hansen & Reich, 2015; Rohs & Ganz, 2015; van de Oudeweetering & Agirdag, 2018). Likewise, some observers and researchers have raised concerns that competency-based education may end up exacerbating inequalities (Silva et al., 2015; Steele et al., 2014). Efforts to address educational equity and social justice present complex issues that obviously transcend any specific innovation such as digital badges. Fortunately, there are already several scholars who are exploring badges from broader perspectives, including philosophy (Willis, Flintoff, & McGraw, 2016) and sociology (Olneck, 2018). Badge users and innovators are encouraged to approach the promise of badges with such considerations in mind in order to deliberately avoid perpetuating inequities and, rather, to leverage badges in ways that maximize their potential to create more generative ways of capturing, recognizing, and endorsing learning.

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Acknowledging All Learning: Alternative, Micro, and Open Credentials

Richard E. West, Timothy Newby, Zui Cheng, Alyssa Erickson, and Kyle Clements

How people learn has changed dramatically in recent years because of the Internet, making it possible for content to be more flexible and accessible. At the same time, changing demands in the marketplace require employees to continually update their skills, making lifelong learning no longer a pleasant idea but a necessity (Šimenc & Kodelja, 2016). Berger (2016) reported, using LinkedIn data, that younger workers particularly are changing jobs frequently—nearly three times on average in the first 5 years after graduation. This increased career mobility is mirrored by industry pressures for companies to stay “ahead of obsolescence curves” created by compressed product and services life cycles (Fawcett & Waller, 2014). The answer, for many organizations, is to maximize employee learning and growth, thus making lifelong learning more important than in previous generations. To meet this need for continual learning, people are seeking opportunities to improve their skills in both formal and informal ways, as well as both inside and outside of traditional universities (Merriam & Kee, 2014).

Traditionally, university credentials have provided the useful service of communicating to potential employers about the skills, qualities, and relative merits of potential employees (Olneck, 2012). These university degrees remain very important in today’s marketplace, but there is an increasing need for alternative credentials that can better document the informal, online, and lifelong development of skills and knowledge both inside and outside of the university. This has led to a call

R. E. West (✉)
Brigham Young University, Provo, UT, USA

T. Newby · Z. Cheng
Purdue University, West Lafayette, IN, USA

A. Erickson
Qualtrics, Provo, UT, USA

K. Clements
Western Governor’s University, Salt Lake City, UT, USA

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for more flexible credentials, including those that document smaller (micro) skill attainment and that are open so that they can be portable across learning institutions (Janzow, 2014).

In this chapter, we first define *alternative credentials* to establish common understanding. We then review the needs that society, educational institutions, employers, and individual learners have, which argue for the importance of these new credentials, along with a theoretical rationale for *open microcredentials* as a potential solution. We then review research findings into flexible microcredentials, including the burgeoning scholarship on *open badges*, launched in 2011 by the Mozilla Foundation. We conclude with recommendations for the design, implementation, and sustainability of these credentials in organizations and educational institutions.

Definitions and Affordances of Alternative Credentials

It is important to understand the breadth of alternative credentials before focusing on open microcredentials, which is the emphasis in this chapter. The term *alternative credentials* represents a variety of certifications including digital certificates, verifiable credentials, micro-diplomas, nanodegrees, digital badges, and open badges. A diverse set of organizations and groups currently issue alternative credentials for learning. These include technical schools, bootcamps, lifelong learning groups and initiatives, professional development organizations, and traditional education institutions from elementary schools to universities. The alternative credentials issued by these groups each serve the similar purpose of documenting a learner's accomplishments and skills; however, they also differ in terms of their data usage, scope, shareability, and verifiability.

Amount of Data

The amount of data displayed on traditional diplomas and credentials is generally limited to what is printed on the certificate. This information typically includes the name of the earner, the title of the organization who issued the credential, and a reference to what was completed (i.e., "Bachelor of Science in Psychology"). Some alternative credentials are simply digital versions of more traditional forms. For example, digital certificates issued by Lynda.com can be downloaded as PDF files that look like a diploma ("Certificates of Completion – Frequently Asked Questions," 2016). Other types of alternative credentials, such as Open Badges, are actually embedded with metadata that explains the criteria for earning the credential and links to evidence showing why the credential was earned.

Scope

Many alternative credentials are classified as microcredentials because they represent the achievement of discrete skills or accomplishments (Ifenthaler, Bellin-Mularski, & Mah, 2016). Other alternative credentials, such as Degreed's Skill Certifications, seek to document skills that may have been learned over months or years (Degreed, 2017).

Shareability

The digital nature of alternative credentials allows for them to be shared in a variety of ways online. For example, Udacity nanodegrees come with digital images that earners can post on their personal websites, LinkedIn profiles, and other social media platforms (Morel, 2016). Many other types of alternative credentials are shareable but only within the system they were issued. These alternative credentials increase their shareability when they follow established technical standards for open sharing. Such standards are maintained by several organizations including IMS Global and the World Wide Web Consortium (W3C).

Verifiability

Verifying a traditional diploma or certificate's authenticity often requires contacting the issuing organization and requesting the verification. Many alternative credentials are issued with a unique ID number that can be verified by visiting the issuing organization's website. Other credential types, such as Open Badges, also embed evidence directly into the credential (Gibson, Ostashewski, Flintoff, Grant, & Knight, 2015).

Needs and Challenges with Educational Credentials

Credentials, including the alternative credentials defined above, serve an important role for many stakeholders, including those who *interpret* the credential (e.g., employers, supervisors), *earn* the credential (e.g., students), and *issue* the credential (e.g., educational institutions). In this section, we will discuss the unique needs and challenges facing each of these groups of stakeholders in the area of learning credentials, articulating a need in particular for open microcredentials because of their unique affordances as micro (scope)-, shareable, verifiable, and data-rich credentials.

Credential Interpreters (Marketplace)

Many different people are end interpreters or consumers of a credential who interpret its value for their organization or the marketplace. Employers, for example, rely on educational credentials to identify potential employees with the right skill set. Within organizations, supervisors may rely on professional development credentials to identify employees for advancement or assignment. Team members may rely on credentials to help ascertain who on a team can fulfill certain jobs. And as Cai (2013) reminded us, employers may interpret credentials more than once, for example, credentials might need to be able to send a different signal or message to attract employers' initial attention and then a different signal when the employer is making a final decision among candidates.

However, current educational credentials underserve the marketplace because they do not represent all the learning and skills a potential employee may have. In particular, there are four primary failures of typical educational credentials: they are (1) incomplete, (2) data-poor, (3) cognitive-centric, and (4) difficult to understand.

Perhaps the primary failure of educational credentials is that they are simply an incomplete record of what a person knows, has accomplished, and can do. For example, a student may earn a degree but then also develop valuable skills in an internship, through continuing professional development, or through self-regulated online learning. In addition, many careers require "T-shaped" expertise, where a person has deep knowledge in one area but breadth in many others (Conley, Foley, Gorman, Denham, & Coleman, 2017). This breadth is not communicated well in traditional credentials that typically are from a single discipline.

Second, educational credentials are data-poor, usually only communicating the final institution attended. Transcripts provide more information but usually only the courses completed and a final grade. They also do not show the difference between what was known before the educational experience and what was gained during the education (Arkes, 1999; Bills & Wacker, 2003). This lack of additional data about specific skills and knowledge and how the learner has progressed makes it difficult for employers to understand what the credential means and really represents about the learner. This may be part of the reason why college degrees are losing their value for employers both in the United States and in other countries (Hu, 2013; Wanner, 2000).

Third, typical credentials report students' cognitive accomplishments but rarely their acquisition of soft skills that most employers seek. Rivera (2011) argued that "extracurricular activities have become a credential of social and moral character that serve as capital in elite labor markets" (p. 87), but unfortunately, despite their apparent value, most extracurricular activities are poorly represented in traditional credentials.

Finally, educational credentials are typically difficult to understand and interpret. This is so much the case that tutorials may be provided for reading an academic transcript (see https://handbook.psu.edu/content/understanding-a-transcript-and-academic-verification). Morel (2016), dean of the College of Professional Studies at Lipscomb University, declared, "transcripts are a relic of the pre-social media past," and gave the example that employers may know the difference between a BS and a BA, but not what the requirements were to earn a C in a particular class of interest. In the end, many employers screen candidates based on the prestige of a credential rather than its actual content (Rivera, 2011).

How Microcredentials Better Communicate to Interpreters Microcredentials have inherent affordances that better address these four marketplace concerns. Because microcredentials can be earned in formal as well as informal settings, they can represent all of a student's learning. Because many forms of microcredentials are based on open technology, they can be created and issued by nontraditional education providers, such as museums, internships, and employers. They can also be organized into collections to represent different kinds of expertise that may be important about a learner. Because microcredentials can be issued by formal as well as informal institutions, they can better represent social skills (e.g., they may be issued by internship supervisors or even team members—those who best know the person's social skills).

In addition, if microcredentials are digital, they can hold embedded digital metadata about what was required, what evidence was provided to meet the requirement, the date of issue/expiration, endorsements from outside entities with expertise in the discipline, and other information that may vary from credential to credential. Because they can be organized into collections, only the credentials important for a particular employer can be presented, thus improving the potential for understanding and relevance.

Credential Earners

Learners seek to earn credentials in order to show others, as well as themselves, that they know or can do something. They seek credentials that will help them develop credibility and station within a community (e.g., place of employment or even personal network). Disadvantaged populations such as women and minorities, in particular, benefit from these credentials (Bailey, Kienzl, & Marcotte, 2004). In addition, the "new economy" of substantial risk and uncertainty from frequent career transitions (Adams & Demaiter, 2008) makes continually earning credentials even more important.

Current credentials often fail to fully represent the learner's profile, including what is learned both formally and informally, and "hard" skills as well as soft, as described in the previous section. Thus, learners can feel that their degree does not fully represent them. Also, because credentials are owned by institutions, it is difficult for learners to own and display their credentials or merge credentials from multiple institutions. This is problematic since 60% of students will end up transferring from one college or university to another, some multiple times (Schneider, 2015). Many times, learners must retake courses because they cannot transfer one credential from before into their new institution. Finally, because most educational credentials represent learning after several years, a learner who does not complete the full program may be left with roughly the same ability as other people, but no credential, leading to a large difference in potential earnings—what is called the sheepskin effect (Bailey et al., 2004; Ferrer & Riddell, 2002; van der Meer, 2011).

How Microcredentials Better Support Learners Because microcredentials are managed and owned by the earners, they are more portable and easily managed, returning more ownership to the earner. They can also be more easily shared in social media and other venues that matter to an earner. In an age where data is considered a prized part of one's digital identity that should be owned by the individual, it is critical for people to own some of the most important data about themselves—what they have learned. Also, as traditional degrees decline in their power to deliver quality employment (due to a volatile and competitive market), people increasingly see the need to add additional value to their degrees to gain an edge (Tomlinson, 2008), a need that could be fulfilled through microcredentials continually earned throughout one's career.

In addition, there are reasons to believe microcredentials could positively affect students' learning as well. This is because they offer (a) a list of criteria or standards of performance/skills/knowledge; (b) the possibility of performance feedback; and (c) a confirmation that a skill/knowledge level of proficiency has been achieved.

Review of research on self-regulated learning (SRL) has shown overwhelming evidence for its enhancement of student performance and achievement (e.g., Nilson, 2013; Pressley & Ghatala, 1990; Zimmerman, 2002). From the various models of SRL, key elements that enhance learning include the learner's ability to plan, monitor, and evaluate what is to be learned (Schraw, 1998, Zimmerman, 1990). To facilitate SRL development, learners need to have opportunities where they can assess what learning is required, compare that with what they currently know, plan how to obtain and learn that which is lacking, and learn to obtain and use feedback appropriately. Cucchiara et al. (2014) explained that microcredentials such as digital badges enhance SRL development by supplying learners with a list of expected performance criteria to use to compare and self-evaluate their level of knowledge or performance. In addition, this list of criteria allows the learner to plan what needs to be accomplished and to set goals in order to effectively accomplish what is needed. Goal setting behaviors enhance SRL and are dependent upon the learner being able to compare current capabilities with a given desired end state or set of criteria (Wills & Xie, 2016; Bergamin, Ziska, Werlen, & Siegenthaler, 2012). Microcredentials provide the needed criteria or standards and have been proposed as possible ways to promote goal setting in students for meaningful learning (Cheng, Watson, & Newby, 2018).

In many cases, microcredentials also provide a revision cycle that allows learners to receive feedback based on their level of knowledge attainment and/or skill performance. Decades of research on feedback have shown a "preponderance of evidence that feedback is a powerful influence in the development of learning outcomes" (Hattie & Gan, 2011, pg. 249). Microcredentials, such as digital badges, integrate feedback in order to help the learner note performance discrepancies and areas of possible improvement.

Microcredentials also enhance motivation and the desire to invest effort into the task to be learned (Jovanovic & Devedzic, 2015). From an internal perspective, motivation can be increased by setting and achieving goals and by having autonomy and personal control to direct one's own actions (Malone & Lepper, 1987; Wills & Xie, 2016). From a more external perspective, being awarded the microcredential for successful completion can be reinforcing and may boost one's level of confidence (Keller, 1987).

Credential Issuers (Educational Institutions)

Educational institutions issue credentials to reward and recognize students but typically limit formal credentials to macro-time periods (e.g., 4-year degrees). Institutions use credentials not only to benefit the students but also themselves, as the value of a degree reflects back on the institution. As Gardner (2015) reflected, institutions go cross-eyed with one eye on the benefit to the student and one eye on their own financial return and sustainability.

In addition to institutional goals, individual departments and faculty have their own goals regarding university credentials. Often, faculty or programs want to recognize students' accomplishments in "micro" areas not traditionally recognized in a diploma (e.g., successful presentation at a conference, effective project management, teamwork) and do not have a method for doing so. Often, faculty are asked to describe these skills about students in lengthy letters of recommendation for only one recipient. Another problem is the lack of prerequisite skills and knowledge for various courses and how to signal which students may come to a course prepared while others need remedial assistance.

Finally, departments may wish they could reward students for following a prescribed path through coursework, perhaps collecting skills and coursework around a particular theme not well represented in the name of the department issuing the credential. For example, one student may graduate from an instructional technology department with vast experience and knowledge in open education, and another may be an expert in K-12 classroom technologies—and yet their degree may read exactly the same.

How Microcredentials Support Issuers Microcredentials may be able to provide substantial benefit to the issuing organization, particularly in promoting the brand. Because microcredentials are typically easier to share on social media, they can become a strong marketing force for a university as earners share their microcredentials on Twitter, LinkedIn, Facebook, or other websites. In much the same way that blogging or tweeting about a published article can increase its citations (Shema, Bar-Ilan, & Thelwall, 2014), and open access can lead to higher citations for high-quality journals (Koler-Povh, Južnič, & Turk, 2014), open and shareable credentials may lead to greater visibility for a credential-issuing organization like a university. They can also help an institution distinguish clearly to others who has skills that they value and who does not. For example, Davies, Randall, and West (2015) proposed open badges as a method for addressing the challenge of certifying skilled evaluators within the American Evaluation Association.

Secondly, microcredentials may allow for more flexibility within programs to issue a credential for what they value in a way that does not undermine the more formal and regulated credentials/degrees of the institution. For example, a department may issue microcredentials related to research skills a student has acquired, positions of leadership in group projects, chunking of learning opportunities along various thematic threads, or recognition of skills across multiple modules, as Higashi, Schunn, Nguyen, and Ososky proposed (2017). None of these would detract from the overall diploma but instead enhance the student's experience and marketability postgraduation. In this way, badges and microcredentials provide "value added" to traditional university credentials. Also, badges may be used as prerequisites for certain courses, as we have done at both Purdue and Brigham Young University.

Initial Research Findings into Open Microcredentials

From an educational standpoint, the value of open microcredentials has been based on three primary functions: (a) the *credentialing* function and the value of how learned skills and knowledge are recognized, communicated, and perceived; (b) the *motivational* function and how effort and participation may be incentivized; and (c) the *pedagogical* function and how microcredentials may be used to support and scaffold learning in users (Ahn, Pellicone, & Butler, 2014; Giannetto, Chao, & Fontana, 2013). Although overlapping in some cases, these functions have guided researchers to investigate the impact of microcredentials. In our synthesis of research findings for this chapter, we review current research studies that have investigated the following sample research questions and discuss implications based on their findings.

Research on Microcredentials as Effective Credentials

A large, longitudinal survey of Americans conducted by the US Census Bureau (Ewert & Kominski, 2014) reported about 25% of Americans had earned alternative credentials, with this rate increasing in proportion to education level. Much of these credentials represented government licensing. However, the authors reported that "professional certifications, licenses, and educational certificates have labor market value, especially for those with low levels of education (i.e., below the bachelor's degree level) and people with professional degrees" (p. 11). Leading scholars in microcredentials recognize that for microcredentials to help provide this value, there is a need for a "shared, collective belief in the value of specific badges" (Grant, 2014, p. 11). Increasing the perceived value of these credentials requires the effort of many people in a trusted network who build value by aligning badges to learning outcomes, standards, internships, credits, and job requirements. This increases the relevance of badges to both the learners and outside parties. This section will first look broadly at how badges are used in credentialing and then more specifically at how they are used for youth, students in higher education, and employers.

Connecting Institutions Sheryl Grant, an expert on open badges from Duke University, said that "badges are about making learning that is already there more visible, and connecting that learning across different institutions" (Grant, 2014, p. 25). Some of this connection among institutions has occurred through competitions and sponsored worldwide efforts, including the Badges for Lifelong Learning Competition in 2011, in which HASTAC provided almost $2 million in grants for badge systems and research, which continued as the Digital Media and Learning Competition until 2016 ("About Open Badges," 2016). This competition was also supported by the MacArthur Foundation, Gates Foundation, Mozilla's newly released Open Badges initiative, and the US Secretary of Education (Gibson et al., 2015).

Another example was the two Million Better Futures initiative, launched in 2013 by the MacArthur Foundation at the Clinton Global Initiative, supported by Mozilla and HASTAC. This initiative was a 3-year commitment to provide support for schools, universities, companies, and other organizations in using their badging systems ("Better Futures,", 2013). After the first year, due to positive response, the program expanded from improving the futures of two million students and workers to 10 million. This 10 million Better Futures initiative began in 2014 and continued until 2016 ("10 Million Better Futures," 2014).

For Youth and K-12 The city of Chicago supported the 2 Million Better Futures initiative by setting in motion the Chicago Summer of Learning in 2013, in which over 100 youth organizations offered digital badges to the city's youth. Chicago's initiative surpassed its expectation by awarding almost 100,000 badges to youth that summer. The Summer of Learning continued the next year and is now the ongoing Chicago City of Learning initiative ("Mayor Emanuel Announces," 2013). This effort sparked several other large cities to begin their own badge initiatives. New York, Chicago, and Pittsburgh all currently are a part of Hive Learning Networks, which connect learning opportunities for youth ("About Hive," 2014). Their supporting organizations include museums, libraries, and other programs that transfer credentials across the Hive Learning Networks, accumulating "data packets," which are akin to digital badges (Grant, 2014, p. 26).

Additionally, some school districts such as Aurora Public Schools (APS) in Colorado have implemented badge systems so that their students can present credentials to universities and/or employers. APS, inspired by a Mozilla Foundation conference on badges, implemented this badging system in all 19 of its schools in 2016 and connected with local partners that agreed to recognize the badges by providing internships interviews and other opportunities to students (https://sites.google.com/aurorak12.org/badge/). This district created a network in their community, seeing the value of digital badges for recognizing skills and achievement.

In Higher Education Although many universities view badges as a threat to traditional credentials, others use badges to augment their degrees or college programs. According to a 2016 survey conducted by UPCEA and Pearson, one in five colleges have issued digital badges ("Digital, Verified," 2016). For example, Illinois State University actively uses a badge system to augment their traditional degrees. The honors program and faculty teamed up to create digital badges in Credly, which requires the submission of meaningful evidence. This encourages students to earn badges that are curricular and cocurricular, such as independent study, volunteer, or internship experience ("Digital, Verified," 2016). Others have suggested that universities in the future may serve as microcredential certifiers, granting traditional credentials like degrees for independent work completed and microcredentials earned for other types of learning activities (Mazoue, 2013).

Indeed, many consider open microcredentials and badges as complementary to university goals. For example, Mah (2016) proposed using digital badges and learning analytics to predict student success and personalize feedback in a way that increase student retention—a significant challenge for many institutions. The University of Central Oklahoma now maintains a Student Transformative Learning Record (http://sites.uco.edu/central/tl/stlr/) that serves as a second transcript of transformative learning and the acquiring of career skills leadership, service, civic engagement, and global/cultural competencies. Northeastern University recently partnered with IBM to award credit for IBM badges (Northeastern News, 2017). Michigan State University, on the other hand, specifically separates their open badges initiative from academic records but still offers students the opportunity to receive this recognition for achievements outside of formal grades (https://badges.msu.edu/).

Other examples of digital badge use in higher education are more focused on specific programs within a university. Brigham Young University and Memphis offer open badges through badgeschool.org to K-12 preservice and in-service teachers learning new classroom technologies. Santa Barbara City College uses Pearson's Acclaim platform for digital badges in select departments ("Digital, Verified," 2016). The Colorado Community College System allows local manufacturing companies and their system of colleges to collaborate in creating digital badges for engineering, math, and faculty development ("Badges," 2016). The Learning Design and Technology program at Purdue, along with Brigham Young University, uses open badges as prerequisite requirements for certain instructional technology courses.

For Employers Traditional university courses often do not teach or provide credentials for soft skills that are extremely valuable to employers (Grant, 2014, p. 29). Erickson (2015) conducted a study in which he measured how badges are perceived by employers in the hiring process. Twenty hiring directors of small or medium tech companies in Minnesota were selected to participate. Erickson found that these employers were interested in badges, especially if they could lower costs of professional development and increase the pool of qualified applicants with specific skills. However, these hiring directors also indicated that in order to accept badges, they would need to see high standards in the requirements for the badges that prove that the badge is credible, valid, and trustworthy (Erickson, 2015). Liyanagunawardena, Scalzavara, and Williams (2017) found in their review only three research articles on employer perceptions up to 2015 but learned in those papers that employers overwhelmingly indicated interest in learning more about open badges.

One of the most notable examples of a company that actively issues and recognizes open badges is IBM, the largest computer company in the world. IBM offers technology courses and badges that seek to improve professional development, to attract new talent, and to demonstrate competency to clients (Leaser, 2016). IBM uses Credly and Acclaim to award digital badges on the IBM Skills Gateway site and for completing online courses on their Big Data University platform. Anyone outside or inside the company, except for a few badges that are strictly internal, can earn these badges for free. IBM digital badges are shareable on social media, including LinkedIn, and hundreds of thousands use these online resources. IBM has already reported many positive impacts that came directly from their badging system, including increased talent, motivation, and sales (Leaser, 2016), and Microsoft (https://www.microsoft.com/en-us/learning/badges.aspx), National Instruments (http://www.ni.com/white-paper/53685/en/), and others have released badging programs.

Research on Microcredentials as Motivational Agents

Although the potential impact of microcredentials on learner motivation has been discussed widely (e.g., Gibson et al., 2015), actual research findings are only now coming to the forefront. Promising areas of research indicate microcredentials have a potential impact on motivation of learning and performance from extrinsic, as well as intrinsic perspectives. From an extrinsic viewpoint, the microcredential serves primarily as a reward or reinforcement for task accomplishment. Based on the law of effect (Thorndike, 1911), responses that produce a satisfying outcome are more likely to be repeated. Badges, for example, have been used within the gaming world as recognition and rewards for the attainment of specific levels of performance. These have proven effective to increase user engagement (e.g., Bowser et al., 2013; Hamari, 2017). In a study involving more than 1000 participants, Denny (2013), for example, showed significant increases in target behaviors of asking and answering questions when badges were awarded for task involvement.

Moreover, as quantity of the target behavior increased, the quality of the responses did not diminish. In some cases, research indicates mixed results (Abramovich, Schunn, & Higashi, 2013; Dominguez et al., 2013; Hakulinen, Auvinen, & Korhonen, 2013) and even negative results (Hanus & Fox, 2015) from the utilization of badges as extrinsic rewards. Researchers have also expressed concern that badges as extrinsic rewards may have a deleterious effect on learner's intrinsic interest in a task (e.g., Jovanovic & Devedzic, 2014; Reid, Paster, & Abramovich, 2015). That is, by giving rewards for completing tasks that were initially intrinsically interesting, the task may come to be viewed with less interest once the reward structure is removed (Deci & Porac, 1978; Lepper & Green, 1978). The use of microcredentials as extrinsic rewards may impact behavior; based on these and similar results, design and implementation strategies are being generated to ensure maximized effectiveness and minimized challenges that they may create (e.g., Tran, Schenke, & Hickey, 2014).

Of even more importance is research that focuses on the potential intrinsic or internal motivational affordances potentially provided by microcredentials. Two of the most researched affordances include goal setting and corrective feedback (Wills & Xie, 2016).

Goal setting allows participants to reflectively consider task requirements, review and compare their current capabilities, and then become challenged to "meet the mark that is set for them" (Antin & Churchill, 2011, p. 2). This motivates because "once people commit themselves to certain goals, they seek self-satisfaction from fulfilling them" (Bandura, 2013, pg. 149). Locke and Latham (1990), for example, compared the level of motivation and the performance of individuals who were given difficult, specific goals with the performance of individuals who were instructed to simply "do your best." In all cases, those with specific goals outperformed those without. They concluded that goals with specific criteria help to reduce performance variation by reducing the ambiguity about what and how a performance should be completed (Locke & Latham, 2002). Those with the stated goals knew what they were supposed to do and thus had a greater tendency to invest effort in the task to achieve that which was needed. Performance improved whether the goals were self-set or assigned (Locke & Latham, 2013).

Microcredentials such as open digital badges generally include criteria that must be attained in order for the credential to be awarded. These listed criteria facilitate and guide the goal setting process. Moreover, badges can be stacked in a way to not only show what is needed to be completed but what other alternative pathways to success also exist. Research comparing the performance of groups with and without badges suggests that badges can help students with initial lower levels of goal orientation, that is, the badges facilitated their goal setting capabilities and their subsequent investment of effort (Biles, Plass, & Homer, 2016). Moreover, allowing learners autonomy and control over goal and pathway selection can also increase levels of intrinsic interest and subsequent motivation (Dickinson, 1995).

Closely aligned with the motivation provided through goal setting is that which comes from the feedback generated within microcredentials. “Feedback is information that is provided to a learner, meant to enhance their understanding of their performance and comprehension” (Fanfarelli, Vie, & McDaniel, 2015, p. 57). Feedback’s significant benefits in learning and achievement are repeatedly cited and replicated within the literature (e.g., Nicol & Macfarlane-Dick, 2006). In addition, feedback with the opportunity to resubmit allows learners to work to task mastery (McDaniel, 2016). In such situations, feedback comes to be viewed as highly motivational because of the communication roles it fulfills. It provides (a) confirmation that a desirable action has occurred and/or an advancement has been made; (b) directions for a manageable goal or next step in what needs to be done; and/or (c) guidance to resources to accomplish that goal (Fanfarelli et al., 2015).

For example, using open badges as a means for immediate feedback, students were shown to improve their awareness of the goals required for successful task completion, as well as increasing reflection on their task completion progress (Charleer, Klerkx, Odriozola, Luis, & Duval, 2013). In a separate case study of preservice teachers in an undergraduate educational technology course, the impact of feedback on groups of badge users was compared with those completing similar projects without the use of badges (Besser, 2016). The open badge system used in the study allowed for increased instructor opportunities to provide feedback when compared to the normal classroom experience. Moreover, in cases where needed, increased numbers of revision cycles were invoked prior to the awarding of a badge in order for task mastery to be achieved. Besser (2016) describes a hierarchy of feedback types that were generated and how and when they are best utilized to maximize motivation.

Research on Microcredentials from a Pedagogical Perspective

Although the pedagogical function of microcredentials overlaps to some extent with its credentialing and motivational function, it is particularly important to discuss how microcredentials benefit teachers/instructors, learners, and instructional designers who frequently interact with specific teaching and learning tasks and activities.

The academic literature on the pedagogical value of microcredentials is just now beginning to emerge; however, a review of the literature that does exist reveals that microcredentials can be integrated with pedagogical practices in two major, innovative ways—as signposts/guideposts and as portable learning platforms—to support self-regulated learning (SRL) and social learning (SL).

Microcredentials as Signposts/Guideposts in Pedagogical Practices From an instructor's perspectives, microcredentials can serve as guideposts that chart learning routes by designating values to selected knowledge, skills, learning tasks, and activities and by directing and steering learners' behavior to achieve desired goals (Ahn, Butler, Alam, & Webster, 2013; Anderson, Huttenlocher, Kleinberg, & Leskovec, 2013; Jovanovic & Devedzic, 2014). From learners' perspectives, they can use microcredentials like digital badges as signposts to map learning trajectory (O'Bryne, Schenke, Willis, & Hickey, 2015; Ostashewski & Reid, 2015), plan learning by referring to the given explicit criteria and requirements (Rughinis, 2013), and reflect on their learning experiences (Jovanovic & Devedzic, 2014). Some scholars have worried that the use of microcredentials in teaching and learning is too outcome/performancebased, thus potentially distracting learners from focusing on the learning content and activities (e.g., Reid et al., 2015; Stetson-Tiligadas, 2016). However, microcredentials not only recognize performance but also provide stamps all along the progress of learning to reward students for their efforts and improvements, making students more persistent on learning tasks and activities (Jovanovic & Devedzic, 2014; Rughinis, 2013; Santos et al., 2013).

Microcredentials as a Portable Learning Platform in Pedagogical Practices From a more microscopic perspective, a single microcredential can be used as a portable learning platform that is embedded with instructional elements and pedagogical strategies as metadata (Randall, Harrison, & West, 2013). For example, the instructional badges developed by Purdue University carry instructions, examples, explanations, demonstrations, and simulations (Newby, Wright, Besser, & Beese, 2016). From an instructor's perspective, microcredentials can support learning by affording multimedia content design, corrective and summative feedback, scaffolds, and communication tools (Antin & Churchill, 2011; Besser, 2016; Newby et al., 2016). From learner's perspective, a microcredential serves as a portable learning unit with rich instructional materials that can be accessed anywhere and at anytime (Grant, 2014; Newby et al., 2016).

Randall et al. (2013) and others (e.g., Cucchiara et al., 2014; Wills & Xie, 2016) described ways in which microcredentials may promote the development of *self-regulated learning,* which has been shown to increase student achievement (e.g., Hattie, 2009; Pintrich, 2002). For example, "a badging system can potentially support self-regulated learning by offering very specific and attainable goals as badges…. In addition, [it] can offer multiple choices of badges for students to complete, giving the students greater choice and autonomy" (Randall et al., 2013, pg. 89). Beyond autonomy, microcredentials support personalization of learning goals and the selection of learning paths (Wills & Xie, 2016). To examine this more closely, Cucchiara et al. (2014) have designed a badge ecosystem for use by students studying biomedical research to monitor how those badges support SRL development. From a *social learning* (SL) perspective, people learn from interacting with the environment through observation, imitation, and modeling (Bandura, 1977). However, a lot of challenges remain for social learning in an online environment because of physical limitations (Hill, Song, & West, 2009; Song, Singleton, Hill, & Koh, 2004). Serving as social objects and boundary objects across different contexts, digital open badges can signal community, help develop subcommunities that share the same interests or goals (Peer 2 Peer University & Mozilla Foundation, n.d.), and involve the community in student learning and assessment (Vanacker, Demedts, & Van Puyenbroeck, 2018). For example, "badges are made completely public as to increase the overall awareness of students' achievements and motivate engagement through social comparison…and award earners certain roles associated with both privileges and responsibilities in the learning community (e.g., becoming moderators, facilitators, editors, etc.)" (Jovanovic & Devedzic, 2014, p. 58–59). As with most areas of research with digital badges and other microcredentials, additional research is needed to map microcredential affordances to the development of SRL and SL.

Conclusions

The research literature about open microcredentials is small but growing (the number of journal articles nearly tripled from 2014 to 2015, according to Liyanagunawardena et al., 2017). This is unsurprising given that they are a relatively new technology. However, previous successes of alternative credentials support the belief that the open and micro nature of open microcredentials will only improve the value and applicability of alternative credentials as companions to traditional credentials. In our review of the literature, we found emerging support that these open microcredentials can improve learner motivation when designed appropriately, augment and increase the value of credentials and the signals they provide to employers and other interpreters, and have some effect on student learning and individualized, autonomous education. However, additional research is needed that not only describes case studies of badging systems (which is what most of the current articles provide) but evidence for positive outcomes that can be useful to decision-makers weighing the option of offering these credentials. In particular, we need to expand our view to consider research evidence on open microcredentials in other languages/countries (Liyanagunawardena et al., 2017), as the open international standard provided by IMS Global has allowed the movement to expand globally. Finally, Hickey and Willis III (2017) delineated an excellent research framework for needed research in open microcredentials and badges, explaining that we need:

1. Research *of* badges, systems, and ecosystems.
2. Research *for* badges, systems, and ecosystems.

3. Research *with* badged evidence and *of* badges, systems, and ecosystems.
4. Research *with* badged evidence and *for* badges, systems, and ecosystems.

As more of these studies are completed, we will be better able to ascertain the true value of these open microcredentials.

Perhaps the biggest challenge impeding greater microcredential adoption is concern over their sustainability. Recently, solutions have been proposed, including the use of consortiums, crowdsourcing, pay-per-credential systems, and scaffolding of undergraduate assistants. In addition, alliances have formed to support individual credential issuers. However, challenges remain, particularly in managing the workload associated with offering open microcredentials and establishing their validity. Much research and practice have been focused on how to use the Internet to improve access and quality to educational content and relationships. The next step, we believe, is to create scalable models for how to use the web to improve access and quality of educational credentials. This step will enable education to embrace the potential of twenty-first-century disaggregated, global, and lifelong learning.

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Research Chapters Afterword: What Role Could and Should Instructional Designers and Technologists Play in Achieving Larger Educational Goals?

Barbara A. Bichelmeyer

Now we are getting somewhere!

I fully agree with Reeves and McKenney when they state in the Foreword that there are signs of hope throughout this 5th edition of the *Handbook of Research on Educational Communications and Technology*. It is cause for celebration that this edition of the *Handbook* shifts the perspective of research and practice in the field of instructional design and technology so that:

(a) Instructional technology is positioned less as an end unto itself and, more usefully, as a means to the end of addressing critical challenges we face across the globe today.
(b) Instructional design is treated as a complex process that is best understood through real-world cases that introduce the disciplined use of precedent to shed light on the scope and variety of approaches to practice.
(c) Instructional technology and instructional design and research and practice are each presented as distinct, unique, basic elements of our field, while at the same time they are integrally linked as building blocks by which we will both provide solutions to critical challenges and advance our understanding of our work.

Defining Our Challenge and Our Role

The editors of this volume have accomplished no small feat and none too soon. To remind you of the landscape Reeves and McKenney painted for us, while noting they did not overstate the matter, our entire planet is currently in peril due to extreme nationalism, racial and religious tensions, conflicts between superpowers, growing

B. A. Bichelmeyer (✉)
University of Missouri – Kansas City, Kansas City, MO, USA
e-mail: bichelmeyer@umkc.edu

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economic inequality, and climate change that threatens our one and only habitat (Harari, 2015). Surely, the best hope for addressing the ignorance, vulnerability to propaganda, and the resulting fear and hate that are the root of most of these perils is to increase engagement in quality education at a scale the world has never before seen. So, if there was ever a time in history when we need to harness instructional technology in service of better educational solutions, to design instruction across a great scope and variety of contexts, and to link research and practice to better understand our successes and failures—the time is now. Simply put, the achievements of this volume are also the legend to the map for how we will overcome our current deficit of learning opportunities and ineffectiveness of educational programs, which will allow us to find our way past the seemingly insurmountable obstacles that currently block our progress toward a better destination. This journey is going to require all of us—researchers and practitioners of instructional designers and technologists in schools, universities, businesses, government agencies, and nonprofit and nongovernment organizations, on every continent and in every country on this planet—to find our way together by working collectively and collaboratively in service of this greater good.

To be clear, I'm not saying that researchers and practitioners of instructional design and instructional technology should simply have a role in this work. It is critical, I would argue, for instructional designers and technologists to *lead* this work if we are to achieve our larger educational and societal goals. In this transformational moment, we who research and practice in the field of instructional design and technology are in a unique position to recognize the major shifts in technology and society that are moving education, training, learning, and performance closer to each other and closer to the fabric of people's daily lives. Our mission is to understand and leverage the impact the Internet is having on disaggregating our massively complex educational systems, which is moving us toward more personalized learning systems that will provide just in time, just in place, just as needed instructional experiences for learners in both formal and informal educational contexts.

I remember, in the mid-1990s, serving as discussant for an AECT session in which four presenters shared findings from their various research projects, all of which focused on how to integrate computers into K-16 classrooms. I had an aha moment as I listened to the themes that were repeated in each presentation. In my summary remarks, I wondered aloud if asking how we were going to integrate computers into classrooms might be asking the wrong question and whether we would be better served by asking how networked computers might eliminate the need for classrooms at all. This moment in educational history has been a long time coming.

I'm writing this piece on June 3, 2019, as I'm in Tempe, AZ, for a leadership summit sponsored by Civitas Learning, a higher education data analytics company focused on improving student success. I'm listening to Syracuse University Distinguished Professor Emeritus Vince Tinto tell the audience that, in the near future, learning will no longer be time-boxed and age-boxed as it is today. NCHEMS President Sally Johnstone argues that we need to build parallel structures to integrate living, learning, and working, that these environments should allow us to work *with* students instead of presenting *to* students, and that our connections with students should not be just for 4 years but rather should support learners throughout their lifetimes. Civitas cofounder Mark Milliron posits that we are moving toward the golden age of learning. Milliron notes that we have more tools and technologies than ever before to promote learning, and we need a totally different orientation to data, a culture of care, and faculty communities of practice dedicated to continuous improvement of the student experience. Three different leaders, three different visions of the future—all squarely describing the research and practice of instructional design and instructional technology. The opportunity we have been waiting for is literally right in front of us.

Clarifying Our Goal to Address Our Challenges

In this edition of the *Handbook*, it has been made clear that we face global peril, that we need new approaches to education in order to address the perils we face, that we need a shift in perspective about how we go about the work of research and practice in instructional design and technology, and that we are in a unique position to lead this work. Additionally, in this edition of the *Handbook*, we have a compelling call to action, which I predict will re-energize our field and revitalize our reputation among those outside the field who so greatly need help and answers on a scale beyond what we've previously delivered. On behalf of instructional design and technology researchers and practitioners everywhere, I thank the editors, authors, and members of the International Advisory Board for this contribution.

So yes, we are definitely getting somewhere with this edition, and still, we are not quite there yet. As Reeves and McKenney and the editors have noted, this edition leaves one important ambition unachieved, since no one answered the call to complete a review for a planned seventh section which asked, "What role does instructional design and technology play in achieving larger educational goals?" Reeves and McKenney stated that, while they were disappointed, they were not surprised by this situation, given the fact that our research has historically focused on specific technologies—hard, soft, and emerging—rather than focusing on the problems that these technologies might help to address.

While I agree with Reeves and McKenney that we have historically focused too much on technologies and not enough on problems, I also propose there might be a deeper, though related, reason why no one answered the call to address this question. It seems to me this question begs other, more fundamental questions about our field that we haven't yet answered. First, in order to answer the question of what role instructional design and technology play in achieving larger educational goals, we must frame it by answering the question: What are our larger educational goals? Then, after we've clarified our larger educational goals, we may answer the question of how we, as instructional designers and instructional, might go about achieving them.

The question about our larger educational goals brings to mind a lesson I learned almost 25 years ago from Michael Molenda, associate professor in the Department of Instructional Systems Technology (IST) at Indiana University, who was teaching courses on foundations and theories of the field. Each fall, when IST faculty would review syllabi for these foundational courses, Mike would remind us of the purpose of education and opine on the difference between information and instruction. Mike would explain that information is the reduction of uncertainty and note that information is a necessary but insufficient condition for instruction. Further, he would describe instruction as the intentional act to educate. Finally, he would define education as the increase in capability such that a person could do something she could never do previously—whether it be completing a psychomotor activity, categorizing a concept, applying a principle, or addressing any complex cognitive task.

Mike's definition resonated with me because it acknowledged that education occurs in a nested activity system—information dissemination is an activity nested in an instructional system, instruction is an activity nested in an educational system, and education is an activity nested in a human performance system, whatever the goals of that performance may be. The idea of education as an activity in a nested system recognizes that instruction can only do so much. Instruction can't make up for deficits that may exist in the larger systems that impact human performance, systems that involve processes and resources and incentives, and that determine whether a student is able to transfer learning beyond a classroom and into the "real world" —whether the real world is home, work, or larger society.

If our "larger educational goals" are to help people do things they could never previously do, then we must also ask, "What responsibility do we as instructional designers and technologists bear for working with others to ensure that, when our students step out of classrooms and into the real world, they are able to put their newlydeveloped knowledge and skills to good practice?" Answering this question honestly may lead us to more respectful, productive collaborations with our interdisciplinary colleagues and professional partners, in fields such as management and leadership development and coaching and human resources, in social, industrial, and organizational psychology.

The first time I considered this question in earnest was in March 1984, some years before I would call myself an instructional designer, when, as a secondary school teacher, I took a group of students to spend a week at Hope House, an education and service program in New Orleans, led by Sister Helen Prejean. One morning, a brilliant woman who was serving as a school district superintendent met with our group. She talked about the lack of resources available to her students and the lack of support they received from their families, from their communities, or from government entities. She talked about the fact that, in America, we are taught to believe in the power of education, and we assume that, if people are provided with enough or good enough education, they will be able to pull themselves up by their bootstraps. Then she paused for what I remember as a very long time, and with a weary voice, she asked in a very hushed tone, "…but what happens if they don't have any bootstraps?"

In summer 1988, I was offered a graduate research assistantship as part of a grant from Apple Computer, to evaluate teachers' perceptions of a newly established computer resource network that was designed to support their teaching. Each participating teacher received her/his own personal computer and comprehensive training on how to use it for teaching activities and class management. Still, very few adopted the computers into their work in any meaningful way during the first 3 years of the program. I was faced again with the fact that, even in a situation that involved the most willing teachers and the most current technology, education alone was not enough to ensure change or improvement in performance.

In 1991, as I was finishing my dissertation, I found myself working as an instructional designer at the then newlyforming Sprint Corporation. Sprint had contracted with Joe Harless to implement his turnkey process, known as Accomplishment-Based Curriculum Development (ABCD), for analysis, design, development, implementation, and evaluation of training programs. Harless said ABCD was his solution to a problem he had experienced repeatedly, in which he designed instruction that provided students with new knowledge and skills, only to watch them leave the classroom and never fully utilize what they had learned. The goal of ABCD (Harless, 1987) was to help instructional designers work with managers to engineer performance environments so students would have the supports required to transfer and apply the skills and knowledge they had acquired during training back on their job and in service of larger organizational goals.

Elsewhere in this *Handbook*, the editors cite Reeves and Reeves (2015), who are calling upon instructional designers and technologists to recognize that we live in a volatile, uncertain, complex, and ambiguous (VUCA) world and who encourage us to start focusing on solving problems created by this reality, rather than focusing on adopting technology for the sake of its own use. It is precisely because we live in a VUCA world that I have shared the stories above. My hope is to illustrate that we, as instructional designers and technologists, must be absolutely clear that our goal of teaching people to do things they could never previously do is a nested goal in a larger human activity system, it is wildly audacious, we cannot afford to fail, and we cannot do it alone. It is critical that we understand a large part of the complexity we face in our work is precisely because all of the work we do in our nested activity systems and in service to our goal is either in a system over which we have very little control or is completely outside our control. What this means for us in practice is that, if we have any hope whatsoever of being successful in our work, we must have both laser-like focus on our goal and absolute humility about how little we control, so that we will be able to work appropriately in partnership with others as we design and implement solutions.

To Advance Understanding of Instructional Designs and Technology Integration, Focus on Precedent, Failure, and Theory

In the Introduction to the Research section of this *Handbook*, the editors clarify their intention that this edition "should be organized in a way that can meaningfully inform design practice by [fostering discussion] on how research findings/

technological developments might be relevant for particular tasks, challenges or problems." Further, they express their hope that the field of instructional design and technology might evolve such that it is "characterized by putting actual issues and real problems at the core" so it becomes "a field that is truly scientific and relevant."

Similarly, in the Foreword, Reeves and McKenney call on us to practice both research-informed design and design-based research, which they describe as a genre where "the iterative development of solutions to practical and complex educational problems also provides the context for empirical investigation, which yields theoretical understanding that can inform the work of others" (McKenney & Reeves, 2019, p. 6).

If we are to live up to the editors' aspirations of being truly scientific and relevant in solving the perils of the day, we simply must commit to researching and teaching differently. Certainly, we are going to need to make sure our research does not study technology simply for its own sake. Beyond that, and with a further way to go, we can start by taking up the charge presented to us by the editors when they say we need research that captures design precedent and we need research that captures and exposes us to design failure. Just to be clear, when I read about design precedent and design failure, I take it to mean not only precedent and failure in instructional design, but I also take it to mean precedent and failure in our designs for technology implementation and integration.

Finally, going beyond the charge to study precedent and design failure, I feel the need to explicitly state and dwell for a bit on a statement made by the editors and Reeves and McKenney, which is we need research that is clearly built on theory and that adds to our theory base.

Studying Precedent The editors of the Design Case section make a strong argument for the importance of studying precedent, noting that instructional design and technology as a field is prone to issues of "deceptive clarity," which they explain as, "in the absence of understanding the complexity of design practices, inexperienced designers tend to envision a relatively simple and straightforward scope of work required to produce an effective learning experience." The consequence of this situation is that instructional designers are ill-equipped to work in nested systems and in situations where they lack control (which will be most of the situations they face) and are ill-prepared to address the volatility, uncertainty, complexity, and ambiguity about which Reeves and McKenney have warned us.

Simply put, studying design cases and the precedents they reveal will help us to identify aspects of design processes that are both more and less in our control and will draw our attention to the most and least useful features of a design for addressing a particular problem. Further, by bringing structure to the study of precedent, design cases allow us to make sense of complexity as they provide details that bring out the richness of contextual factors and nuance that strengthen our understanding of design.

As the editors explain, the study of precedent in design cases brings context and nuance "firmly and pervasively in mind for us as researchers when we engage in theory-building or developing theory-based prescriptions intended to benefit practice the field." Conversely, they warn us that "if our research is not informed by appreciation of the wide array of practice in the field" (which is available to us through design cases), then "we risk narrowing our theoretical research and the knowledge it produces, until we are not relevant in many of the contexts where we could, and should, be making a difference."

In 1990 (almost 30 years ago!), Steve Tripp and I coauthored an article on rapid prototyping that was published in *Educational Technology Research and Development (ETR&D)* for the express purpose of providing an alternative instructional design strategy to the ADDIE model, which we found to be relatively unworkable in practice (Tripp & Bichelmeyer, 1990). Using precedent from another field, the goal was to articulate an iterative model of design and evaluation that looked much more like how we actually engaged in our practice of instructional design. The fact that this is one of the more popular instructional design models in the history of *ETR&D* (Pacetti-Donelson, 2018) demonstrates three important points to support the editors' claims that we need more research on precedent and more design cases: (1) instructional designers and technologists are hungry to understand and use processes that might help them to do their work better and to more effectively solve educational problems; (2) in the absence of well-grounded research about precedent, instructional designers are left with models that are based on other, less-than-ideal criteria such as simplicity or logic which have not been vetted through real-world experience and therefore may not be workable in actuality; and (3) our appetite for precedent is not likely to diminish, because the need to reinvent practice and research is ongoing in a field where we are always working with new technologies and where our work will always be done in nested systems and complex environments.

Studying Design Failure In most human affairs, one of the greatest opportunities for learning is the reflection that inevitably comes after failure. Earlier in this chapter, I explained that Joe Harless developed the ABCD model to address repeated failures he experienced as an instructional designer. The design of the ABCD model is foundational and arguably one of the more important contributions to the field of human performance improvement. Yet, if Harless had authored a study of the failures that led him to design this innovative turnkey system, it is not likely that a peer-reviewed journal in our field would have published it.

Lest you think this claim may be an exaggeration, allow me to draw from my own experience to make my case. Some years ago, while they were students at Indiana University, Kursat Cagiltay, Trena Paulus, and I designed and implemented a study that leveraged computer networks to connect students in three secondary classrooms on three continents, in order to teach lessons about appreciating diversity and intercultural communication. The initiative was riddled with problems throughout, and we learned a variety of lessons about what *not* to do when setting up an intercontinental network in secondary schools—which had to do with everything from unanticipated firewalls, lack of interactivity between the same computer systems configured in different countries, and matching up teaching schedules across multiple time zones. While you may assume these are things we should have figured out prior to the study, the point is that we learned them by the end of the study, and though the project implementation was a failure by all accounts, we were a lot wiser as a result, and we wrote a great case study about our failure, which I am sure would have helped any teacher who also wanted to solve the real-world problem of helping her/his students develop intercultural understanding. The problem was no peer-reviewed journal would publish it.

As the Design Case section editors point out, we do not have any traditions in the field of instructional design and technology of explicitly and purposefully sharing our design failures. We miss all of the lessons that so many other disciplines—such as medicine and law and engineering (just to name a few)—are able to capture from their failures, which allows them to advance their knowledge base by exploring, understanding, and correcting the erroneous assumptions and activities that led to failure. By not publishing failure studies, we are leaving on the table important lessons that would improve our practice and increase the effectiveness of our interventions. As a result, much of our research invariably "proves the success" of our instructional designs, our technology integration, or our performance interventions—which makes it appear to others (and perhaps rightfully so) as though our field is more pseudoscience than science, where our research (on things such as technology integration) relies on confirmation bias rather than on rigorous attempts to refute or disprove our theories and claims.

I agree with the Design Case section editors when they argue that we should embrace the study of design failure and that such studies should be seen as "the inevitable healthy rethinking and appropriate re-direction of effort that characterizes every design project."

Studying Theory While I share the same hope expressed by Reeves and McKenney in the Foreword that this edition of the *Handbook* might lead to the enrichment of theoretical knowledge about instructional design and technology, I have come to the conclusion over the course of my 30 years as a researcher, teacher, and practitioner in the field that we are not likely to enrich our theories as a result of our practice if we don't explicitly design our practice (whether that is instructional design, technology integration, or research) so as to test a theory in the first place. To illustrate this point, I return to the example of human performance improvement.

The question of how to best engineer human performance is traced to social psychologist Kurt Lewin, who was interested in applying general systems theory to understand human behavior in organizational settings. Lewin (1939) created the first "performance equation," which posited that human behavior is a function of both the person and the environment. The performance equation may be thought of as a theory that has been adapted by various researchers and practitioners in the field of instructional design and technology, including Harless (1972), Gilbert (1978), Rossett (1992), Wile (1996), Chevalier (2002), Bichelmeyer and Horvitz (2006), and by Boise State University Assistant Professor In-Gu Kang (2014) in his yet-unpublished dissertation, which received the 2017 Distinguished Dissertation Award from the International Society for Performance Improvement. Testing the theory behind the performance equation using multiple solutions and across multiple contexts would lead us to a better understanding of the relationship between education and human performance, as well as to a better understanding more generally of the key influences, or combinations of influences, that lead to improved human performance and the achievement of organizational goals. The performance equation could and should provide guidance to anyone who is responsible for engineering organizational systems to improve human performance, however human performance is specifically defined and in whatever specific domain it occurs. Yet, to date, there have been very few projects or research studies in our field that have tested this theory. Each and every time we decline to articulate a theory that guides our instructional design, our performance intervention, or our research study, we waste a valuable opportunity to better understand the applications of a theory, its limits, its potential, and its relevance to our work. Each and every time we decline to articulate theory, we waste the opportunity to work together to advance our knowledge base and improve our practice.

Instructional designers and technologists who say we want our designs to make a significant contribution to educational success, and we who say we want educational successes to transfer beyond classrooms into the real world where our greatest aspirations play out against our grandest challenges, we simply must articulate the theories that guide our work and design our interventions to put our theories to the test. It was Lewin (1943) who said, quoting "a business man," that "there is nothing so practical as a good theory" (p. 118). As was true for Lewin, anyone who practices, teaches, or researches in any field that strives to improve human performance should want to ensure that their work is not only useful and relevant but also that it is scalable and sustainable so it can outlive its' originator. Scalability and sustainability don't happen by accident; they happen when we are able to use theory to influence practice across a wide variety of settings.

Emphasizing Our Unique Knowledge and Skills as Instructional Designers and Technologists

The part of the question posed here that asks "What role *could* be played by instructional designers and technologists…" considers what skills and expertise instructional designers and technologists bring to bear on their work. Some years ago, Professor Charlie Reigeluth, my colleague in the Department of Instructional Systems Technology (IST) at Indiana University, joked that the field of instructional design and technology is "the contentless content area." He meant that, in a school full of programs in math education, science education, and language education, IST was/is uniquely focused not on the content (math, science, language) of education but rather on the *systems*, *processes*, *and technologies* of instruction. This is exactly the role instructional designers and technologists could and should be, and in many cases already are, playing in achieving our larger goals of designing educational systems that better support human performance.

Instructional designers and technologists are able to engage in systems thinking, task analysis, reverse engineering, formative evaluation, process mapping, and technology utilization. As explained in the beginning of this chapter, it is not overdramatization to say that these are skills the world critically needs right now in order to engineer the human performance that is required for our survival. We desperately need instructional designers and technologists who can and will take the lead in working with others to reeducate citizens about how to engage in civil discourse in the era of social media, to deliver broadband access in rural areas, to advance information literacy for global citizens in an age of information overload, and to address global climate change for future generations.

MJ Bishop notes that, in her work as founding director of the William E. Kirwan Center for Academic Innovation at the University System of *Maryland, her colleagues think she has special talents, while she knows she is simply applying knowledge and tools of instructional design.* When I was first asked to take on an administrative role at Indiana University, I accepted the position in part because some of my graduate students dared me to practice what I preached—and researched—related to the need for technology integration to better support personalized learning and human performance. I believe that instructional designers and technologists are often tapped as problem-solvers because our skills are the answer to the challenges our world faces. We are called upon because we are designers, and design is so important because "it allows us to initiate intentional action out of strength, hope, passion, desire, and love" (Nelson & Stolterman, 2014, p. 20).

Mark Milliron is right—this *is* the golden age of learning and therefore also the golden age of instructional design and technology. The world needs us, and this is our time. Let us claim our role—not only in order to address the perils and problems of the past; let us also build the future to which we aspire.

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PART 2
Design Case Chapters

Introduction to Design Case Chapters

Vanessa Svihla and Elizabeth Boling

What Is this Section?

This section of the handbook presents detailed descriptions of 13 instructional designs, the contexts in which they were created, and how they came to be what they are. Proposals for the chapters in this section were solicited and reviewed similarly to those appearing in the previous section, but the intent of the chapters themselves is entirely different. Rather than presenting research, or overviews of research, they present design and the results of designing.

What we have gathered for this handbook are design cases that share, in addition to descriptions of design, insights about instructional design processes and decisions. The authors of these cases write explicitly about the contexts in which these designs were conceived or modified, about critical decisions that went into their creation, and about aspects of the designs or design processes deemed by those authors to be of particular interest to other designers. We have held these authors, through cycles of blind and developmental reviews, to standards of rigor tied to the descriptive value of their cases. Trustworthiness in representation and writing comes about through taking a critical stance and writing about both successes and failures with transparency and inclusiveness. Design cases that highlight their own distinctiveness and, through editorial selection, present variety and make a contribution to precedent in the field.

V. Svihla (✉)
Organization, Information & Learning Sciences, University of New Mexico, Albuquerque, NM, USA
e-mail: vsvihla@unm.edu

E. Boling
Instructional Systems Technology, Indiana University, Bloomington, IN, USA

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What Are Design Cases?

Design cases are a form of knowledge-sharing, and consequently knowledge-building, common to – and critical in – fields where design is a central practice. Readers may have noted elsewhere books, periodicals, and even awards events, in which, collectively, thousands of design examples – architecture and interior design, product design, graphic design, design engineering, urban planning, set, production, and costume design – appear in varying levels of detail. While some of these can be, and are, interesting for the general public, the robust investment made by designers, writers, curators, and publishers in many fields of design to produce and circulate such material is intended first to benefit designers.

The description of a design – what we will term a *design case* – may be as simple as the image of a chair or a logo as, for example, in *LogoLounge 2: 2000 International Identities by Leading Designers* (2006). Others are expanded to include multiple images and some text describing the context of a design, as in juried design annuals published in multiple fields (e.g., *Trade Fair Design Annual 2018/19* (Marinescu & Poesch, 2018); *Illustrator's Annual*, (Bologna Children's Book Fair, 2018); *Red Dot Design Yearbook 2018/2019: Living, Doing, Working and Enjoying* (Zec, 2018)). Still, others are as comprehensive as a full-length book dedicated to presenting one design from conception to implementation and ultimate abandonment or destruction, as in the classic example of *Twin Towers: The Life of New York City's World Trade Center* (Gillespie, 1999), or an in-depth presentation of how a feature film has been designed and created, like *Guillermo del Torro's Pan's Labyrinth: Inside the Creation of a Modern Fairy Tale* (del Torro, 2016).

The format for design cases in this volume is extended and rigorous, although not comprehensive, one. Authors have been encouraged to give readers a vicarious experience of what has been designed – the experience, materials, course, or system – and to be selective but critical and transparent, in presenting key decisions or processes contributing to these designs. We have not required authors to include findings, conclusions, or lessons learned that are intended as generalizable outcomes based on their design efforts; indeed, we have discouraged them from doing so. Design cases are self-contained and particular; they are created to allow readers, always assumed first to be other designers, to build episodic memories usable to them later. Such memories can be used by direct application to new design situations, but they are more often used in analogous ways or by building design schema that affect future design activities and decisions. In other words, the knowledge obtained from a design case is not exclusively, or even most often, valuable in the event that it can be understood and applied immediately or explicitly. This knowledge is acquired provisionally, added to an existing store of experiences, and possibly not even recalled in any literal sense, even at the time of its eventual use. The knowledge *is* the vicarious experience.

What Is this Section Doing in a Research Handbook?

If design cases are created and shared primarily to benefit designers, why have we decided to include them in this handbook? While past versions of the handbook have presented up-to-date perspectives on topics and technologies relevant to the field, with the focus in this version on problems, we see several reasons design cases belong in such a volume.

First, the focus on problems in this edition of the handbook makes learning and instructional design particularly salient. As we read chapters from the first volume, we find ourselves envisioning not just research studies that investigate these problems but also considering the kinds of learning experiences that might be beneficial in addressing those problems. While past handbooks shared what was already known – solutions to problems past – this version presents the unresolved edges of our field. By refocusing the handbook around problems, we are primed - and hope to prime readers – to also think like designers. And because designers' work is first and foremost *problem framing*, it is a natural fit to bring together problems and precedent. Reading and understanding representations of designs actually occurring in the field demonstrate how abstract problems are framed in the world of practice that research is aiming to understand and support. Such precedent can inspire and inform us, whether we work as instructional designers or as researchers who design learning experiences in order to study new forms, sequences, and configurations of learning.

This precedent may also inspire our research more directly, by influencing the ways we think about designing studies. The care and focus on contextual factors that design cases express can help researchers think about ways their own studies might be bespoke, rather than off-the-rack. While this represents a trade-off with generalizability, it sensitizes us to considerations of transferability, necessarily considering the ways any design is fit to one context and may need to be altered for another. As we watch adjacent fields struggle with failed replications of studies, we agree that context can influence outcomes in myriad ways (Stroebe & Strack, 2014), making its consideration a central responsibility for researchers. Thus, design cases may inspire us and provide much-needed knowledge about ways designers approach and understand context in their work. Table 2 provides a crosswalk of design cases and research chapters to help readers discover ways in which these in-depth presentations of individual designs can inform and inspire you as a scholar.

Our second reason for investing considerable effort to include design cases in this handbook is that design cases are themselves a form of scholarship; they build knowledge through empirical means. Just like papers that report on research studies, published standards exist for evaluating design cases (Boling, 2010; Smith, 2010). Also like papers that report research studies, authors new to the genre typically struggle to produce papers that represent designing and designs (Howard, 2011), that is, there is intellectual effort required to represent a design evocatively and to select and discuss the critical aspects of how it came into being when the future use of your work is unknowable to you as an author. It is critical to understand that the means by which design cases build knowledge are different than those applicable to generalizable studies. They build knowledge within the individual reader – who is assumed to be a designer. Each of these readers is accumulating a store of knowledge unique to herself – although in a field where many, many cases are available and are curated through competition, edited collections, teaching canons, and so on, the individual store of knowledge may overlap with, and be significantly influenced by, widely shared vicarious experiences gained through exposure to design cases. Prior to publication, then, peer judgment focuses not on their demonstrated contribution to established knowledge but on their accessibility to other designers and appropriateness as propositional knowledge for indeterminate future use.

Thirdly, design cases also shed light on the scope and variety of design practices in use. Instructional design is often, although not always, taught as a prescribed sequence or iteration of steps focusing on processes (e.g., ADDIE), with clarity about the kinds of activities that should be undertaken in each step. While other methods encourage designers to be agile and iterative, the limits of courses, even client-driven design projects, can render such moves artificial. Design cases provide insight into authentic drivers of iteration. Likewise, while models like ADDIE suggest designers should treat every setting and group of learners as if they are foreign and unknown, and dutifully conduct analysis to fill in these unknowns, we see from design cases that this is seldom how designers operate. Rather than deploying a necessarily broad-and-shallow approach to analysis, designers build on the familiarity they have, concentrating their efforts on actual gaps, often resulting in deeper yet efficient analysis.

More broadly, design cases highlight *where* people are designing and *what* they are designing; this raises framing questions in educational technology research. Specifically, are the conditions of low resources, profound discrepancies in access and preparation for education, conditions of social, cultural, and geographic remoteness from and between learners, and imperatives set by governments or institutional hierarchies firmly and pervasively in mind for us as researchers when we engage in theorybuilding or developing theory-based prescriptions intended to benefit practice the field? And if our research is not informed by appreciation of the wide array of practice in the field, which we hope to open a window onto through these design cases, we risk narrowing our theoretical research and the knowledge it produces, until we are not relevant in many of the contexts where we could, and should, be making a difference.

How this Section of the Handbook Might Be Used

While readers may simply elect to read design cases that hold appeal, perhaps because of their settings or the specific designed solutions they present, as editors, we can also offer several perspectives from which to appreciate this section of the handbook.

Perspective: Context and Focus of the Designs

An immediately accessible path into the design cases may be to consider when, where, and to what purpose each design was developed, choosing those of personal or professional interest (Table 1).

Perspective: Scholar's crosswalk of research problems and cases For researchers, it may be particularly useful to begin by reading design cases that relate to the research problems they study. To this end, we have created a matrix that links the research chapters to the design cases (Table 2).

In this process, we also noted a few gaps. Specifically, there are research chapters that relate to few design cases and design cases that relate to few research chapters. In the former instances, the research chapters are narrow in scope. For instance, chapters that focus on particular disciplines, like mathematics; learner types, like students with learning differences; or specific issues, like digital badging, are certainly areas in which instructional designers are committing time and effort, but few submitted viable cases for this collection. In the latter instances, where design cases relate to few research chapters, we note that this is not because of a lack of relevant research problems. In fact, two of the cases in particular – design cases 3 and 8 – report on scaling systems to achieve larger educational goals, focusing more broadly on equitably improving student success. As noted in the foreword, this is an area the research chapters failed to address. Several of the design cases shed light on ways instructional designers grapple with this larger goal of scalable, sustainable, and equitable change. Understanding how designers cointend with these issues, which are often in tension, could provide researchers with insight about fidelity (and generalizability) versus adaptability (and transferability) in their work. We discuss some of these issues in more depth in the curator's notes below.

Perspective: Cases as a teaching and learning tool Design cases are particularly useful for learning and instructional design courses and for those who have limited prior design experience. The honesty and authenticity of design cases provide a window into professional practice that students who plan to enter the field commonly crave, tracing the sometimes mysterious terrain between context, problem, knowledge, and solution that a set of prescribed processes does not fully map out for the as yet inexperienced. In this use, design cases are not the same as teaching cases, although both may be used to good effect. Teaching cases may be derived from real-world examples of practice but are typically refined and organized to ensure that the learning points they contain are discoverable to students. Design cases, in contrast, offer students a chance to explore practice in the terms that designers themselves elect to offer when they speak to other designers and typically provide a vicarious, concrete experience of what was designed. They may be a useful adjunct or augmentation for teaching cases in this regard. Like teaching cases, scaffolds help students notice salient aspects, such as "What decisions did the designers make? If you had been involved, what other ideas or decisions would you have suggested?"

Table 1 Design cases with identifiers for location, learning context and focus of the design

Design case	Location	Learning context	Focus of the design
DC1. Khendum Gyabak: WASH by design: A design case on the collaborative curriculum project for elementary schools in rural Papua New Guinea	Oceana	Elementary teachers; village schools	Sanitary practices
DC2. Camille Dickson-Deane: Designing with forgiveness in mind for the process	Australia and Latin America	Higher education, faculty development	Faculty development and ID practice
DC3. Michael C. Johnson, Larry L. Seawright, & Jason K. McDonald: A design case of an enterprise-wide learning management system	North America, USA	Higher education	Learning Management System (LMS)
DC4. Ana-Paula Correia: Finding junctures in learning design and entrepreneurship: A case of experiential learning in online education	North America, USA	Higher education, online graduate course	Instructional design and entrepreneurism
DC5. Julaine M. Fowlin, Carina Gallo, & My Lilja: Expanding the reach to first-generation students: a collaborative learning experience between criminology students in Sweden and the United States.	North America, USA and Western Europe	Higher education, online undergraduate course	Criminology
DC6. Robert Monk, Carrie Lewis Miller & Hunter King: Reinventing military science in higher education: Using service learning and cloud computing to develop future leaders	North America, USA	Higher education, service learning	Military science; ROTC
DC7. Ali Kürşat Erümit An activity-based design case for step-by-step teaching of programming to secondary school students	Middle East	Secondary school	Computer science; programming
DC8. Wendy Martin, Megan Silander, Katherine Culp, Cornelia Brunner, & John Parris: Supports for digital science games: visualizing and mapping analogies	North America, USA	Middle school	Science; games

(continued)

Table 1 (continued)

Design case	Location	Learning context	Focus of the design
DC9. Drew Polly & Christie Martin: Design case for asynchronous online professional development in primary grades mathematics	North America, USA	Elementary teachers	Mathematics, assessment
DC10. Robin A, Medley, Charles Nolly, Tony LaBriola, Yevette Brown, Mick Polowy, Victoria Lloyd, Ciny S. York & Lisa Yamagata-Lynch: Evolutional and technological influences in design: a longitudinal examination of the PRIDE design case.	North America, USA	Government; adult education	Foster parent training
DC11. Jonan Phillip Donaldson, Amanda Barany & Brian K Smith: Situated learning through situating learners as designers	North America, USA	Higher education, undergraduate and graduate students	Teacher preparation
DC12. Jeroen Breman & Lisa A. Giacumo: A cross cultural instructional design case situated in a global workplace learning context	North America, USA, the UK, Africa, the Middle East, South Asia, the Caribbean	International Nongovernmental Organization (INGO)	Performance improvement and training
DC13. Diane P. Janes, Janice Makakois & Kathryn Campbell: Reconciliation as design: a design case	North America, Canada	Higher education / community	Nehiyaw (Cree) teachings and critical thinking

"What were some challenges the designers encountered? How do you think you would have responded in their place?"

And, as previously noted, design cases serve as the means to build up the store of vicarious experience – precedent knowledge – of any designer, aspiring or experienced. This is particularly important in fields like ours, where we have abundant experience *as learners*. As learners, we have encountered a range of situations in which the drivers of design are compliance and tradition – rather than research on learning and context. From settings that depend on learner compliance to trainings that are agnostic to actual learning outcomes, we may carry a burden of unhelpful precedent, or, if we are optimistic about it, a surfeit of helpful examples of design failure. While this is also true in design fields like architecture and fashion, where, on a daily basis, we may encounter utilitarian and mundane designs that could dampen creative potential, we are also able to celebrate innovations in these areas in

Table 2 Crosswalk between research chapters (listed vertically) and design cases (listed across the top)

	DC1	DC2	DC 3	DC 4	DC 5	DC 6	DC 7	DC 8	DC 9	DC 10	DC 11	DC 12	DC 13
R 1.1				x				x	x				
R 1.2		x		x							x		
R 1.3				x	x					x	x		
R 1.4	x			x					x	x		x	
R 2.1									x				
R 2.2	x				x		x			x		x	x
R 2.3										x			
R 2.4		x			x					x		x	
R 2.5	x				x		x			x		x	x
R 2.6	x			x	x		x	x				x	x
R 2.7												x	
R 3.1		x		x						X			x
R 3.2		x		x		x				x	x		
R 3.3										x		x	x
R 3.4	x			x	x								x
R 3.5				x							x		
R 3.6	x					x							x
R 4.1							x	x	x				
R 4.2							x		x				
R 4.3				x							x		
R 4.4									x			x	
R 5.1	x						x					X	x
R 5.2							x						
R 6.1			x						x	x		x	
R 6.2				x							x		
R 6.3													

broadly available ways, such as red carpet looks and television shows dedicated to uncommon building design. There is no such parallel public sharing of innovative instructional designs for our field. Indeed, we have no tradition of sharing design failure explicitly either, so we are left largely to the conceptually inchoate store of personally experienced designs which, during our education in the field, if not equally during practice, is an insufficient basis for knowledgeable practice.

Instructional and learning design, as a field – in contrast to architecture and fashion – is also prone to issues of deceptive clarity. By this, we mean that in the absence of understanding the complexity of design practices, inexperienced designers tend to envision a relatively simple and straightforward scope of work required to produce an effective learning experience. Notably, fields like graphic design are also subject to this concern, but inexperienced fashion designers and architects seldom look at a wedding dress or skyscraper and think they have all the knowledge needed to design such products simply by having worn such a dress or visited such a building. Design cases, therefore, can play an important role in helping future designers build up professional vision (Goodwin, 1994).

In doctoral programs, for those already experienced in instructional and learning design, engagement with and production of design cases can validate the body of expertise and experience they bring. We think this matters because, while such students may have much to learn about conducting research studies, if they build on their foundation as designers, they stand to conduct research that has both scholarly and worldly significance. Those interested in contributing their own design cases to the field should consider the *International Journal of Designs for Learning* (IJDL) or the Design Showcase juried at the time of this publication through AECT'S Design and Development Division at the annual convention. We hope there will be many more, and more varied, opportunities for disseminating precedent knowledge in the field as time goes on.

Perspective: Curators' Notes

As curators of design cases, we are designers ourselves and use that knowledge to find our way into the cases. We begin these notes by briefly summarizing each design case.

> Khendum Gyabak shares how she worked with elementary schools in rural Papua New Guinea to design a curriculum and teacher guides to increase the use of sanitation and hygiene practices. Her case provides insight into design for low-resource settings yet is salient for anyone designing for settings with which they are not already familiar. She shares ways she worked with teachers to support them to develop relevant learning activities.
>
> In her design case, Camille Dickson-Deane provides a forthright account from the point of view of a newlyhired university-based instructional designer tasked with moving an existing face-to-face training – to prepare faculty to teach online - into an online course. Recognizing both learning needs and opportunity, she sought to create a learning experience that would not only address technical aspects of teaching online but also support faculty to teach in a more learner-centered manner. She details how she navigated mismatches in faculty and supervisor expectations.
>
> Michael C. Johnson, Larry L Seawright, and Jason K. McDonald describe the process of developing and deploying an in-house learning management system (LMS) at a university. Driven by concerns over the costs and responsiveness of commercial solutions, this case is distinctive in sharing how these same drivers impacted the design process, characterized by its compressed timeline and need to be responsive both across the design and development team and to faculty needs and expectations. The case details the team configurations and processes, including how they created workflows to deal with distributed design and development on a short timeline.

Ana-Paula Correia shares how she designed and taught an online graduate course as a learner-centered, team-based entrepreneurial course focused on educational technology design. Both designer and instructor, she recounts how an institutional culture that valued her expertise buoyed her efforts and how her autonomy allowed her the freedom to investigate the desires and needs of prospective students and creatively meet these needs. She provides a vivid account of both the scope and sequence of learning activities as well as successes and challenges.

Julaine Fowlin, Carina Gallo, and My Lilja detail the context and design decisions, along with outcomes, from a criminal justice course spanning 4 weeks and two universities in two countries, the United States and Sweden, where theories and perspectives on criminology are distinctly different. The authors discuss challenges, social and technical, involved in implementing this design - including cross-cultural issues and some issues affecting first-generation college-goers.

Robert Monk, Carrie Lewis Miller, and Hunter King engaged in collaboration between the Army Reserve Officers' Training Corps (ROTC) program at a large institution and ROTC candidates at a small branch campus of a private Catholic institution, incorporating Cloud technologies and large service learning projects in the community. The design focused on the personal development objectives within the ROTC curriculum, and the case features an interesting full integration of military processes with supporting technologies into the project/teamwork context.

Ali Kürşat Erümit shares how he led a team of Turkish graduate students with expertise primarily in computer programming to develop a sequence of lesson plans that could engage secondary students in a range of programing activities. He provides a vivid account of how they reviewed existing designs, considered key constraints, and drafted initial lessons, which they subject to internal review, teacher review, and pilot testing, with revisions after each review. This provides insight into the kinds of insights that seem likely depending on the degree of familiarity one has with the context and learners.

Wendy Martin, Megan Silander, Katherine Culp, Cornelia Brunner, and John Parris share details about a multiyear, iterative project that focused on designing digital games to address misconceptions in science. Working with game developers and science education experts, the team sought to create games for use in classrooms, crossing platforms over time. Finding that teachers were not teaching with the games, however, the team details how they developed attendant instructional materials for teachers.

In their design case, Drew Polly and Christie Martin share their efforts to develop online professional development to support teachers to implement specific mathematics teaching strategies following face-to-face professional development. They identified the areas teachers felt uncertain following the initial professional development and identified logistical needs and constraints, resulting in an asynchronous case-based format that scaffolded teachers. They reflect honestly about the shortcomings of a strictly asynchronous design and highlight the successes of tailoring their design to the teachers' needs.

Robin A. Medley, Charles Nolley, Tony Labriola, Yevette Brown, Mick Polowy, Victoria Lloyd, Cindy S. York, and Lisa Yamagata-Lynch share a longitudinal design case spanning multiple formats and decades. They detail the development of a digital training for foster parents that traversed major technological shifts from CD to learning management system. Like many design cases, we gain insight into team negotiations, but additionally, this case is distinct in its foregrounding of traversals amidst myriad changes.

Jonan Phillip Donaldson, Amanda Barany, and Brian K. Smith describe their redesign of a course for preservice teachers, in which they took advantage of the opportunity of a format change - from fully online to hybrid – to also align to learning theories such as constructionism and situated learning. Based on formative assessment, they made adaptations within the course to better meet students' learning needs and position students as designers.

Jeroen Breman and Lisa A. Giacumo describe a project that created training materials for international nongovernmental organizations (INGOs) to enhance in-country partner organizations' capacity related to supply and logistics - a major hurdle for delivering aid, especially during a crisis. They developed standards, assessments, and trainings, including a train-the-trainer model, and piloted these in five countries. This design case reveals complexities of designing for many contexts at once.

Diane P. Janes, Janice Makakois, and Kathryn Campbell detail the design of a course on indigenous industry relations in Canada. Distinctive aspects of this design case include the detailed historical, political, and cultural contextual information that was central to the design and the decolonizing approach the team took to designing instruction. As such, this case provides insight into design practices that shift power imbalances and open spaces for designers to be learners.

Reading across these cases, we note clusters or themes that may draw individual readers toward some of the cases either to explore the theme or to deepen the vicarious experience each case in a group provides, thereby making them all memorable and forming (or adding to) a precedent schema of possible future utility.

Engaging with context Across these cases, the influence of context is pervasive, and designers' approaches to knowing, appreciating, and understanding context vary considerably. Gyabak may stand at one extreme, having traveled to Papua New Guinea and, once there, determined that without a physical tour of the village spaces where learning was to happen, she could not support and facilitate lesson design with teachers there. Janes, Makakois, and Campbell, in a context equally socially and ethically complex, but closer to home – that of the Indigenous Peoples in Canada – focus on forming a design team inclusive of indigenous members, two of whom carried out the entire first iteration of the design. These cases exemplify instructional design efforts being carried out in contexts that stood at a far removed from their own. At the other end, Dickson-Deane situates her case in a context – higher education – not foreign to her but made complex through the human relationships she needed to negotiate in what might have otherwise been a less complicated process. The case by Bremen and colleagues provides a contrast as they sought to design for global audiences using translation and localization of scenarios, finding challenges with both when piloting in countries. Monk, Miller, and King juggled three contexts: the ROTC program at a large institution, ROTC candidates at a small, private institution, and service clients in the community, as they addressed personal development within the military framework for their students.

Orientation of the authors As curators, we draw attention to the orientations and motivations present in author backgrounds and the situations that prompted them to design. Many of the design cases are shared from the lens of *as designer*, rather than designer; this is perhaps because of the nature of this volume, where we disseminated the call for cases, and the relative value different communities ascribe to publication. For instance, the three cases authored by Martin, Silander, Culp, Brunner and Parris, Polly and Martin, and Donaldson, Baranay and Smith are told by researchers-as-designers. In each of these cases, design was central to their research, and their research benefited from a designerly stance. In both Polly and Martin, and

Martin and colleagues' design cases, scalability – of games to address persistent science misconceptions in the former and mathematics formative assessment software in the latter – was a goal, but reaching this goal required iterative refinements and contextual understanding. Both of these were grant-funded research projects that emphasized scale, but we note that it was a designerly stance that made them particularly effective. In Donaldson and colleagues' design case, conducted as design-based research, a designerly stance allowed them to adapt the design based on formative assessment. In this way, this case is likewise told from a teacher-as-designer perspective, but what is common in all the researcher-as-designer cases is an initial problem framing based primarily in research literature rather than worldly precedent. As editors, we received many and accepted few proposals for design cases that were written from the perspective of researcher-as-designer and had to scaffold authors who treated the scholarly literature as precedent to be clear about whether and if they also drew upon worldly knowledge. It is challenging for researchers to shift in this way, to admit that some of their design decisions are made on the fly, instinctually, based in knowledge of context and practice, rather than carefully warranted by research. Part of this is because, as experienced researchers, many of us have developed "good instincts" and can easily make posthoc justifications based in the scholarly literature, even if that was not actually our inspiration. With its emphasis on theory building, design-based research is an uneasy companion to design.

Several design cases are told from a teacher-as-designer perspective, including these five cases: Correia, Erumit, Dickson-Deane, and Donaldson and Janes their colleagues. In these, we note that precedent or prior experience can shape learner expectations in ways that mismatch the teacher-as-designers' intentions. In several cases, this led teachers-as-designers to iterate or adapt their designs on the fly. For instance, as Correia realized students would benefit from more or deeper focus on a particular topic, she was able to expand the time allocated.

Power dynamics In the cases, we see that instructional designers practice within hierarchies and that factors apart from designing itself play a role in how products come to be. Sometimes, designers have power over developers or teachers. In four cases – Gyabak, Erumit, Polly and colleagues, and Martin and colleagues – the authors take distinctly different approaches to the power relationships between themselves as designers and the teachers with whom they were working, sometimes addressing their approaches directly and others describing interactions that reveal power positions indirectly. Read these cases to observe power being negotiated between designers and developers, designers using their power to interpret what teachers are doing, and designers working to reduce power differentials between themselves and teachers with whom they are working.

Several authors, or their designs, hold implicit or explicit power over learners. This aspect shows up as designers – often also in teacher roles – seek to shift the focus from knowledge transmission to learning. Donaldson and colleagues discuss the dilemma of learners who are accustomed to, and who prefer, a familiar classroom position *without* power over the shared power offered through their course design. It shows up again when Correia finds that she must share power with her online masters students in order to accomplish her vision of developing an entrepreneurial mind-set in them as instructional designers. Monk and colleagues' case exemplifies how designer/teachers find themselves sharing power with the clients of their students as they implement an intensive service learning course.

In other cases, authors must navigate power dynamics with subject matter experts whose knowledge claims trump their positions or struggle to enact good designs when those who have power over them do not understand design processes. Dickson-Deane is most forthcoming regarding this aspect of power as she navigates the power dynamics at play for her as a new instructional designer. And, interestingly, Fowlin, Gallo, and Lilja describe an interesting and shifting power dynamic between the students in their cross-national college course on criminal justice. Medley, Nolley, Labriola, Brown, Polowy, Lloyd, York, and Yamagata-Lynch detail shifts in power dynamics over time while using care to prioritize the subject matter expert understanding central to their design work.

Some design cases also reveal concerns over power dynamics in context. The two cases by Janes and colleagues and Breman and Giacumo shed light on this. For instance, in the former, Breman and Giacumo discuss negative reactions from a participant during pilot testing that reflected local oppressive views of women. They contended with whether or not to change their design, to align with, and therefore reinforce local inequitable power dynamics.

Problem framing versus problem-solving In contrast to well-structured problems that have a single correct solution, design problems are framed and reframed by the designer. Tentative and final solutions reveal possible problem frames. For instance, online, required training for conducting research involving humans typically includes substantial text to review and multiple choice quizzes that assess factual information. This suggests either that the problem was framed as researchers needing greater factual information, acquirable through cognitivist design, in order to be ethical, or as institutions needing a means to defend themselves, should misconduct occur.

Designs themselves reveal little about the work of framing. Here, the cases provide an interesting lens into this work. For instance, in the two cases by Medley, Martin, and their colleagues, we see how changes in technological capability and different designers' styles and precedent contributed to reframings over time and iterations. Likewise, Johnson, Seawright, and McDonald detail the efforts they took to feasibly develop an LMS and how the context shaped their framing.

From the cases, we see a range of approaches to framing that could leave inexperienced designers wondering about the role of analysis. A fruitful way to consider the need for analysis and the work of problem framing is *distance* from the learners and relevant contexts, as well as from the content or practices to be learned.

In many of the cases, the designers have deep understanding of the content or practices because they are approaching designing from teacher-as-designer or researcher-as-designer stances. And while the former typically also have little distance to cover with regard to learners, a few cases highlight that treating this distance as nontrivial can result in generative framings of design problems. For instance, as Correia relates her efforts to bring entrepreneurialism into her course, she details on-the-fly reframings in response to student learning needs that became apparent as a result of their engagements with her design.

Some of the designers explicitly acknowledged their own distance from the learners or learning context. For instance, Erumit, who took care to assemble a group of designers knowledgeable about the computer programming content, recognized their gap in understanding of secondary classrooms could be only partially filled by reviewing external sources. By bringing teachers into the critique process and then by pilot testing in classrooms, they narrowed this distance. By staying tentative in this process, they remained open to reframings.

Gyabak closed the distance between herself and the learners and context effortfully, recognizing the importance of understanding a context very foreign to her. She visited villages and developed ways to design *with* teachers. Likewise, the case reported by Janes and colleagues showcases how an instructional designer might narrow this gap by first being a learner, an experience that is common for many instructional designers, though seldom to the degree and depth displayed in this case.

Role of design failure While it sounds ominous or pejorative, we use the term *design failure* to encompass not just the failure of an entire design but the inevitable healthy rethinking and appropriate redirection of effort that characterize every design project. In the narrative of a design case, failure can be addressed more or less directly and in more or less detail, sometimes using the term *failure* and other times just describing some of its many facets. As design failure is addressed in these chapters, the authors describe the different roles it played in their designs. Interestingly, Gyabak details the way in which a specific prior design failure was a key driver in her case, a situation many designers face when they are requested to refine, revise, or even replace prior designs. Janes and colleagues reach even further back in time from their immediate case to identify design failure at the societal level – that of the Indian residential school system in Canada – as a framing factor, indeed the originating motivation, for their design effort. In other cases, the discussion of design failure highlights the normal, expected role it plays in shaping design decisions. Donaldson and colleagues state explicitly, “Design decisions were made, rejected, and revised in a fluid and emergent fashion throughout the design process,” and discuss some of the shifts in their decisions that occurred during the project. Readers of every case will recognize points at which this role is fulfilled by design failure of one kind or another. Design failures may also occur in implementation, playing the role of forcing reflection on a designer or team regarding either their original decisions, anticipation of future stresses on the design, or factors in their processes. Fowlin and colleagues, for example, describe unpredictable implementation issues, power failure, and student attrition, which affected their design, while Johnson and colleagues write at length regarding both organizational challenges early in their process and problems in the rollout of their LMS linked to process decisions. Likewise, Bremen and colleagues discuss insights from critical feedback in pilot testing that led them to question whether their design ought to reinforce or interrupt local, oppressive gender norms. Dickson-Deane presents multiple sources of design failure, including organizational and process issues, and in the process makes clear the role of design failure in the professional development of a designer.

Conclusion

While precedent knowledge may be built and shared jointly within a tight community of designers, or imposed as a canon on a widely dispersed group (usually students), much of this knowledge is built–experience by experience–within the individual, who will use it later in unknown ways at an undetermined time. A disciplined use of precedent knowledge results in schemata, or constantly developing constructs for recognizing design situations, which make new precedent salient and easy to store, as well as accessible when it is needed (Lawson, 2004). As curators of the cases collected in this volume, we aspired to assemble design narratives across multiple contexts and within multiple domains of learning to facilitate as many vicarious experiences as possible for readers of the handbook. In this chapter, we have offered a head start on relating those cases to schemata that designer/readers may already have in place or – for the researcher/reader – guidance toward the illuminating cases that deepen and enrich the mental landscape you bring to your studies.

We would note as a general point that design cases share with all direct narratives of experience a certain level of appeal from one human being to another. In some ways, this can make reading a design feel less weighty, or of less import, than reading a report of research, a review of literature, or a theoretical argument. That feeling may be underscored by the highly particular nature of design cases; by analogy, you have to eat one orange at a time instead of drinking a glass of juice – the nutritional (or knowledge) value of design cases has to be acquired one case at a time instead of being aggregated through abstraction into consolidated form. Therefore, any single case may not appear on the surface to make a large, or immediate, contribution to your knowledge. We argue however (to extend the analogy) that a steady diet of them will improve our design knowledge over time in a different way than consuming the more concentrated outcomes of research, even what is called design-based research. Furthermore, while reading a well-written design case is engaging and may, for that reason, appear effortless, producing them is a rigorous and difficult process. Designers' attention must be focused on noting and retaining the salient features of an activity that unfolds, sometimes quickly and often in complicated ways; at the same time, the design process is demanding attention. Decisions have to be made regarding what will be discussed, and how, in order to afford the reader a vicarious experience of the design and understanding of how it came to be. This has to be done honestly and transparently, resisting the impulse to generalize and thereby lose the force a design case should carry. All this must be accomplished understanding the indeterminate nature of how the case is to be used in the future, in trust that the effort put into this case will yield benefit to an unknown number of other designers an unknowable number of times. Reading cases and adding them to one's store of knowledge likewise require, for designers, the effort of attention, imagination, and analogous thought, wherein the case is valued not only for its literal content but for the potential it represents as an intentionally acquired experience. Non-designers may find it difficult to apprehend the deep processing required to make most effective use of design cases, but we anticipate that scholars in the field may certainly appreciate the insights yielded via reading cases through some of the perspectives we have outlined here.

As editors, we hope that including these design cases in the handbook will provide immediate benefit to readers of all kinds but also that it may spur understanding and use of this form of design scholarship. We hope as well that anyone in the field who is engaged in design will give serious attention to how they may produce and share design cases of their own. In fact, while we have not published any journalistic cases in his handbook (cases in which an individual who was not part of the design process interrogates either those who were, or the artifact, to build a description of what was designed and how), these are equally valuable in knowledge building, and perhaps some readers will consider undertaking them. It is difficult to imagine, after years in which very little investment has been made in this form of design knowledge within the field, the size of the void to be filled or the vibrant practice in which we could be engaging. The small taste provided here gives, we hope, a taste of what could come.

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WASH by Design: A Design Case on the Collaborative Curriculum Project for Elementary Schools in Rural Papua New Guinea

Khendum Gyabak

Context: Situating the Design

The village of Warike, located in the Western Highlands of Papua New Guinea (PNG), has been the home of the Warike tribe for a number of years. In Tok Pisin (the creole language used in PNG), Warike means “spread out” and refers to the people who left their lands in the mountains of the highlands to settle in the fertile valley of the Western Highlands region. During the Australian occupation of PNG, most of the fertile land in the region was owned by Australians who developed coffee and tea plantations around the area. The economy in the highlands region is mainly driven by the coffee business and has attracted a number of tribes moving from the Eastern Highlands to land jobs in the many coffee plantations in the Jiwaka and Western Highlands region.

Fifteen years ago, Dr. Larry Hull, an American orthopedic surgeon, bought a coffee plantation in the Warike village and began community development efforts by starting the Na Wokabaut non-profit organization to improve the health and wellness of people living in areas within the Warike village. Dr. Hull was awarded a Rotary International grant in 2014 and began a partnership collaboration with the Water Hands Hope (WHH) non-profit organization in the United States, to start the Papua New Guinea Madan Water and Sanitation Project. The goal of the collaboration was to pilot a curriculum on sanitation and hygiene in schools in and around the Jiwaka province of Papua New Guinea.

Infectious diseases easily spread in Papua New Guinea. Access to clean water and proper sanitation infrastructure is a national issue, and the situation is most dire in the rural areas, where it is common practice for people to defecate outdoors or in

K. Gyabak, Ph.D (✉)
Instructional Systems Technology, Indiana University Bloomington,
Bloomington, Indiana, United States
e-mail: khendum@gmail.com

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unhygienic pit latrines (UN report, 2014). According to Dr. Hull's observations of the schools around the Warike village, the schools in the Jiwaka province are constructed without appropriate water and sanitation services. Due to the limited supply of water and lack of sanitation infrastructure, many students cannot attend school due to diarrhea and other waterborne diseases, and classes are oftentimes disrupted when the water runs out in the schools. In addition, none of the schools have a proper Water, Sanitation, and Hygiene (WASH) curricula, and teaching these topics is challenging as the PNG people don't seem to take the concept of washing hands and using proper toilets as very important or as basic health habits (personal communication, March 25, 2015).

Over the years, there have been concerted efforts to improve this situation made by missionaries and medical doctors who have donated WASH teaching materials to the schools and the community health clinic run through Dr. Hull's Na Wokabaut non-profit organization. However, it was challenging to implement the WASH curriculum in the schools as teachers themselves were not familiar with the concept of WASH. Readability issues, limited resources in the classroom, and contextual irrelevance of the curriculum also meant that materials were often left unused in the schools. The community health clinic in the Warike village has been collecting data from their patients for the last 2 years (2013–2014) and reported a high rate of patients (mainly infants and children) suffering from waterborne diseases and sickness related to poor sanitation and hygiene.

Making Up the Design Team

The Madan Water and Sanitation Project collaboration with Water Hands Hope non-profit organization provided a unique and interesting opportunity for me, both as a researcher and designer. With an invitation from the Department of Education and the founder of the WHH non-profit organization, I volunteered to travel to Papua New Guinea and live in the Warike village for two months to gain a deeper understanding of the cultural norms and sanitation and hygiene practices of the PNG people. The goal was to form partnerships with local community leaders and teachers in order to develop a deeper understanding of their values, teaching, and learning practices and the cultural norms that influence the way they think about sanitation and clean water. As part of these efforts, I facilitated a 2-week design workshop for teachers to sit together and brainstorm solution ideation for a WASH curriculum for their schools.

My Role as a Researcher and Designer

As a design researcher, my interest is focused on understanding how design can be used as a tool to empower underserved schools and communities around the world. Having worked on similar research projects in Bhutan (Gyabak & Godina, 2011), and studying the instructional technology interventionist programs carried out by scholars, non-profits, and local government organizations in similar contexts (Kim et al., 2012; Madon, Reinhard, Roode, & Walsham, 2009; Marsden, Maunder, & Parker, 2008), my view was that in order for this project to be sustainable we needed to do away with the idea of importing a WASH curriculum from outside. Instead, by framing this pilot project as a community-driven effort, I intended for teachers to spearhead the project, and I invited teachers from the schools in the community to join me in the process of designing a context- suitable curriculum for their classrooms. I believe this direction took a different approach from the past efforts taken by medical practitioners and missionaries.

As an outsider, it was important for me to understand WASH practice in the schools and to understand the infrastructure they had available. I visited four elementary schools in the village, surveying the school facilities for toilet and handwashing practices and facilities. The United Nations Children's Fund holds WASH as one of their organization's primary development goals and over the years has been actively promoting WASH in a hundred developing countries. I carried out my survey using the directions from the UNICEF WASH toolkit. I also spent half a day in each school making observations and asking questions of teachers and students about their WASH practices.

Identifying Stakeholders in the Community

Tribal culture trumps the rule of law in Papua New Guinea. This is especially evident in the rural areas where issues related to land and community matters are typically resolved by the chief of a tribe (Smith, 2013). In the Warike village, the chief of the Warike people was employed as the manager in Dr. Hull's coffee plantation. It was important to get the chief on board because without his endorsement of the pilot project, it would be difficult to get the people from the community involved in the project.

It was also important for us to garner support from the Ministry of Education if we were to implement the curriculum in the schools. Through the Ministry's support, a letter of invitation was sent to principals in neighboring elementary schools asking them to nominate teachers to participate in the development of the WASH elementary curriculum. Eight teachers from four elementary schools around the Warike village in the Jiwaka province of Papua New Guinea were nominated by their principals, and an initial meeting was set up with the teachers, the chief of the Warike tribe, and key personnel from the Ministry of Education.

We held an initial meeting that was helpful in talking through the current condition of the sanitation and hygiene practices of the community by sharing data that was gathered from the community health center. The teachers in the meeting pointed out that currently they did not have a proper WASH curriculum and were unequipped to teach students topics that were relevant to addressing the issues of poor sanitation and hygiene practices in the community. After much discussion, I proposed facilitating a design workshop for teachers, to have a space to think through the outcomes of the pilot curriculum design project.

The Design Process

The design process was framed around the activities conducted during the design workshops (see Fig. 1). The process involved the team understanding the concept of WASH together through the activity of content analysis. By using the activities of brainstorming and reflection, teachers were also able to ideate the outcomes of the curriculum design project within the 2-week time frame of the workshops.

Design Workshops

The two week workshop was designed as a space for the design team to come together to ideate the outcomes of the pilot project. The workshop was set up with the goal to teach teachers about WASH and to introduce learner-centered strategies for teaching the WASH curriculum. Based on my observation of the teacher's classroom instructional practices and from individual conversations with them, it seemed they had no experience with writing curriculum, and many of them were not even trained in the teaching profession and became teachers right after high school. Since

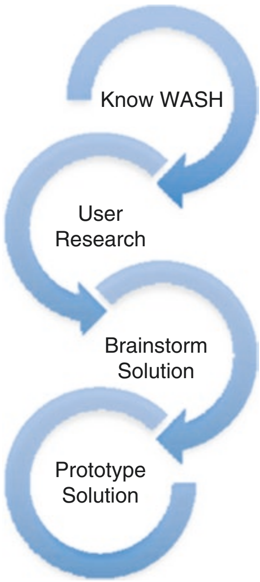


Fig. 1 The design workshops comprised four activities: understanding WASH content; looking for existing content that had reference to health and hygiene in some of the teachers' resource books and in manuals and handouts brought by medical missionaries in the past; carrying out user research in understanding WASH practices and infrastructure in the schools and community (the design team visited six elementary schools in the village and made observations on the WASH practices of students); brainstorming solutions for a viable curriculum and then prototyping the teacher's resource manual as the solution for the design problem at hand

WASH Curriculum Design Workshop
June 26th, 2015
Madan Coffee Plantation
Agenda

Icebreaker activity: Getting to know each other – 20 minutes
Overview of workshop: – 5 minutes
Team breakout – 5 minutes

1. Identifying group mentor
2. Group activities
    a. Designing learning objectives – 1 hour
    b. Knowing your learner – 1 hour

SPICE UP ACTIVITY (Signature raffle draw) and LUNCH BREAK

    c. Content Research – 1 hour
    d. Guest lecture: Tok WASH with Dr. – 30 minutes

Wrap up: Moment of reflection (revisiting new WASH learning objectives, discussing learning styles, how do things come together), scheduling

Fig. 2 Due to the limited time and availability of the design, a daily agenda was developed to keep pace with the milestones for the curriculum design. Most work was carried out in teams and some time was allocated for a moment of reflection. The reflection time was useful for summarizing the activities and topics carried out for the day and also opened a space for the team to address issues and challenges they faced with the activities

WASH was a practice related to health habits and involved young children practicing these health habits, it was imperative teachers found ways to engage students with the topic using inquiry-based and activity-based instruction rather than have students memorize procedural knowledge. The workshop was designed to involve activities that modelled learner-centered instruction (see Fig. 2).

Know WASH: Curating Content

In ideating the outcomes of the workshop, it was important to curate precedents that would be useful to the team when thinking about the outcome of the curriculum design project. Before arriving in PNG, I was made aware that I would not have access to any library or the Internet. I carried with me a book on health curriculum design, the UNICEF Wash toolkit manual, and a copy of a resource manual on WASH that was donated by a missionary group to Na Wokabaut non-profit organization.

WASH as a topic was new to the cultural context of Papua New Guinea; it was therefore important for us as a team to go through resources in order to study the topic together. Na Wokabaut identified a health worker through the local rotary organization who was involved in disseminating community health information in the Western Highlands. I thought it would be a great opportunity to interview him on his dissemination methods and also have him share his resources with us. The health worker shared with us a book that he had curated from the Internet consisting of images depicting the right and wrong method of various health habits. He mentioned that he would take the book with him to villages and verbally explain each page in Tok Pisin. This was quite an ordeal as he usually took an entire day explaining concepts and mentioned furthermore that it was difficult explaining esoteric concepts such a germs and dirty water to the people.

During the content analysis activity, the teachers broke out in teams and went through the resources that were provided to them, in addition to the "Community and Culture" textbook they brought with them. They used Post-it notes to mark any mention of WASH in the books and then came together as a team to discuss the relevancy of the content.

Apart from reviewing content that was available to us, I invited one of the physicians volunteering in the community health clinic to give a brief talk to the teachers on the concept of clean water and germs and the dangers of open defecation. Having guest speakers come to the workshop provided some credibility to the importance of WASH, and teachers also expressed feeling a sense of empowerment to be active agents in disseminating WASH knowledge in their classrooms.

The workshop also included activities for teachers to make connections with pedagogy (see Fig. 3) and their current classroom instructional practices (see Fig. 4).

Most teachers in the team did not have experience with writing curriculum and heavily relied on the textbooks for carrying out their instruction in their classrooms. They needed examples in writing learning goals and objectives for the WASH curriculum. During every workshop time, examples for activities would be sketched on a chart paper and pasted on the window for teachers as they worked in teams to write the curriculum (see Fig. 5).

Activities like the design challenge provided a fun and engaging method for teachers to think through the WASH content by sketching themes (see Fig. 6) for the curriculum project and engaging in critique (see Fig. 7).

Fig. 3 Teacher going through Bloom's taxonomy. Going through pedagogical resources was helpful for teachers while making connections with designing the activities related to teaching WASH in their classroom contexts

Fig. 4 Teachers review their own curriculum and supplied resources. Teachers carried out a content analysis of any mention of WASH topic in their current Elementary Community and Culture textbook provided to them from the Ministry of Education of Papua New Guinea

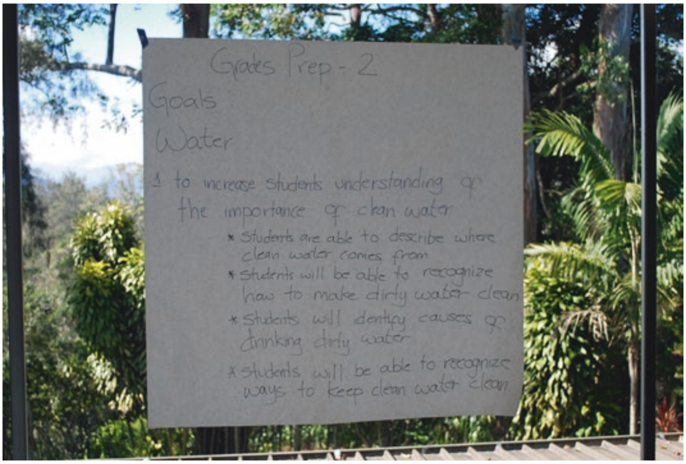


Fig. 5 Learning goals posted for reference during the design workshop

During the Know WASH part of the workshop, the design team found a number of irrelevant pictures, diagrams, and figures in the resources (textbooks, community health worker book, UNICEF resources). Instead the team decided to draw depictions of WASH-related topics that were relevant and meaningful for the people in the Warike village. The design challenge also helped the team identify an artist within the team, and as a prize, the teacher's artwork was used in the final outcome of the project to satisfy the team's decision to use relevant images in the final materials (see Fig. 8).

Fig. 6 Teacher sketching themes for the design challenge. The design challenge was a fun space for teachers to dabble with their imagination and creativity. The goal of the challenge was to get the winning sketches published in the teachers' resource manual

Fig. 7 Critique session. Teacher justifying the cover page he sketched for the design challenge

User Research

In the initial meetings with the community, the decision was made to design a curriculum for all schools in the Warike village, but after conducting user research of identifying WASH infrastructure in the schools, it did not seem a viable option to design a curriculum in a school that had an absence of such infrastructure because children needed to practice the health habits in the schools. According to a United Nations Children's Emergency Fund report on WASH interventions (UNICEF, 2010), recommendations for WASH infrastructure were necessary to go hand in

Fig. 8 Artwork produced by collaborating teacher. The teachers determined that familiar depictions of objects and places would be more meaningful for their students than those in supplied materials produced elsewhere

Fig. 9 WASH infrastructure installed by the Madan Water and Sanitation Project. Tippy taps for handwashing, a toilet built on the idea of reusing human waste for agricultural purposes and water catchment tanks (empty May–August in the dry season and surrounded by trash at the time of the photo) provided some infrastructure for WASH practices at four village schools. These photos were captured as part of the user research activity of observing schools. (**a**) Warike Elementary School children interacting and using Tippy Taps installed for handwashing. This is an alternative to the rain catchment tanks during the dry months from May to August; (**b**) To address the lack of running water composting toilets were installed in some schools. After bowel movements sawdust is added to the waste converting it to compost; (**c**) A rain water catchment tank is a secondary source of water (primary: river) that has been installed in every school. During the dry months of May through August this tank is empty therfore teachers and students have to walk to Wagi river for water

hand with the curriculum. Since then the Madan Water and Sanitation Project had installed tippy taps, water catchment tanks, pit latrines, and compost latrines at four schools in the village. The design team decided to develop a curriculum based on these four schools and later implement the curriculum in the other schools once the infrastructure was in place (see Fig. 9).

Rationale for Design Decisions

A number of decisions were intentionally made during the process of the curriculum design. Most of the decisions were negotiated among the team and were based on the constraints faced in their own contexts, as well as on our own discovery of what seemed to be the most viable solution for making this pilot project a reality.

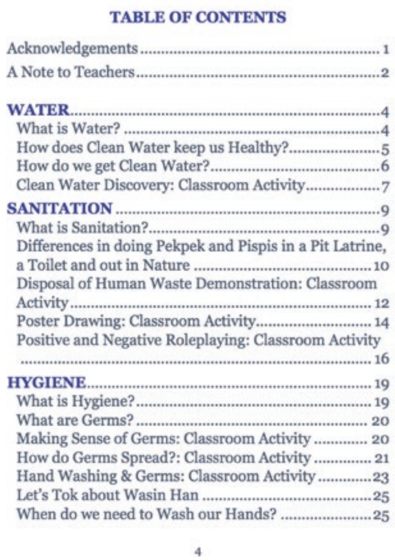
The reflections in the workshops allowed for a number of decisions to be negotiated by the team. As an outsider, I wanted my role to play out as a facilitator who encouraged teachers to think through the process of finding a viable solution for the pilot project. The teachers had only 2 weeks of their time available to participate in the workshop as school then broke for summer vacations. The limited time was a big constraint to the project, so very early in the project I had to bring up the talk of discussing the outcomes from the workshop.

After going through the content on WASH from the resources provided by the community health worker and from going through the teaching resources teachers used in their classroom to cover the "Community and Culture" class, the team brainstormed ideas like coming up with designing posters for WASH, a handbook for students, or a resource manual for teachers. The resource manual was chosen because all teachers typically utilized a manual for every class period and the idea of coming up with a resource manual (see Fig. 10) for WASH fit into the "Community and Culture" objective-based education system mandated by the Ministry of Education of Papua New Guinea. Furthermore, the teachers were familiar with the format of a resource manual and could easily refer to the resource manuals they used for other subjects as examples for the WASH resource manual.

Based on the classroom observations made in the four schools in the Warike village, it was evident that the classrooms had very limited teaching and learning resources (see Fig. 11). It was paramount to consider what was available in the natural surrounding for the implementation of the activities designed in the manual.

During the brainstorm sessions in the workshops, teachers got into their teams and discussed with one another the resources that were available to them. From their discussions, the design team made considerations to utilize reusable materials and resources from their natural surroundings. Due to the unavailability of water supply in the village homes, most villagers collect empty soda bottles to collect water from the nearby Waghi River. In one of the activities in the book titled "*Clean Water Discovery*," teachers could reuse soda bottles to bring clean and dirty water from their homes to demonstrate the differences to their students (see Fig. 12).

In this design case, all resources were minimal, from physical (infrastructure in classrooms) to conceptual (information resources and teacher training), to temporal (limited time for the workshop). The challenges were high because the object of the design effort was to change behaviors around deeply entrenched social practices and introduce new knowledge within a community structure unprepared to take it in. As a design facilitator, I saw the full involvement of local teachers as the only viable path to a useful result and felt that this process did result in the most progress possible given our constraints. These teachers created local materials appropriate to their own use in their own schools.



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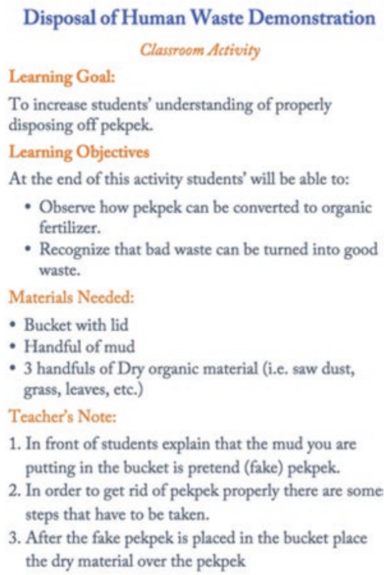


Disposal of Human Waste Demonstration

Classroom Activity

Learning Goal:

To increase students' understanding of properly disposing off pekpek.

Learning Objectives

At the end of this activity students' will be able to:

- Observe how pekpek can be converted to organic fertilizer.
- Recognize that bad waste can be turned into good waste.

Materials Needed:

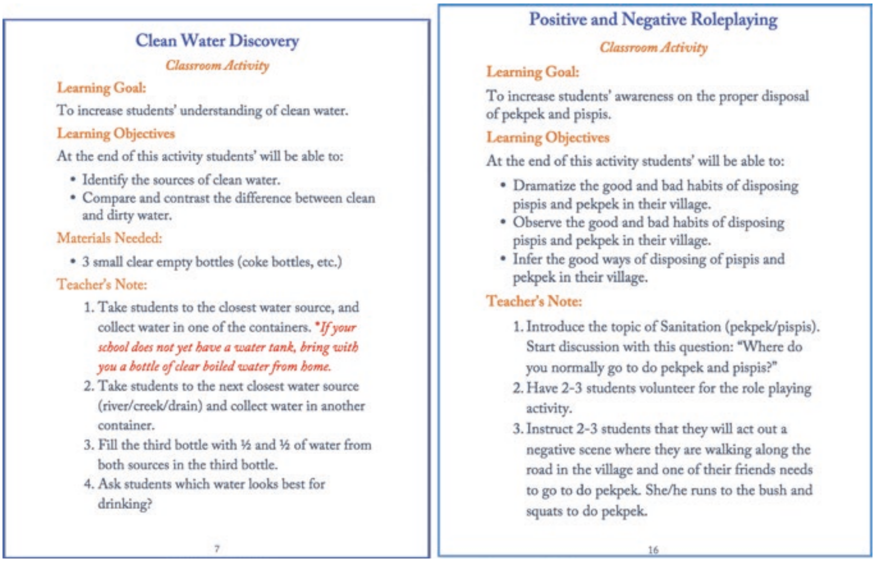
- Bucket with lid
- Handful of mud
- 3 handfuls of Dry organic material (i.e. saw dust, grass, leaves, etc.)

Teacher's Note:

1. In front of students explain that the mud you are putting in the bucket is pretend (fake) pekpek.
2. In order to get rid of pekpek properly there are some steps that have to be taken.
3. After the fake pekpek is placed in the bucket place the dry material over the pekpek

Fig. 10 The teacher's resource manual and sample activity. The table of contents for the teachers' WASH resource manual. Each topic contained brief information on the topic and how it related to the culture in rural PNG, followed by a learn by doing activity for students to make connections with the topic. (**a**) The table of contents for the teachers' WASH resource manual. Each topic is chunked into three main units on Water, Sanitation and Hygiene that is followed by a classroom activity; (**b**) An example of a classroom activity covering the concept of sanitation. The activities developed in this manual can be carried out in a low-resourced classroom setting

Fig. 11 Warike classroom. As a researcher, it was important to make connections with the current teaching practice to the kind of pedagogy that was effective to teach WASH for elementary children. I made a number of observations in the classrooms of the teachers who were participating in the curriculum design project



Clean Water Discovery

Classroom Activity

Learning Goal:

To increase students' understanding of clean water.

Learning Objectives

At the end of this activity students' will be able to:

- Identify the sources of clean water.
- Compare and contrast the difference between clean and dirty water.

Materials Needed:

- 3 small clear empty bottles (coke bottles, etc.)

Teacher's Note:

1. Take students to the closest water source, and collect water in one of the containers. **If your school does not yet have a water tank, bring with you a bottle of clear boiled water from home.*
2. Take students to the next closest water source (river/creek/drain) and collect water in another container.
3. Fill the third bottle with ½ and ½ of water from both sources in the third bottle.
4. Ask students which water looks best for drinking?

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Positive and Negative Roleplaying

Classroom Activity

Learning Goal:

To increase students' awareness on the proper disposal of pekpek and pispis.

Learning Objectives

At the end of this activity students' will be able to:

- Dramatize the good and bad habits of disposing pispis and pekpek in their village.
- Observe the good and bad habits of disposing pispis and pekpek in their village.
- Infer the good ways of disposing of pispis and pekpek in their village.

Teacher's Note:

1. Introduce the topic of Sanitation (pekpek/pispis). Start discussion with this question: "Where do you normally go to do pekpek and pispis?"
2. Have 2-3 students volunteer for the role playing activity.
3. Instruct 2-3 students that they will act out a negative scene where they are walking along the road in the village and one of their friends needs to go to do pekpek. She/he runs to the bush and squats to do pekpek.

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Fig. 12 "Clean Water Discovery" activity and use of Tok Pisin in materials. Due to the limited availability of teaching and learning materials, considerations for the materials required for classroom activities were based on what was readily available in the teacher's natural surroundings. Similarly, even if English was the medium of instruction mandated by the Ministry of Education, Tok Pisin was the language spoken in the community and mainly used by teachers in their instruction. To cater to the reality of how instruction was conducted in these rural classrooms, Tok Pisin words were used in the manual to make the content relevant and meaningful for the teachers and students (**a**) An example of a classroom activity covering the concept of clean water. Considerations for materials required for classroom activities were based on what was readily available in the teacher's natural surroundings; (**b**) An example of infusing Tok Pisin in the resource manual. Even if English was the medium of instruction mandated by the Ministry of Education, Tok Pisin was the language spoken in the community and mainly used by teachers in their instruction. To cater to the reality of how instruction was conducted in these rural classrooms, Tok Pisin words were used in the manual to make the content relevant and meaningful for the teachers and students

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Designing with Forgiveness in Mind for the Process

Camille Dickson-Deane

Context

In this design case, I discuss my experiences as a newly hired instructional designer, where I redesigned a mandatory online certification course for faculty members. Prior to being hired, I had experience as both an academic and a practitioner in several institutions, which were diverse in demographics, educational offerings, settings, and strategic objectives. I took the job to be closer to family and looked forward to using my prior experiences to create new educational innovations. It was an opportunity that I had a great hunger for because I felt I would be challenged to be great. I remembered that feeling of being hungry for challenge when I was told to prove that the current design did not work by redesigning a certification course; thus I accepted the opportunity to showcase my abilities.

Faculty members completed the certification course to get approval from the institution to teach online. In my mind, the redesigned course was an opportunity to provide faculty members with an opportunity to increase their online learning design and delivery skills. A number of factors influenced my redesign of the existing course, including my own lack of awareness of the institutional knowledge of the field of instructional design (ID), insufficient access to faculty, which prevented me from adequately assessing their needs, and an impending concern that the institution would not meet accreditation criteria for delivering online educational programs.

As most institutions fight to stay competitive and address the ongoing need for the use of online technologies, preparing faculty to deliver online content is a major initiative. Some institutions prepare faculty by providing access to courses offered by third-party training organizations, while others approach the need through the

C. Dickson-Deane (✉)
Faculty of Science, University of Technology, Sydney, NSW, Australia
e-mail: Camille.Dickson-Deane@uts.edu.au

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use of a homegrown solution. Institutions that choose to offer homegrown or customized solutions typically hire new employees specifically to design and deliver a solution (Elliott, Rhoades, Jackson, & Mandernach, 2015; Mitchell, Parlamis, & Claiborne 2015) as this provides a maximum benefit toward their strategic objectives.

The certification course was part of a mandatory professional development program which would prepare faculty to teach in the online environments—a key initiative to assist with an upcoming accreditation exercise. It was one of two courses that faculty could take, but this course was the only one used as a gateway for faculty to teach online with the hope of improving the quality of the online education offered at the institution. The institution at the time was generally familiar with online education and its associated standards but did not have clear policies or guidelines to determine quality. Developing guidelines was integral to assessing the quality of the professional development program due to the accreditation process, and therefore the certification course could definitely help. The need for the course was described by senior management as directly improving the current offering of online courses that are designed and delivered by faculty.

The Case

As a new employee charged with designing a homegrown solution, I felt committed to providing a true learning experience for online students, albeit for this project the students would be faculty members. In this context, my decades of experience of delivering online education guided my actions. My experience encompassed both curriculum designer and instructional designer roles. Even though I had this expertise, I was aware that as a new employee there was still some need to acclimatize to the cultural context, which would inform my current and future performance as an instructional designer at this institution.

While interviewing for this position, I interpreted the need for my skills as being based on the institution's limited expertise in the field of ID. This interpretation was informed by discussions with panel members in the interview process for the job and later confirmed in discussions with my supervisor at the beginning of my employment. The expressed need that the institution wanted to grow its offerings in the online environment underscored the need for my skills and expertise in achieving this strategic goal. This made it clear to me that my skills could directly influence the institution, which in turn increased my willingness to share my experiences and my eagerness to meet or exceed the requirements. Still, as I processed the directives, there were gaps in what I was told about the institution's history of working with an instructional designer or its understanding of the field of ID. These gaps led me to believe that there was no clear historical precedence for formal ID; I therefore felt I should take the initiative to direct the project. This assumption was directly related to the institution's lack of appreciation and awareness for the field of ID.

I was given access to the learning management system (LMS) being used at the time and was told that I could source any other technology resources I needed.

While I had other colleagues around, they were not assigned to assist in any way, though they were accessible if needed. I was also given access to a hard copy of the existing certification course (i.e., the online version of the course) and a copy of the assigned textbook used in the existing course. One of the major requirements for the redesign was that the course must allow faculty to move from one mode of delivery (i.e., face-to-face) to at least one more mode (i.e., blended or fully online).

Creating Opportunities to Share Expertise

As I was assisting a faculty member load the existing certification course into a new shell in the LMS, the faculty member asked for assistance in delivering the course. Both the faculty member and senior management wanted an improved learning and teaching experience, but the faculty member was not certain what improvements could be made. This was very exciting to me, and I took the opportunity to demonstrate my knowledge and abilities. As I continued to load the existing content into the LMS, I shared clear and concise guidelines for how faculty should deliver content.

As I reviewed the existing course design and content and thought about the learners—faculty—I discovered that the material was geared toward using the LMS only as a conduit for content. I noticed that faculty had limited opportunities to acquire actual skills for teaching online—the explicit primary goal of the course as stated in the first learning objective, "Demonstrate relevant pedagogy and effective course design practices through the complete design of an online or blended course utilizing the LMS." I discussed my perceptions with my supervisor, who challenged me to redesign the course to meet its intended objectives. I enthusiastically took the challenge as this was an opportunity to showcase not only my instructional design abilities but also my knowledge of online learning pedagogies and learning theories relevant to online education (Anderson, 2008).

Critical Decisions Considered

I sought answers from colleagues in my department who were at the institution longer than me by asking questions about the existing course, such as who the audience was and what characteristics they had; these questions received very few answers. As time passed and with my supervisor repeatedly responding saying "just design what you said you could," I decided to approach the redesign of the certification course by asking for forgiveness as opposed to asking for permission (CHIPS Magazine, 2002). Asking for permission creates many gates through which my design progression would be assessed. My concern here was that the assessors of my design progressions would be less informed about online design pedagogy than I am, thus requiring further explanations. This was a bold move, given my perception that the organization treated outcomes with forgiveness for success and retribution for failure. However, by using this approach, I believed that I would meet the aggressive schedule.

As time passed, the promised additional human resources were reassigned to other projects and those who were available did not feel capable of assisting; hence the design team was a team of one. This meant I had to enable myself and make decisions based on prioritizing the outlined needs of the project (Appelbaum, Hebert, and Leroux, 1999). The requirement to have a redesigned certification course completed and ready for implementation on a tight deadline meant that as the instructional designer, I also needed to act as the project manager. I created the project plan and delivered all the requirements. Understanding the variety of hats worn to get the project delivered—instructional designer, program evaluator, subject matter expert, and program manager—meant that I also had to prioritize the task lists. These factors created a flurry of quick decisions, including not divulging my prioritized list, which was in line with asking for forgiveness rather than permission. By not asking for permission, I kept to my deadline and was quickly making the progress that was expected. Most of my decisions were based on experience from previous ID projects, thus drawing on my prior knowledge in an effort to reduce the risk of failure. In addition to the priority list, I made key decisions regarding delivery, pedagogy, materials and resources, faculty skills, and learning outcomes.

Delivery. In developing a course that would prepare faculty to design and deliver a course in an online environment, I had to redefine "online course" for the faculty. Most faculty expected to meet face-to-face sometime during the certification course. But to me, this defeated the purpose. To certify the specific skill set required for online design and delivery, I felt they should experience a fully online course.

Pedagogical (Re)Design. I specifically felt the design of the course should reflect what faculty should be doing in their own course designs. There were rumors of student evaluations stating that the students felt isolated in the online courses. When I first attempted to conduct the needs analysis, I found that many of the current online courses did not have any instructor-to-student or student-to-student interactions and were not classified as being self-paced. I believed that creating a sense of community within the redesigned course environment would encourage faculty to reconsider how they design and deliver their own learning environment, as has long been studied and suggested in research into online learning environments (Garrison, Anderson & Archer, 2000).

Materials and Resources. I considered using open educational resources (OER) as a source of learning material in the certification course as an alternative source of content. The existing textbook was outdated and there was an expressed need to not have the redesigned course affect the budget. I used my professional network to source OERs and thought that adjusting my plans to include OERs would provide a reduced or no cost solution while introducing faculty to new sources of information and knowledge for their own courses. This decision led me to build relationships with faculty members who were teaching online elsewhere, as I sought to have someone test this solution to see if it was user-friendly. I also used these connections for their expertise to guide some of my design decisions.

Faculty Skill Level. I assumed that the faculty had some level of technology and Internet literacy, but recognized that there could be some variability in their readiness to pursue a fully online certification course. Previous to this project, I had designed a self-paced module to increase students' readiness to pursue online education at the same institution. I felt that if I made some tweaks to the self-paced module, I could use it as an optional prerequisite course for faculty who needed it, thus creating a mechanism to control the skill level of learners coming into the redesigned certification course. I made this decision because I lacked sufficient information on faculty readiness for online education. Although I made a request for additional time to do a more thorough needs analysis, the request was denied. I was told to forget about collecting data, just produce the design.

Course Purpose and Learning Outcomes. Selecting the topics for the certification course proved to be the most difficult part of the design process. I was the curriculum designer and subject matter expert for the certification course. I did my own research and based on experience and the literature I found, I decided on the topics for the redesigned course. The activities in the existing course focused on guiding faculty members to know the features of the LMS and how each feature functioned in the environment. The redesigned course objectives focused on how people learn, different pedagogical approaches, and how the LMS can be designed to illustrate a pedagogical approach (Ormrod, 1999; Anderson, 2008). I ensured that the changes to the goals of the redesigned course directly aligned with the institution's strategic objective of a quality learning experience for the students. I felt that this was a sufficient justification for the changes. To achieve these goals and objectives, I felt it was necessary to create a learning experience faculty could recreate in their own online courses.

Showing My Value

I embraced the task of redesigning this course as a chance to showcase my knowledge and abilities to my employers. I felt that by including a plan to outline how future enhancements to the certification course could be handled proactively was a good move on my part. I documented all of steps I took to redesign the course as evidence that could be used by those who delivered the redesigned course and by my direct supervisor; I saw this as a way to manage new needs and incorporate them into any future redesigns. My planning document was in the form of a formal report, as my superiors seemed to value this format more than an informal design journal. The content of the report included learner reactions to the content, notes on design decisions (e.g., why an item was in one area instead of another), and most importantly, questions from the learners. As a designer, questions are the best way to analyze how a faculty member may approach the redesigned course. In some instances, the questions were colored with concern, critique, being overwhelmed, or even dismissive. I reviewed the questions in relation to the learner activity and categorized them. Some of the questions presented a lack of commitment and low levels of participation in the course. Faculty perceived the course as a hurdle to the prize. The prize in this instance was being certified to teach online. Where there were low levels of overall performance, I interpreted these behaviors as faculty who were slowly learning. The redesigned course presented more new information than the faculty anticipated, and therefore the course took much longer for them to complete, which resulted in faculty being frustrated. The behaviors exhibited by the faculty could also indicate that the course content was beyond the reach of the faculty. Regardless, I truly believe that when the expected effort does not match the required performance, there may be a lack of comfort during the learning process. Finally, some faculty participated as expected, actively engaging with the content, though with a few hiccups that could be resolved via teaching or design prompts.

Description of the Redesigned Course and Its Infrastructure

The course environment uses Blackboard's basic template with the color of the institution in the navigation pane on the left (see Fig. 1), which included four areas. The announcements page provided the most recent of the weekly announcements displayed at the top. The course materials section included links to each week of course materials along with a brief description of the topics. The course modules included 4 weeks of activities, each of which was again divided into a sub-navigational area to the left and a content area. The navigational area outlined a table of contents for the week, and the content area provided the detail for each of

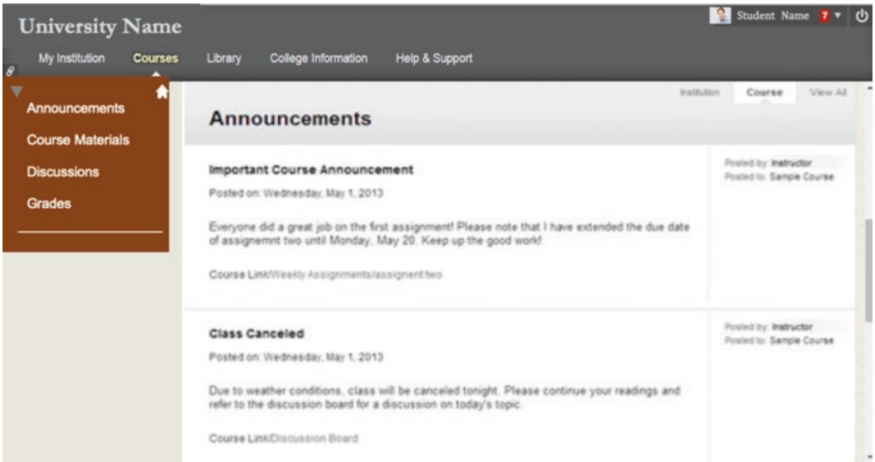


Fig. 1 The Blackboard course environment showing the navigation pane with the navigational items (i.e., announcements, course materials, discussions, and grades)

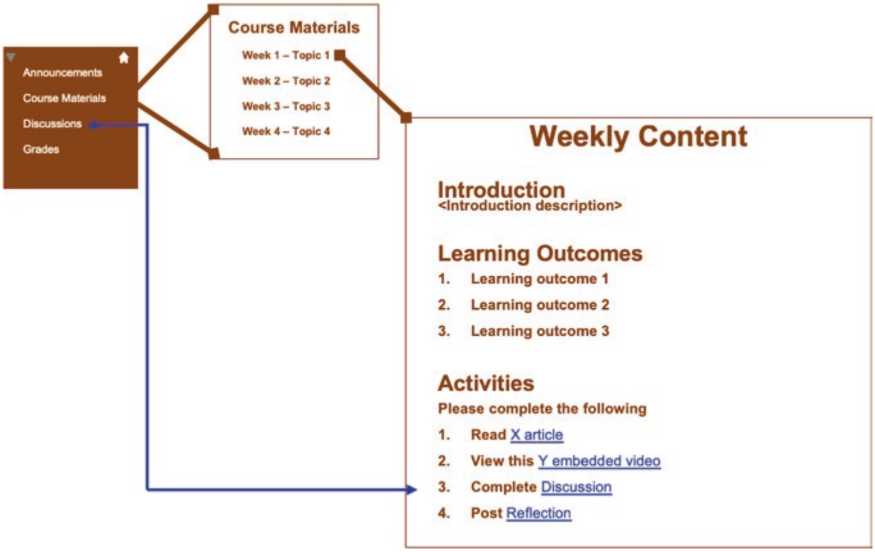


Fig. 2 The pedagogical design used to map the course content to the navigation pane

those items. The table of contents (see Fig. 2) for each week displayed an introduction to the week; the learning objectives for the week; course materials, including readings, videos, and demos; and weekly activities.

The discussions section included the title and purpose of each discussion forum. For instance, a discussion forum titled "Ask me!!" allowed participants to ask questions, and weekly discussions were titled with the week number (e.g., "Week 1 discussions"). The grades section relied on the default gradebook for Blackboard; I designed it to act as a checklist for completed tasks, rather than a quality check.

Intended Experience for the Redesigned Course

My intent was to redesign the certification course where each click immediately provided information, thus reducing the three-click rule of thumb down to one or two clicks ("3-click rule | Usability.gov," 2013). To create the infrastructure for the redesigned course, I attempted to manage faculty expectations by including purposively selected Blackboard tools. I used the Blackboard module tool to create the weekly content and provided guidance using a bulleted list of steps. I used the tools provided in the Blackboard LMS based on their function as well as their potential for pedagogical contribution to the content. For example, I directly linked readings that were text or available from a website to the OER source using HTML; I embedded video or simulation materials into the course environment; and I provided instructions to complete the activities and directly linked these to each activity (see Fig. 3).

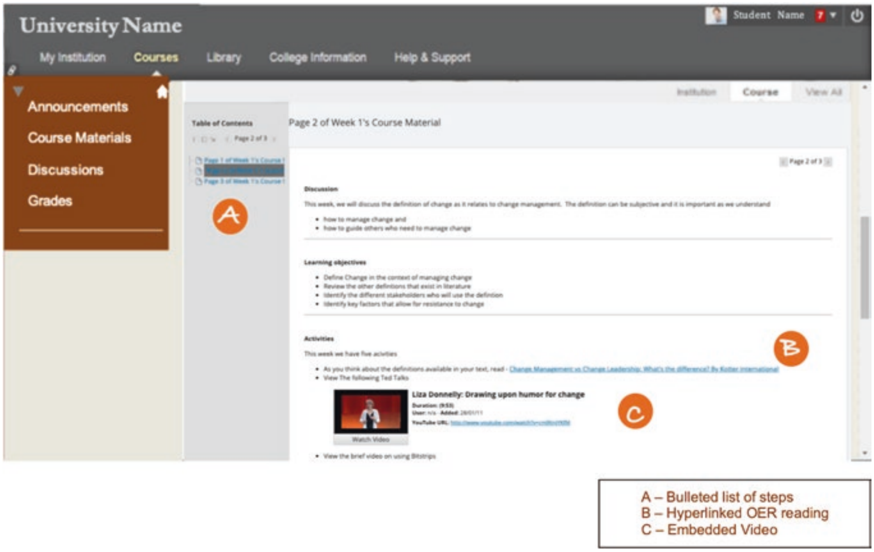


Fig. 3 The instructional design of each week of the course content

Pedagogical Design of Content

In order to facilitate interactions between myself and the faculty members as well as to encourage sharing and collaboration between them, I designed discussion activities that required each faculty member to post and respond to peers. They could base their posts on their own experience or on the literature to support their position. For instance, they described their ideas about specific parts of their own courses. I instructed them to read all of the discussion posts made by other faculty members and to respond substantively to three peers, providing either a specific suggestion for improvement/enhancement or a critique with opposing view.

Distinctive Aspects of the Redesigned Course

Although the preferred method for pursuing this redesign would have included a cross-functional team with each member having their own expertise and defined roles, I was resolved to make it work. As the sole resource, I used weekly design cycles to test the result (Barab & Squire, 2004), in which I delivered a completed design for one module, received and reviewed feedback on my design and content, and redesigned and incorporated feedback into next the next module. I piloted tested the redesigned course with a group of volunteers during development.

Fifteen faculty members volunteered to participate in the pilot course, two of whom were senior members of the academy. My supervisor received phone calls and emails from these senior members. The phone calls and emails were submitted as official complaints about the course to my supervisor. I received and treated each complaint as feedback and categorized them based on elements in the design of the course, because I believed that the faculty did not feel comfortable providing feedback directly to me. I interpreted this to mean that the pedagogical design of the course—to create a sense of community that includes the ability to respectfully critique one another, including the instructor—was not evident. The main complaints were about the use of Blackboard tools and the content of the course. Specifically, they cited that the Blackboard tools in the redesigned course were uncomfortable to use and that the redesigned course had too much reading. Both of these concerns are addressed below.

Conflicting Expectations

Upon investigation and discussion, I found that my decision to use a specific tool differed from the guidance given to faculty in previously offered professional development from the institution. The faculty had previously been taught to use the Content Item tool and I had used the Learning Module tool (see Fig. 4), in part to reduce scrolling on the screens. These tools are both used to display content, but accessing the content required a different process for each. Faculty showed immense confusion over this apparent conflict between what they had learned previously and what I used in this course.

The content from the previous version of the certification course, as well as the information provided by participants, suggested that the theoretical differences between traditional and online learning environments had not been mentioned. Thus, they did not expect to consider how tools can be used differently to produce specific pedagogical designs, and this was part of the issue. Faculty felt that teaching online was essentially the same teaching activity they did every day, but using their computers. When I demonstrated that there were significant pedagogical differences in the two approaches, faculty were confused. This meant that I could redesign the course again using the design principles that were familiar to the faculty, or I could provide information that would support faculty to understand the principles I used in my redesign.

With an impending deadline, I decided to provide information supporting the principles I used in the redesigned course by including more readings in the course. This did not add any steps to my design and delivery cycle, which made it a feasible approach for me. However, it was not received favorably by some of the faculty members pursuing the course who viewed it as additional reading, on top of the time they had set aside for the certification course.

I also had to manage faculty perceptions that either the original course was taught wrong or that what I was teaching was wrong. This put me in the unfortunate position of being seen as the champion of an approach that faculty did not believe was correct. My supervisor explained that the institution had considerable inertia associated with

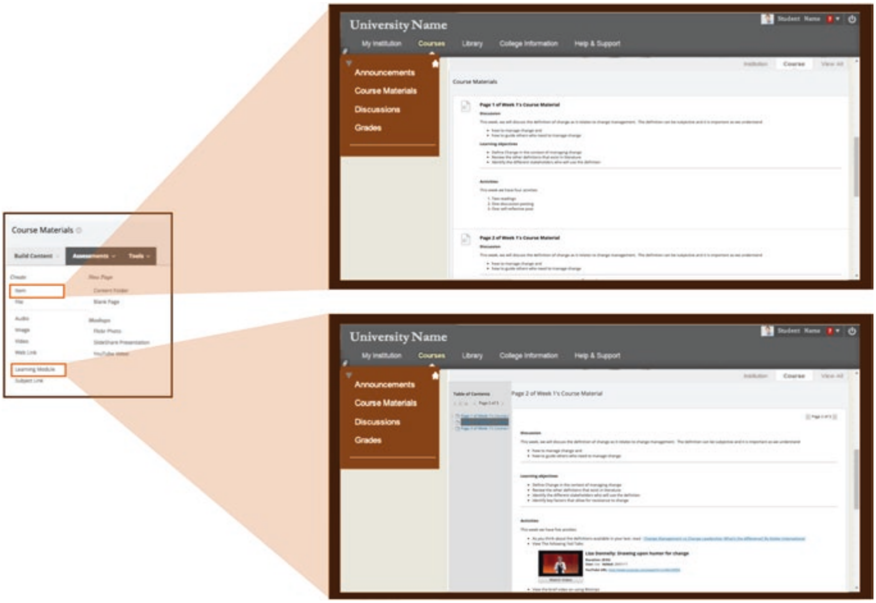


Fig. 4 Illustration of how the same course content looks when designed in Blackboard when using the Content Item tool vs Learning Module tool

its devotion to conventional instruction and its belief that it could be translated directly to online learning contexts. This was one of the gaps in my understanding of the history and culture of the institution.

Being asked to decide on the content as well as the design meant that I determined what learning objectives were needed to close the gap to achieve the new learning outcomes. The new learning outcomes focused more on how people learn and thus how to design for learning and less on how Blackboard tools work (Ormrod, 1999). The material on how people learn was interpreted by the senior faculty members to being that they do not know how learning occurs. I inquired more about expectations of the certification course and found that what the faculty members expected was a technology course on the tools available in the LMS, where they were located, and what they were used to produce; they did not expect a course about how to design and deliver online courses. They believed they had that knowledge as they were seasoned professors.

Managing these expectations based on previous offerings was difficult to resolve. I was not given time to perform a detailed needs analysis, in part because my supervisor saw it as an unnecessary step. I designed and delivered the course with limited knowledge or feedback from anyone. After three pilot offerings of the redesigned course, my redesign was rejected by my supervisor—based on the concerns from the senior faculty members.

Underlying Aspects That Influenced the Redesigning Process

I was employed for a specific purpose and I made many assumptions and decisions that influenced how my performance and outcomes were received. One of these assumptions was my own understanding in managing the expectations of any design activity at this institution. Attempting to guide my own actions by asking for forgiveness rather than permission was a major factor that influenced the redesigned course. I attempted to balance the demands to perform my assigned duties without fully understanding the organization's culture; this was a key influence on the design outcome. This balancing act required a great level of experience in managing expectations. Having had numerous experiences in different organizations and a measured understanding of inter- and intrapersonal skills, it was a self-guided failure.

I needed to do more homework to fully understand the organization. From my perspective, I tried to show enthusiasm through the use of my abilities to prove worth to the organization. Because this was not included in a statement of intent and coupled with a progress report, it was misinterpreted.

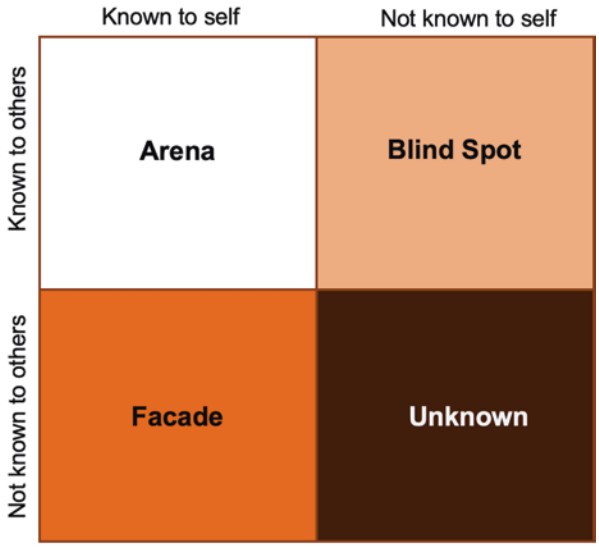
This is also pertinent for instructional designers placed under a functional arm—as opposed to the academic arm—of the organizational hierarchy because this can contribute to differing perceptions of the role of the instructional designer in the organization. The multidisciplinary nature of the field of ID encompasses a wide range of professional skills and knowledge. Where the instructional designer is placed in an institution has bearing on how they can contribute professionally to the institution's strategic goals—especially when that activity includes change and innovation (Dickson-Deane, Tolbert, McMahon & Funk, 2017).

I came to the project with an expectation that I had a solution to a problem and a belief that my approach to the solution would be received positively, but it was met with resistance that ultimately resulted in the failure of the initiative. This failure was reflected on all those related to the project. Most importantly, I felt disappointed because I had hoped to sell the power of the field of ID.

Lessons Learned: Moving Forward

Reflecting on my experiences and how they fit into my career has been key as I moved forward in the ID field. Being aware of behaviors—established and covert alike—has allowed me to build my own library of lessons. Helping those unfamiliar with the ID field understand my abilities so I can use them effectively is a skill I am still working on. In this process, I rely on the Johari window method (Luft and Ingham, 1955), a tool that provides a good way to categorize lessons into known-knowns, known-unknowns, unknown-knowns and, the dreaded unknown-unknowns (see Fig. 5), thus allowing me to understand how to package and repackage my own belief systems as I approach different contexts.

Fig. 5 Measuring interpersonal awareness using the Johari Window method



Understanding how I have used the façade of my knowledge (i.e., known-unknowns) to guide my performance has contributed to new knowledge and experiences and thus abilities. The drive to continue to use what is known to me to contribute to what I believe is valuable to the field can only be attributed to my own personality. As an instructional designer, I believe that having an element of fearlessness is important due to the problem-solving nature of the field (Dickson-Deane & Asino, 2018). How and when that fearlessness is used is a very subjective yet contextualized activity that each individual instructional designer must determine. Thus, this project was one of my greatest lessons in understanding how an unknown can become known through a process of trial and error.

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A Design Case of an Enterprise-Wide Learning Management System

Michael C. Johnson, Larry L. Seawright, and Jason K. McDonald

Introduction

In this case we describe the in-house design and development of an enterprise learning management system (LMS) at Brigham Young University (BYU). The purpose of the project was to replace a commercially available LMS that was becoming too costly as well as unresponsive to the interests of faculty and other stakeholders. In the case we discuss why administrators made the decision to develop a complex piece of software using university resources instead of relying on other commercially available products. We also describe their goals for the project and how we attempted to meet those goals by designing the new system on a foundation of existing components and by focusing on the most frequently used functions from the previous LMS. A central feature of our discussion is how we and other participants made decisions in a high-stakes environment of multiple stakeholders and a compressed timeline, which had an impact on the emerging design of the product. We also examine some of the challenges that arose among members of the design and development teams during the course of the project as pressure on the team became more intense.

Throughout the case we focus primarily on the actions of the design team located in the university's Center for Teaching and Learning. This team included three instructional designers (one of whom is the lead author on this paper), two members of the Center's leadership team (one of whom was responsible for production and project management and is the second author on this paper), and a user experience

M. C. Johnson (✉) · L. L. Seawright
Center for Teaching & Learning, Brigham Young University, Provo, UT, USA
e-mail: mc_johnson@byu.edu; larrys@byu.edu

J. K. McDonald
Instructional Psychology & Technology, Brigham Young University, Provo, UT, USA
e-mail: jason@byu.edu

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designer. We also describe interactions between us, as the designers, and the development team, which included three, full-time, permanent developers as well as two temporary developers.

Context

Brigham Young University is a private, religiously affiliated university in the United States. The university employs over 1500 full-time faculty, and between 1500 and 2000 part-time faculty, to teach about 33,000 full-time students. BYU has 11 colleges and schools that serve these students. It is accredited through Northwest Commission on Colleges and Universities, a self-governing body of 163 US and Canadian higher education institutions located in the northwest.

BYU has been an early adopter of academic technology. For example, among other academic systems it purchased or created, BYU developed and implemented one of the first telephonic class registration systems in the late 1970s. This resulted in the ultimate development of a custom student information system. The university was also an early adopter of learning management systems, deploying its first in 1999, licensed from a company that evolved into one of the major LMS vendors. This system was used by the university for 10 years.

When BYU began using this product, it received immediate vendor response to not only problem reports but also to new feature requests, because the university was one of the first, large organizations to use the product. However, over the next 10 years, as the LMS grew in popularity, the vendor developed more formal processes for both problem resolution and vetting feature enhancement requests. Additionally, it added a pricing structure for adding custom features that the company determined to be outside the scope of what would be added via the normal feature enhancement process. This meant that changes BYU requested were causing significant financial charges from the vendor. And updates or fixes were being delayed due to the company prioritizing them to fit into a larger product road map.

In response to growing dissatisfaction over both pricing and vendor responsiveness, a university committee of faculty, administrators, and information systems professionals was formed to study the LMS needs of the university and to consider whether to continue to use the existing LMS or switch to another vendor. During that review process, one of the vice presidents on the committee noted the existence of several, internally developed tools that performed some of the functions typical of most LMSs: a Syllabus Builder, a discussion forum (called Digital Dialog), a gradebook, and test scoring system used in the university's Testing Center. Additionally, the university had recently created a system to store and report the learning outcomes for each of its programs and courses. The vice president making this observation noted that more than half of the most used features of the current LMS were duplicated by those tools. He wondered if they could be combined together, supplemented with development to create the remaining most-used features and result in a proprietary learning management system.

Those tools had been developed by the BYU Center for Teaching and Learning in response to various needs that had been observed across campus. Because the Center reported to the vice president who originally noted the overlap with LMS features, he requested that personnel from the Center respond to a request for a proposal for converting the existing tools into an LMS with the following features: a content platform, a communication tool, an exam engine, a gradebook, a schedule, and a syllabus. Additionally, it should link to the BYU Learning Outcomes website as well as continue to display syllabi on the university's website, without authenticating into a specific course (this requirement was to comply with a university commitment made during an accreditation visit to have publicly viewable learning outcomes and syllabi).

In response to his request, Center personnel conducted a brief feasibility study and determined that it could combine the existing tools and add additional functionality, with an estimated initial project duration of 24 months to create a beta product that could be tested. Based on this estimate, the university committee charged with reviewing university LMS needs recommended that the university proceed with development of a proprietary system to be known as BYU Learning Suite. Two primary reasons were cited for proceeding with the development of its own LMS instead of licensing an existing LMS. First, the university could integrate custom-developed learning tools with existing custom university data sources, and second, it could adapt and update learning tool features more quickly than could a commercial vendor. The university's academic vice president and chief information officer convened a meeting in July 2010 to review the viability of the proposal. It was approved. However, due to contract issues with the current vendor, during late 2010, the duration of the project was reduced from 24 months for delivery of a beta product to about 18 months for delivery of the initial public version. This decision would have significant impact on the project and all the people involved, from designers and developers to users and sponsors.

Initial Design Considerations and Guiding Principles

As mentioned, the major components of Learning Suite originated as either standalone products or as components of other systems. University stakeholders originally hoped that because these systems already existed, they could easily be repurposed for the new LMS. But, generally, this proved to not be possible because of differences in the technical architectures of the different products. For example, the Center for Teaching and Learning had previously developed the Syllabus Builder in response to BYU's Accreditation Board, who wanted measures of course learning outcomes across the university and what instructors were doing to align their course activities with those outcomes. Because each syllabus was stored centrally, information about any course using the LMS could be reported to accreditors. Although university administrators hoped the existing Syllabus Builder could be repurposed for the new system, because of differences between the system architectures, developers had to create a new Syllabus Builder from scratch.

Even in cases where the underlying technology between existing components was compatible, we as a design team had difficulty repurposing the original products. Our desire to create a unified user experience meant that the surface layers of each product would have to be significantly redesigned. This was more than the styling of various elements, such as their colors, button styles, etc. While the existing components had designs based on providing an easy user experience in a standalone environment, those designs were not conceived of as being integrated into a larger whole. So one of our primary activities as a design team was to consider how each of these components fit together into a coherent navigational scheme and how they were presented in the context of one course as well as in multiple courses. Where possible, we reused individual design elements, but generally either the new context of use was different enough, or enough additional experience had been gained since the original designs were created that we redesigned more components from the existing tools than administrators had hoped.

As it became clear that significant redesigns would happen, we established some guiding principles for how the unified system should behave. Our primary goals were to keep the user experience easy, intuitive, and, as much as possible, based on existing common academic workflows to which faculty were accustomed. We also attempted to build a product that was considered fast, intuitive, and engendered confidence. Practically speaking, this meant we adopt guidelines (Table 1).

We provide some examples to illustrate how we applied these principles. When someone creates an assignment, for example, we attempt to minimize the number of actions users have to take. So when the original assignment record is created, corresponding records are automatically added in the schedule (on the due date selected when the assignment was created) and in the gradebook. Assignments can also be edited from either of these locations as well as in their original record. Another example is the process of adding discussion prompts. When users create a prompt in the discussion forum, they are able to choose that prompt for all selected users or instantly create multiple threads for each individual or group in the course using the same prompt. Broader than the design of an individual component, these principles also led us to integrate the LMS with other proprietary systems provided by the university's IT staff, including the student information system, the Learning Outcomes website, the Student Ratings website, and the BYU catalog and class schedule. We also integrate with commercial applications used by the bookstore (for a student's booklist) and the BYU library (for copyright reserve requests and information about subject matter librarians).

These principles proved to be a good foundation for creating an LMS that seemed to meet important stakeholder goals. BYU's central administrators achieved their goal of closely associating the LMS with two important sources of accreditation information—learning outcomes and syllabi. Faculty stakeholders benefited because the LMS also helped them maintain those two accreditation sources as part of their everyday workflow within the system. In addition, the system also gave faculty the basic components that 80% had used most of the time in the previous

Table 1 Guidelines we adopted to support our design process

Guideline	Specifics
Simplicity	Design each page from the ground up Remove or hide all non-essential functions Define good defaults
Facilitate communication	Between instructor and student Student to student Instructor to instructor
Every millisecond counts	Treat users' time as sacred Even small performance gains are worthwhile Streamline data entry and other tasks Do not make users do things twice
"Functional" is not the same as "finished"	An unfinished feature might be worse than no feature at all The last 10% of a feature makes a huge difference Polish breeds trust
Start up with style, fail with grace	There are three states to every screen: blank (zero state), normal, and fail The initial screen (with no data) is the first impression Do not abandon users in their moment of need
Have a pleasing "personality" and allow for pleasant surprises	Labels, instructions, notifications, warnings, etc. should always be courteous, cheerful, and concise Layouts should be clean, clear, and calm Interactions should seem loyal, helpful, friendly, and fast

product. Student stakeholder needs were met because most faculty were using the same LMS, in mostly the same way, so it was easier for students to find their courses as well as to develop a consistent mental model of how a BYU course would work. Tight integration into other university systems also benefited students as it meant that changes made by faculty were replicated across other systems and LMS components, eliminating redundant data entry for faculty and enabling viewing across those systems by students.

Description of the Design

To provide a feel for what the user experience is like while using Learning Suite, we provide descriptions of major components. Using Learning Suite begins as one authenticates into the system and sees the list of courses available for the current semester (Fig. 1). Instructors see all courses to which they are assigned through the university's academic management system. Students see a list of all their courses but can only access those which instructors have set up and published. Learning Suite also provides an option to view courses from previous or future semesters, under the same conditions of availability as for the current semester. Additional management tools are also available to instructors. These include creating test

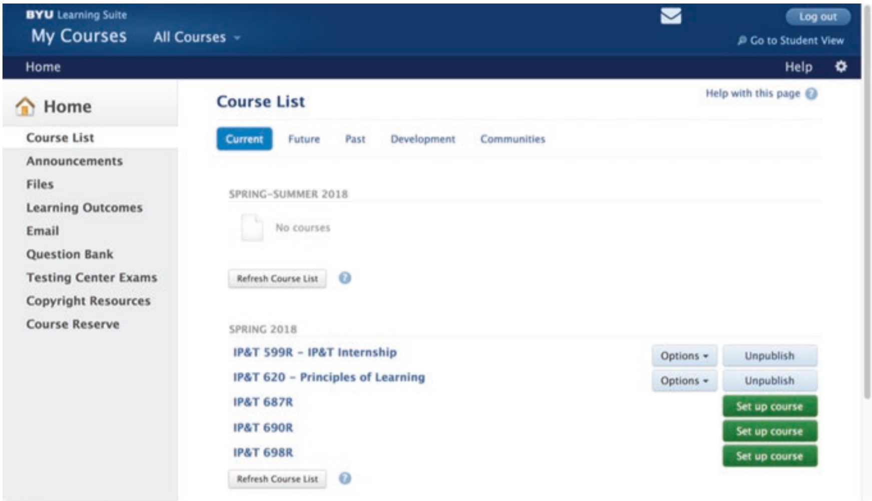

Fig. 1 The Learning Suite course list

questions or uploading files, sending messages, or adding announcements. All of these options are also available within individual courses as well.

When instructors select a course for the first time, they are walked through a set of screens to set up the various aspects of the course, if they elect to use that capability at all. Even choosing Learning Suite as the management tool for that course is an option. Instructors can either elect to make a Learning Suite course available to students, or they can insert the URL of a course hosted elsewhere, such as in another course management system or on an open website (Fig. 2). If they choose Learning Suite for their course, they then set up discussion forums (known within the system as Digital Dialog), exams, content pages, and a syllabus. In each case the first choice is a) whether to open the specific capability using Learning Suite functionality, b) point to an outside URL, or c) to not include it at all. If instructors select to use Learning Suite functions, they can begin to add information, copy a structure from another course (either one of their own or from another instructor who has made a course available to be copied), or return another time to complete either of the previous tasks.

Upon opening a course, the most prominent display is the dashboard, which provides a summary of the upcoming schedule and announcements (Fig. 3). The major course sections can be selected by a set of tabs across the top of the interface, with navigation within a tool available on the left. For example, in the case of the Home tab, the ancillary navigation includes the dashboard, access to the course email system, and, for instructors, course tools like global settings and creating student groups.

Instructors are always able to access every tool through the tabbed navigation. If they have not set up that tool, by selecting it they are presented with the settings information as described earlier. If the tool is set up, they are presented with options

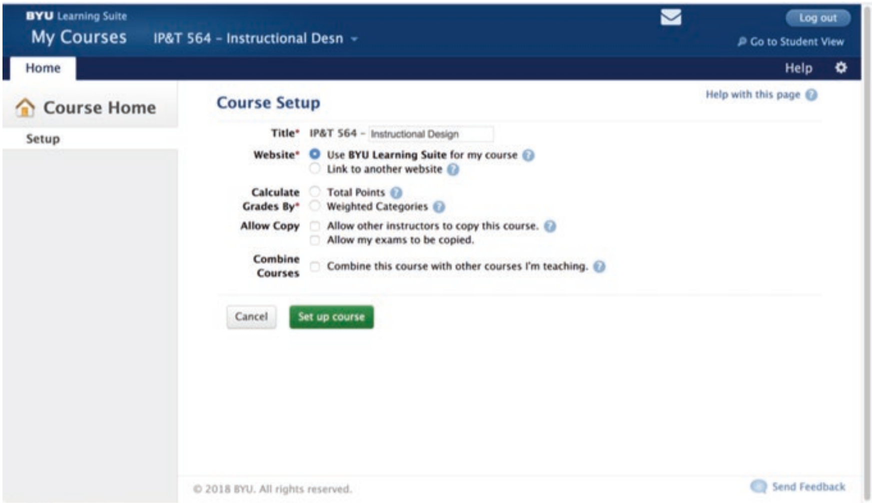

Fig. 2 Initial course setup

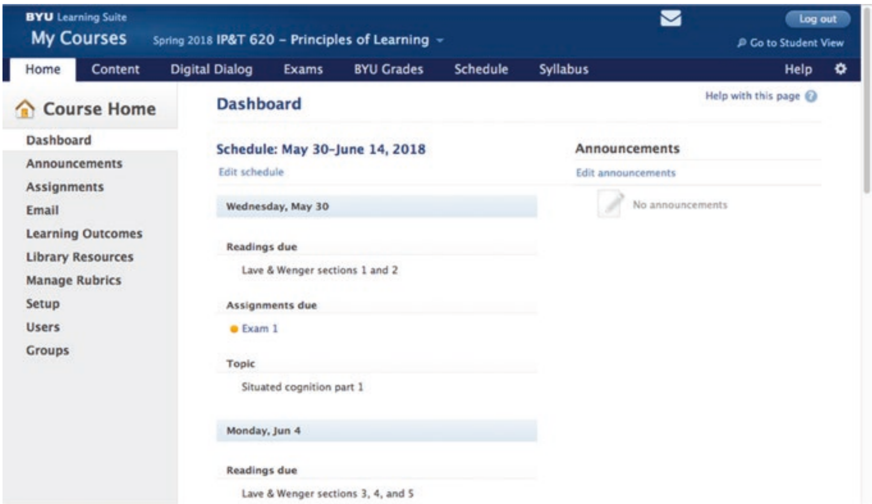

Fig. 3 The course dashboard

to modify settings for that tool or add information or structure to display to students. Students only see tabs for tools that instructors have set up. To give a general sense of the user expereince in BYU Learning Suite, we describe two of these tools in more depth, the gradebook and the schedule.

The initial gradebook display is a spreadsheet that lists all students in rows, with assignments in columns (Fig. 4). Instructors can select any cell within the spreadsheet and add a score directly. In the case of computer-scored assessments, scores

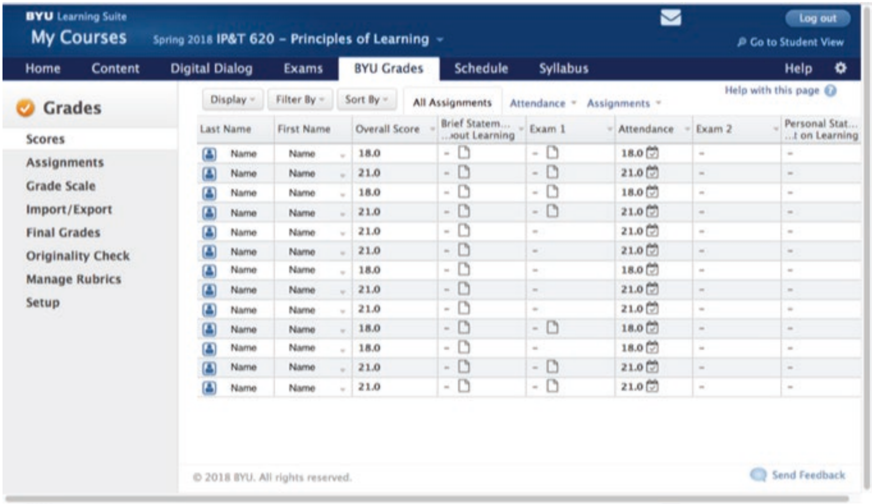

Fig. 4 Initial gradebook view

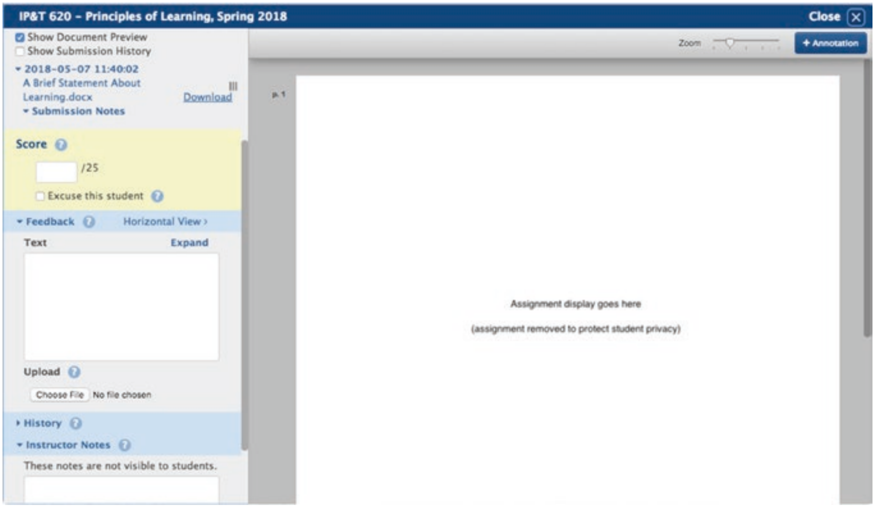

Fig. 5 Assignment grading

are automatically entered by the system. The gradebook automatically calculates a student's final grade based on scores for individual assignments as well as other rules determined by the instructor, some of which include assignment/category weights and grading scale distributions. For an individual assignment, instructors can select the "submitted assignment" icon to see documents that students may have submitted and any comments the student has included with the assignment, offer feedback in return to the student, or grade the assignment using a rubric (Fig. 5).

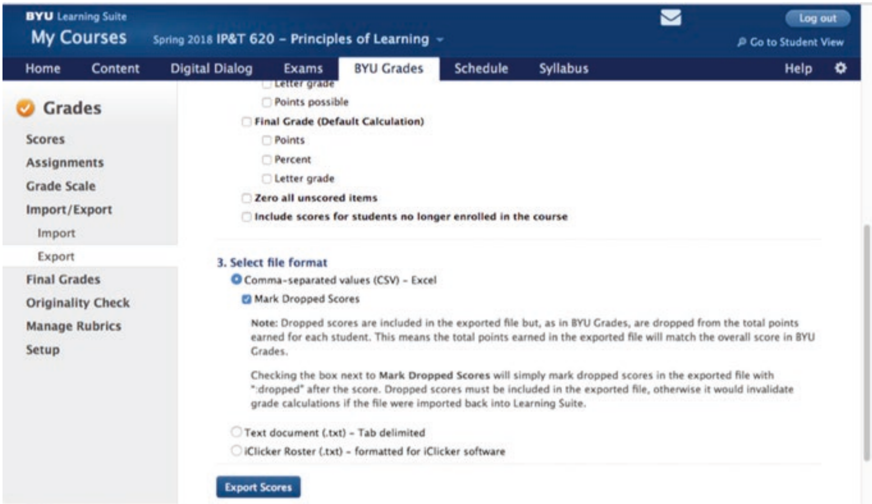

Fig. 6 Exporting grades

Along the left, instructors have additional navigation to create/modify individual assignments, customize the grade scale, export grades, send final course grades to the university information system, perform plagiarism checks, create/modify assignment rubrics, or modify gradebook settings. Selecting any of the ancillary gradebook tools replaces the spreadsheet interface with the requested information, for example, choosing to export grades allows instructors to select through check-boxes what information to export along with choosing among various export formats (Fig. 6).

The schedule is a large, multi-paneled calendar that instructors can customize. A row, representing every scheduled class period for the semester, is pre-populated from the university's master calendaring system. Rows are also automatically added for holidays, other university-wide events, and final exams. Instructors can add additional days if they want. By default at least one column is always available that displays due dates of any assignments (due dates are initially set when instructors create the assignment). But instructors can also add other columns to display whatever information they want students to see about each class period for the semester (Fig. 7). By double-clicking on an open cell, instructors can add any open text they want, including links out to other sections of the course or elsewhere on the Internet. Once information is available in a cell, it can be reopened and modified, dragged to another cell, or deleted. Dragging an assignment to another cell automatically changes its due date in the grading system.

Beyond these components, Learning Suite also includes the following functions:

- Content repository: allows instructors to create simple HTML pages (using a WYSIWYG editor or editing HTML directly). Pages can also embed standard file types.

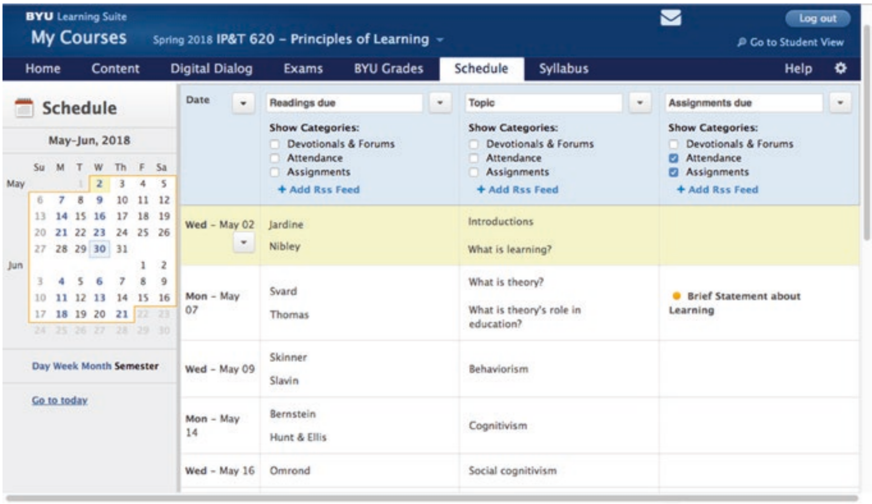

Fig. 7 The course schedule

- Messaging systems: an internal messaging system allows for in-course communication between faculty and students (more similar to an internal email system than a reproduction of the discussion forum). An email component was also made added for messaging outside of the LMS.
- General course announcements: permits posting of announcements that can be displayed when students login to Learning Suite or sent to them through email.
- File system: allows for storage of files that instructors include in their course (e.g., PDFs, PowerPoint slides); files can be linked to in multiple courses using the same location in the file system.
- Groups: allows instructors to segment classes into smaller groups, primarily for discussion purposes.
- Course copy: allows instructors to copy a course or course components from semester to semester. Instructors can also open their course for other instructors to copy.

Effects of the Shortened Timeline on the Product

As noted earlier, within a few months of the decision to create a custom LMS, the central administration made another decision to not renew a license for the existing LMS at the conclusion of its contract. That meant that our replacement product needed to be completed, tested, and rolled out to users in less than 18 months. The effects of this change led to some significant stress for us as well as the development team, but also led to some process innovations that allowed us to still meet the deadline to which we were accountable.

The tight time frame meant that development of LMS components needed to start almost immediately. This was a significant problem for us as a design team; there was little time for any product design beyond basic functionality, and there was not time to adequately iterate any initial design ideas. To compensate, we chose to use existing research on the characteristics of usable learning management systems instead of engaging in our ideal plan to investigate users' workflows and processes directly. We were able to conduct focus groups with faculty and students to get their opinions about the designs of the existing products being integrated into the new system. Using paper prototypes created for those focus groups, we developed high fidelity mock-ups and delivered them to developers so they could begin the actual programming for system components.

However, once designs were handed off to the development team, there was little time to verify that our design intent was actually implemented in what was produced. We initially assumed this would be acceptable because some of the development staff had previous experience creating learning management systems, and we believed their experience could help them fill in the gaps in the designs they received. But what often happened was developers replaced even these too-simple designs with still simpler interactions, to reduce the time needed to create a stable product that could be released. We, as designers, were sometimes not included in this reduction process, however. When a test product was developed enough to be shown to us, we were sometimes surprised that our designs had not been followed. Even more, we were told to keep providing developers with designs so they could stay productive, even though we had not adequately reviewed much of their work that was based on our previous designs.

In fact, this caused a significant degree of conflict during the initial development cycle. We believed we were being asked to approve a product even though it had not been subject to a review that would ensure it was meeting our design specifications. But developers believed they were not receiving designs fast enough to implement them all by the deadline. The resulting stress and inter-team conflict resulted in even less efficiency and effectiveness than both sides were already worried about. Our ability to meet the deadline at all was at risk.

To resolve the conflict, the two teams had to work together on a new process that addressed these concerns at least enough to allow for successful completion of the project. As a design team, we agreed to skip a low-fidelity wireframe stage of our process and only produce high-fidelity prototypes that were annotated with significant information developers needed to know. We created these prototypes using a set of templates created by a graphic designer and that the instructional designers on the team could use to rapidly add interaction elements. We also created a living style guide that developers could use for information about interface elements such as button colors and size and dialog box interactions. We call this style guide living because, although both we and the developers preferred to have all these decisions made before actual coding began, the work patterns created by the compressed timeline led to a just-in-time approach to making new interface decisions only when it became necessary for developers to complete their work (Figs. 8 and 9).

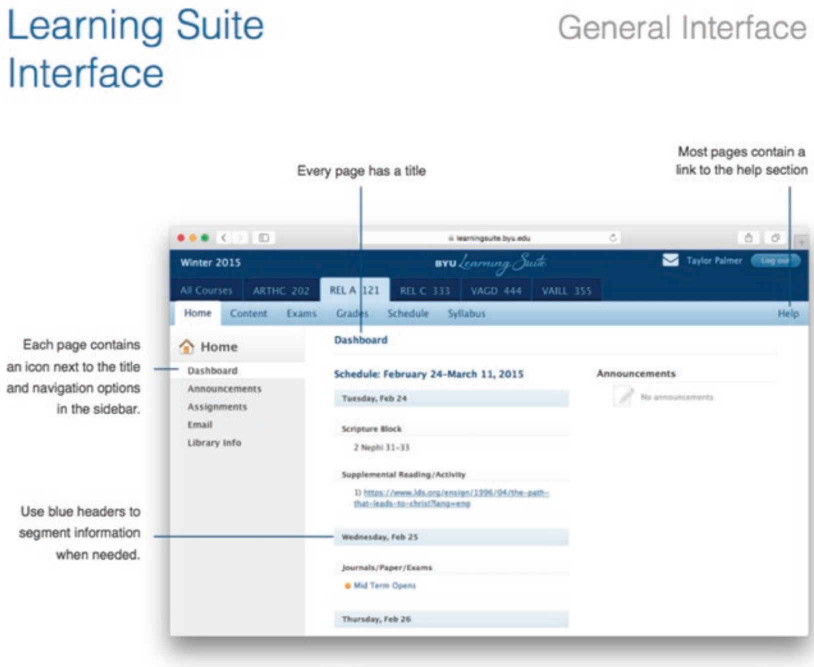

Fig. 8 Example page from BYU Learning Suite style guide

Initial Implementation of Learning Suite

When the Learning Suite LMS was released, it was not as stable or as easy to use as hoped. Initial months after release saw a number of bug fixes and other optimizations. We were still not significantly involved in this phase as designers, because the pressures to make the system stable meant developers had to implement whatever the simplest solution they could create on their own in order to solve the immediate problem.

After the first push for stability, there were fewer pressing deadlines, and we could take more time to produce our design documents for new features, as well as to work more interactively with developers to explain our decisions. Additionally, we became more familiar with the processes used by the developers, allowing us to more clearly articulate the intent of our designs. Over time, the designers and developers have begun to trust each other and work more collaboratively with one another.

This did not completely eliminate all the challenges in developing the Learning Suite user experience, however. For example, when we designed the email tool, we initially sent all messages as a blind carbon copy, meaning that while someone could send a message to multiple recipients, any responses back from a recipient

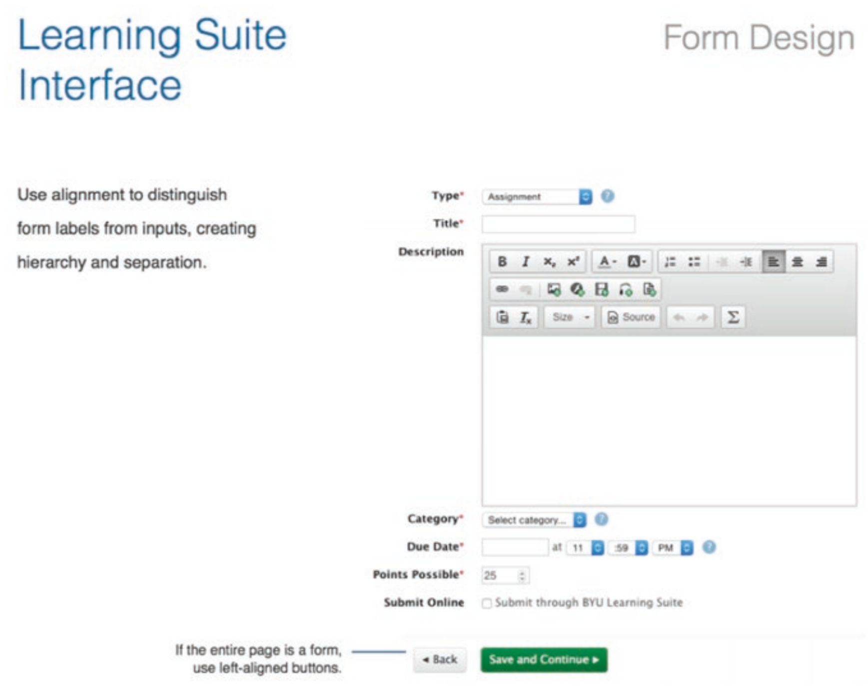

Fig. 9 A second example from the BYU Learning Suite style guide

were only sent to the person originally sending the email and not to the full list of recipients. This did not facilitate communication as well as instructors and students desired, so we built a messaging system internal to the LMS that would more easily allow for many-to-many communication. Yet this still did not meet the expectations of those using the product; they wanted a simple way to respond to messages through their email client and did not want to be required to go into the LMS to reply to messages. Yet, due to lack of infrastructure and competing priorities, we have not been able to add this feature.

Even with challenges such as these, with each successful semester of use, faculty and students have begun to trust the Learning Suite system, especially during high usage periods such as at the beginning and end of each semester. The initial usage of the LMS among faculty was at the same percentage as the previous system—80%. Over the 5 years of usage, faculty usage has grown to above 85%. During that period, faculty and student calls to the service desk for usage support ("how do I do this"-type questions) have grown by 30%, while support calls ("something doesn't work") have gone down by 20%.

Conclusion

In this case we have described the design of BYU Learning Suite, a proprietary learning management system. We described the context and constraints of the design and development of the tool to give a deeper understanding into how these factors influenced the design, design processes, development process, and the relationships between the design and development teams. Finally, we described the challenges faced in implementation.

Though the initial time constraints were tight, the further reduction in the timeline created a seemingly insurmountable obstacle. This in turn further magnified the usual differences that exist between designers and developers. Yet this case shows that, with some innovation and compromise in the product and process, the team was able to complete the project, though initially not the product any had hoped for. Still through iterations and increased collaboration the product has become much more stable, usable, used, and generally accepted. And the design and development team has learned to work together in a much more cohesive manner.

Finding Junctures in Learning Design and Entrepreneurship: A Case of Experiential Learning in Online Education

Ana-Paula Correia

The Case for a Design Case

This design case centers on the creation of an online learning experience for graduate students in a newly created online master of learning technologies at a large public university in the United States. It focuses on the processes used and decisions made in relation to the design and development of an advanced graduate course that dealt with the topic of Applied Learning Design and that was offered in a fully online format. This experience made use of deep learning approaches and took the further step of providing knowledge about educational product design and development, commercialization and licensing, and implementation, along with practice in all these areas. Deep learning in this context happens when "learners relate ideas to previous knowledge, look for underlying patterns, examine claims critically, and reflect on their own understanding" (Weigel, 2002, p. 6). As a result of these choices, the course evolved into a rich, authentic online learning experience that continues to live beyond course completion and the end of the academic semester.

In this design case, I share my direct involvement in this online learning experience that was intentionally designed to educate participants about Applied Learning Design. The chapter documents my sources of inspiration and the problems addressed with the design case and my design philosophy. I also provide a detailed description of the case, including the context, participants' profiles, and key design decisions. Foregrounding the design process and outcomes, it also includes analysis of my initial ideas, the student design teams' projects that were grounded in real-world educational problems, the course content and evaluation, the impact of design decisions, and the difficulties I encountered during the design case's enactment.

A.-P. Correia (✉)
The Ohio State University, Columbus, OH, USA
e-mail: correia.12@osu.edu

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It is hoped that this design case informs design practice and contributes to a design knowledge base that is very much in need in educational technology (Boling, 2010). The design case was inspired by the limited use of pedagogies and processes that allow for the development of transferable and professional skills in online education, and it seeks to provide an example of a learning experience that was successful in achieving these outcomes.

So, What Is the Problem?

It is widely accepted that many programs in higher education are focused more on the transmission and replication of knowledge than on providing opportunities for learning in real-world contexts and "[testing] in action what [students] have learned" (Kolb & Kolb, 2005, p. 208). Since 2005 when I started teaching online about evaluation and learning design, I have tried different pedagogical approaches that were the result of innumerable conversations with my graduate students about the lack of realness in online courses. These students dread online courses with their incessant writing of papers, their limited application to the participants' current and future professional lives, and their general irrelevance to the job market. This problem has been extensively documented, and criticisms of professional preparation programs have highlighted the lack of connection between what is taught in educational technology programs and the reality of the professional workplace (Schwier, Hill, Wager, & Spector, 2006; Williams van Rooij, 2010). Furthermore, in today's world, many young professionals are considering self-employment opportunities and participate in the educational technology start-up movement, but experiences that develop an innovator's and entrepreneur's mind-set are even more rare in current graduate programs.

Now more than ever, students in educational technology graduate programs wish to create highly usable educational products and programs that can serve as evidence of their level of performance and that they can include in their educational technology portfolio. They are famished for learning experiences that are real and that can constitute evidence of the contributions that they can make to the educational technology field as innovators, thinkers, and entrepreneurs. Increasingly, employers in the technology world value what potential employees can do or create more than academic credentials. Employers envision that universities and colleges "equip students with the skills they need to be successful in the workplace and to make an impact on the world at large" (Adams Becker et al., 2017, p. 12), which is why educational institutions need to focus on providing authentic learning experiences.

To make the problem even more complex, online master's degrees in educational technology are flourishing. In many of these degrees, enrolled students are expected to complete courses in instructional design, often consisting of enormous amounts of information, but with limited pedagogies and processes that allow for the development of transferable and professional skills. This pedagogical tendency to privilege information transmission over experience results in problems for the graduates in these programs, since they lack a practical understanding of the field and encounter tremendous difficulties in transitioning from their graduate studies to the professional environment.

The design case in this chapter presents an honest attempt to create an online learning experience that advances innovation and leads to the creation of thoughtful learning products and programs that demonstrate an entrepreneurship mind-set. For this reason, the learning experience in the design case bridges entrepreneurship and learning design and depends on high involvement by the learners. These two aspects constitute its major contributions to the collective enterprise of transformative online education.

A Design Philosophy

Actions speak louder than words. When Google hires people without a formal college degree, the company's hiring decisions are based on the applicants' demonstration of knowledge and skills, rather than on a college transcript (Bryant, 2013, para#24). Internships, employment during college, volunteering, and extracurricular activities provide opportunities for people to showcase how they apply their knowledge and skills, make decisions, and create solutions in real working situations.

When I started designing this online learning experience, I had experienced face-to-face graduate courses that shared some of its design features, both as student and instructor. As a student, I engaged in virtual design work and investigated the idiosyncrasies of geographically distributed teams. As an instructor, I listened to previous graduate students' pleas to create online courses with ample opportunities for experiential learning. I have early realized how eager students were to learn how to push the limits of their class projects and use them as exemplary artifacts on their professional portfolios and meet their current employers' expectations. In response, I have sought to create online learning experiences in educational technology and, more specifically, learning design that involve an entrepreneurial mind-set and a "just do it" attitude. The goal of these experiences is to achieve deep learning, especially in online modes of delivery – that is, learning that is situated in applied contexts and knowledge that is construed from rich interactions with teachers, peers, and reality. As Weigel (2002, p. xiii) argues "education is not about earning a credential, stuffing information into one's head, or performing well on an exam"; it is about deep learning defined by the author as "learning that promotes the development of conditionalized knowledge and metacognition through communities of inquiry" (Weigel, 2002, p. xiv).

Moreover, adult learners demand from any educational experience that their life and professional experiences (e.g., work-related activities, family responsibilities, and previous education) are integrated into their learning. Adult learners wish to know why they are learning what they are learning and see a clear relevance and application to their professions and lives. As a result, more than communication skills and content knowledge, educational experiences and online learning experiences in particular should contribute to more advanced forms of intellectual development and embrace multiple dimensions of human development. To accomplish this aim, experience needs to take central stage in the process of learning and development (Kolb, 1984) and experiential learning to serve as a theoretical basis for design. In this design case, Kolb's experiential learning model was more used as a theoretical grounding point and inspiration than a strict guide to course design.

From an experiential viewpoint, learning may be defined as "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). The focus is on the process of adaptation and learning, as opposed to content or outcomes. Experiential learning in higher education, especially in online education, is often approached through case analysis, role-playing, and live or computer simulations. These activities allow learners to apply what they are learning to new situations and to learn by doing; however, they lack the messiness of reality, because they neglect critical relationships that can only be encountered when working in real contexts.

The shift from simulated learning experiences to experiences grounded in reality is an emergent trend in higher education, as reported by the 2017 New Media Consortium Horizon Report. Real-world skills development and multidisciplinary collaboration are two of the most important themes for education in higher education (Adams Becker et al., 2017), while deeper learning approaches (Weigel, 2002), entrepreneurship, and innovation are key trends when accelerating human development.

In sum, my design philosophy revolves around the concept of learning as situated in real contexts, a decision-making process that takes into consideration the adult learners' lives and professional experiences, and the belief that entrepreneurship and innovation are driving forces in higher education.

Design and Implementation Context

The course, "Applied Learning Design," was designed as part of a larger group of learning experiences that make up the newly created online master of learning technologies that is offered at one of the largest public universities in the United States. This master's degree is a professional degree that focuses on applying current research to solving problems of practice relating to the use of technology to support learning in a various in-person, online, and blended contexts. Students in the degree take a core sequence of seven courses, a research course, one elective course, and a practicum course, completing 30 credits in total. "Applied Learning Design" is one of the core online courses of the curriculum. In the iteration discussed in this chapter, "Applied Learning Design" was the second course in a two-course sequence. "Introduction to Learning Design" was offered from August to December 2016, and the second course was available between January and May 2017. Both courses were delivered via Canvas, the institution's standard learning management system.

"Applied Learning Design" provides more in-depth discussion and exploration of the topics explored in "Introduction to Learning Design" through a project-based approach. In it, students build on what they learned in the introductory course and practice applying concepts, principles, and theory to address real educational problems as part of design teams. They propose solutions to real-world problems using learning technologies. The goal is *to help people learn better* in a variety of learning contexts and make a positive impact on groups and communities.

The online learning experience created as a result of the implementation of "Applied Learning Design" was chosen as a design case for three primary reasons: (1) it was an unparalleled platform for a series of Applied Learning Design projects along with opportunities for development and implementation; (2) it was offered for the first time to a newly formed online cohort; and (3) it was created and implemented by an experienced faculty member (myself) who had just started to work at this particular university. I instantly recognized an opportunity to bring to life many strategies that I had tested and validated in previous online courses at a different university. I was aware that online students in educational technology programs crave opportunities for the type of practical and experiential knowledge that would give them an advantage on the job market, and I have found myself in a scenario where both my students and I had the opportunity for new beginnings. I was motivated to design an augmented online course that provided real-world practice of learning design processes, exposure to product commercialization and educational technology start-ups, and small- and large-scale implementation of students' learning solutions.

In addition, I was valued and supported by a forward-thinking leadership at the department and university level, extremely committed to offer high-quality online courses and programs. As new faculty, I felt that my expertise was respected and my design approaches were appreciated by my fellow colleagues, who were also teaching in the new online program and striving for quality and innovation. My voice was definitely heard and, as importantly, it was trusted. At that same time, the university-wide e-learning unit was promoting an unprecedented culture of innovation and engagement, including support for e-learning solutions licensing and commercialization. I sensed that this was the moment to fuel my vision of an Applied Learning Design online course.

Participants' Profiles

Many discussions took place between "Introduction to Learning Design" students and me about how they would envision the second course in the sequence. These early conversations were an important step in creating a learner-centered online experience. About ten students were contacted informally and met with me via videoconferencing or face-to-face. They envisioned a vibrant online course where they could apply the knowledge and skills developed in the first course of the sequence to create relevant artifacts that they could include in a learning design portfolio. They also expected to learn about what it means to be a learning/instructional designer, what such designers do in real-world professional environments, and what opportunities exist for them in terms of development and employment.

Regarding the learners' profile, 18 students took "Applied Learning Design." They were in their mid-twenties all way to their early fifties. Most of the students were experienced professionals in education (ranging from teachers to training directors) in their early to mid-careers and were motivated to start a new graduate program in an area that excited them. Students in the class also had extensive professional experience in instructional design, data analysis, in teaching languages, distance education and e-learning, career advising and technical expertise in learning management system, multimedia production, and programming. However, all of them strived to find a balance between their professional responsibilities, their personal lives, and their further graduate studies. They were particularly concerned with taking courses and completing a program in learning technologies that would allow them to advance in their current careers or to make a sustainable shift in profession.

The Key Design Decisions

The aim of the design process was to create an online learning experience that was learner-centered and offered deep learning approaches. The following section discusses the key design decisions that were made, adopted, and/or rejected as the design transformed throughout the development and implementation process. Before I start, I would like to make clear there were not any design guidelines that were imposed on me or on any of my colleagues in the program. We were given flexibility to design the finest online courses to meet the students' needs as well as to fulfill the master of learning technologies' vision. However, there were a couple of requirements that consisted in using the learning management supported by the university, Canvas, and a suggestion to hold one or two synchronous sessions a semester per course.

My Igniting First Ideas

After animated discussions with students taking online master's degrees in educational technology during an active session in a national educational technology conference, I found myself flying back home. While on the plane, I developed an initial vision for "Applied Learning Design" and outlined the main ideas on the back of a conference handout during the period that electronics were not allowed to be used on the plane. As Fig. 1 shows, the initial sketches were scribbles, which offered glimpses of the course's design elements and themes. However, four key ideas were salient:

1. The learning activities would allow students to create instructional solutions to address educational issues that they encountered in their local communities and

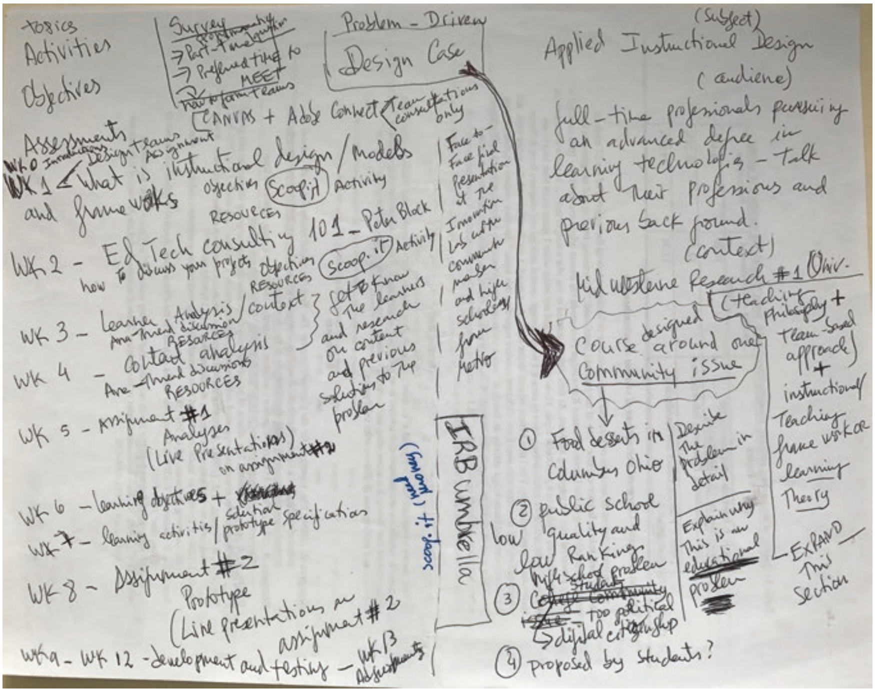

Fig. 1 "Applied Learning Design" initial sketch

surrounding networks. It was important to offer opportunities for students to apply their knowledge and skills in learning design to the betterment of their own communities and networks while they were learning the course content, as it would allow them to address learning problems that were relevant and important to them. These problems were identified and negotiated in their design teams.

2. The course themes included practices and principles of entrepreneurship. Here, entrepreneurship was defined as the pursuit of solutions to complex problems that people actually will use and went beyond making money, starting a venture, or owning a small business (Kao, Kao, & Kao, 2002).
3. Students would work in teams. This aspect of the teaching philosophy rests on the belief that learning to contribute to the success of a distributed design team is a critical skill for a learning designer.
4. The online course would be organized by weekly themes and would use Canvas as the learning management system and Adobe Connect for live interactions. The participants were encouraged to organize their own live interactions at any time, but the mandatory live sessions (which were synchronous) were limited to two in a 12-week period.

Course Initiation, Promotion, Content, and Evaluation

To promote the online course, a promo video was created by the university's office of distance education and e-learning. It may be viewed at https://go.osu.edu/BjYa (Fig. 2).

Even though "Applied Learning Design" was a core course in the online master of learning technologies, I expected to attract students from related programs. I anticipated that the variety of backgrounds and experiences would make the peer-to-peer interaction richer and the educational problems addressed would be more greatly situated in a variety of communities and networks. Ultimately, 18 students registered in the course (see section "Participants' Profiles"). Students from different disciplines enrolled in the course, which allowed us to showcase learning design as an interdisciplinary field. They were English, art education, statistics, kinesiology, nursing, and workforce development in addition to learning technologies.

One week prior of the start of the semester, a welcome email was sent to all students enrolled in the course, which included important elements such as the starting date and time of the course; an introduction to the learning management system; information about the mode of communication, textbook, and readings; and a copy of week two's required reading as an attachment. Part-time online students tend to be anxious about what to expect from a course in its initial weeks, since most of them have to balance a full-time job with one, two, or even more classes a semester. The decision to send out an early email was intended to decrease their level of anxiety, as it gave students an opportunity to have a head start on the work required by the course. Additionally, a set of detailed instructions about how to create an online self-introduction was included in the welcome email, so that students could plan how to introduce themselves to their instructor and classmates.

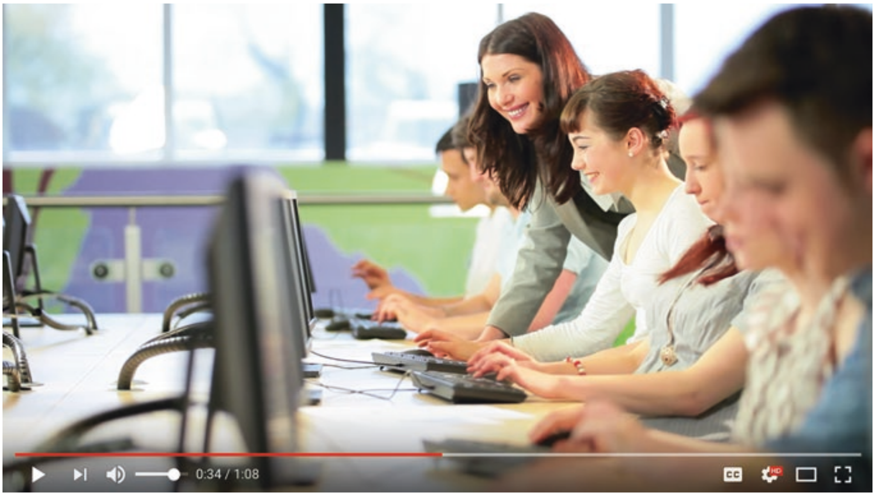

Fig. 2 Screenshot of "Applied Learning Design" promo video

The online course had an overview section that indicated how the course would unfold during the 16-week semester. As mentioned above, each week focused on a specific topic. Each week would kick off with an email sent by the instructor on Tuesday at 8 am and would close on the following Monday at midnight. This email would read something along these lines: "This email serves to officially open week #. Please note that the main activities for the week are…Issues that require your immediate action are…. Upcoming deadlines are… Contact the instructor via email, phone or Skype to address any questions." The consistency of the kick-off email for each week was intended to create a purposeful rhythm for the learning experience and a constant channel of the communication between the students and instructor.

Throughout the 16-week course, students worked through different topics and activities. In most of the weeks, students were expected to contribute to an online discussion or digital curation activity. This activity consisted of identifying resources that were related to a specific topic. Different from content creation, curation refers to finding, providing a link, and offering an analytical comment to content that is already created. Curated content is meaningful, filtered, and directed toward a specific target. The power of collaborative content curation emanates from the fact that it is filtered and organized by humans. For example, the class built collaboratively a knowledge base on "Motivational Strategies" by curating digital resources that were directly relevant to this topic. Text, audio, video, and images were used to help express the curator's point of view and illustrate the analytical comment.

Throughout the course students were strongly encouraged to use audio, video, and images to help create their own meanings and express their own points of view. The online activities were facilitated by the instructor.

Even though no top-down impositions were made from the department/college in terms of online course design requirements, I had to deal with the constraints of the learning management system. Canvas offers as sequence of modules as a way to control the flow of the course. Modules can be organized content around weeks or units in order to create a linear sequence that students should be able to follow. Files, web pages, discussions, assignments, quizzes, and other learning materials can be included in each module. As a result, the course was organized around weekly themes linked to different learning activities. This organization scheme was suggested by the students. They appreciated clearly delimited learning events that they could start and end on a weekly basis and develop a sense of progression in the course.

Below is a list of the topics explored in the course with a rationale for inclusion:

Week 1, *Introductions*. It was particularly important that students spent some time to get to know each other better. Since the main project in the course was a team project, student took their time to learn about their peers and start to form their design teams. The participants' introductory activity in the first week generated 158 different postings, which evidenced the students' commitment to get to know each other.

Week 2, *Introduction to Learning Design in the Context of Educational Technology and the Ever-Changing Landscape of the Field*. The following week explored different foundational concepts, such as educational technology, instructional design, learning design, and learner experience design. The online activities established the ground for the work in the course. The students were randomly assigned to two online discussion groups to allow for a more intimate exchange of ideas.

Week 3, *Review of Instructional Design Models, Approaches, and Frameworks*. In week 3, the concepts learned in the first course of two-course sequence, "Introduction to Learning Design," were reviewed in detail. Students were asked to critically analyze one model, approach, or framework of their choice, using specific criteria proposed by Edmonds, Branch, and Mukherjee (1994).

Week 4, *Defining Problems: Understanding Needs, Audiences, and Tasks.*

Week 5, *Instructional Objectives.*

Week 6, *Motivational Strategies.*

Week 7, *Designing the Instruction: Components, Activities, and Sequences.*

In weeks 4 to 7, students explored the most used components of the learning design process, with emphasis on learning analysis and planning. They were asked to review, analyze, and critique these components of the process, particularly the formulation of instructional objectives. This discussion generated much controversy about the dominance of the cognitive domain, the rigidity of the objectives, and the general obsession with pursuing the observable and measurable.

Week 8, *Design Team Live Presentations* via *Adobe Connect/Instructor Collects Course Feedback from Students.* Design teams worked on their first mandatory live class presentation that took place in the evening via Adobe Connect. Each design team created and shared with their peers a presentation on the main results of their learning analysis. They also stated the educational problem that they were going to address and established the need for instruction. They had complete control of the videoconference system since the live presentation was a student co-led activity. During this week, the instructor collected feedback from the students about the course. Students were asked to: "Provide feedback on the course by filling out the mid-term course evaluation. This survey aims at collecting feedback about the course (and not about you). The purpose is to gather your input at this point of the semester instead of asking you for it when the course is over. This way I am able to act and make any necessary changes that will not only positively impact students taking this course next semester, but also you. If you decide to participate, please do enter your answers by …."

Week 9, *Visual Design for Instructional Purposes.* This topic was explored using a digital curation activity. This activity became an opportunity for students to explore and use an online curation tool and collaboratively build a knowledge base on visual design for instructional purposes. Each student had to curate at least one digital resource and react to other resources curated by one of their peers or instructor. Digital artifacts included, but were not limited to, online articles, videos, podcasts, images, graphics, infographics, etc. Through the curation activity, they were asked to critically analyze relevant issues and summarize key issues demonstrating a level of expertise on the topic.

Week 10, *School Break.*

Week 11, *Evaluation and Usability Testing in the Instructional Design Process.* Exploring this topic would allow students to prepare for one of the most important requirements for engaging in Applied Learning Design: the learners' tryout. During this week, students discussed how to design and develop evaluative instruments, how to collect evidence to judge the value of the instructional materials, and how to frame the testing in terms of specific aspects of the learning experience, e.g., effectiveness, efficiency, and learner satisfaction.

Week 12, *Instructional Materials Development.* At this point in the semester, students focused exclusively on the development of their instructional materials and on their learners' tryout. It was important to have a dedicated time period for this critical phase of the applied learning project, since it offered busy learners an opportunity to focus on the key tasks they had to complete.

Week 13, *Entrepreneurship in Educational Technology (Guest Speaker: Insights from K., Owner and Founder of Learning Design LLC).*

Week 14, *Start-Ups in Educational Technology (Guest Speaker: University's technology commercialization officer).*

Weeks 13 and 14 were dedicated to exploring entrepreneurial opportunities in learning design. The decision to include this topic rested on the fact that many graduates in learning technologies can pursue careers as independent consultants and/or product developers. More about this topic is discussed below.

Week 15, *Design Team Live Presentations* via *Adobe Connect/Instructor Collects Course Feedback from Students.* This week involved the second mandatory live class. In the synchronous session, design teams presented their instructional materials and shared the results of the learners' tryout. They were able to get peer feedback and suggestions for further developing the instructional materials via an online survey. Design teams had to justify the decisions that they made throughout the learning design process, and their peers could ask questions about the process/product too. Results and recommendations based on the tryout findings were also reported during this event.

Week 16, *Course Wrap-Up/Student Evaluation of Instruction Submitted by Students.* In the last week of the course, the students' evaluations and final assignments were submitted. Resources on instructional design jobs and further professional development opportunities were shared with the students.

In addition to the major design project that forms the focus of the next section of the paper, students completed an individual project around Week 3, in which they provided an in-depth analysis of a design model, framework, or approach, following the specific criteria proposed by Edmonds, Branch, and Mukherjee (1994) that they had practiced that week. It counted toward 10% of the final grade.

Course participation was also an important component of the student assessment process, as it made up 30% of the final grade. The online discussions and course activities acted as opportunities for students to reflect on the readings, ask questions, engage in course activities (e.g., digital curation), lead conversations, and discuss any issues about the course. Students were strongly encouraged to express themselves using not only text-based formats but also audio, video, and image formats.

As part of the participation grade, students were expected to contribute to online discussions and fully participate in the course activities.

Contribute to Elevate Social Presence

To strengthen social presence and create a true online learning community, I have shared with the class my Southern European upbringing and international background, which have a major impact on my life and work as a teacher and researcher. To illustrate this influence and the value of social bonds, I set up "The Learning Design Café," which was an informal social space in the learning management system. I used the concept of the Portuguese "café" to foster a discussion that would support socialization beyond readings, assignments, and technical issues (Fig. 3). Participation was voluntarily, but it became a place to share challenges and victories and post available positions in the field and professional development opportunities.

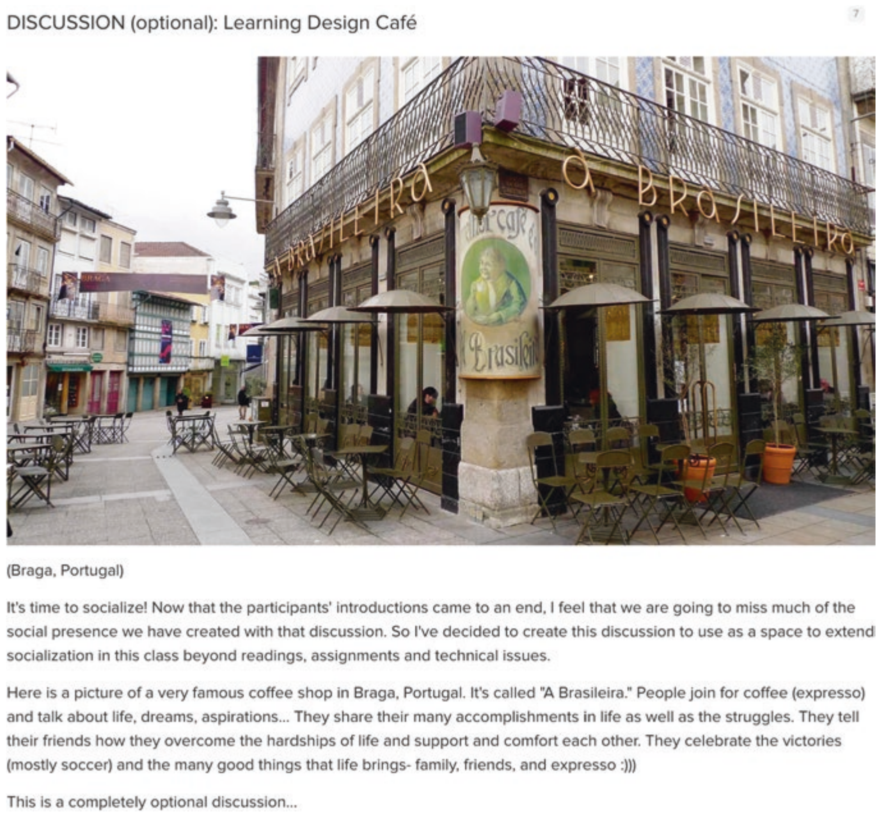

Fig. 3 Screenshot of "The Learning Design Café"

Moreover, a major effort was put forth in the first weeks of the semester to create an online community where students employed a variety of media (e.g., video, text, audio, still images) to introduce themselves to each other and develop a sense of social presence. In my previous conversations with students, they were eager to explore other forms of expression other than writing/text. They really pushed for the utilization of the multimedia capabilities of the learning management system from the students' end. They wanted to create content for the course that allow full expression of their points of view.

The members of the online learning community (including myself) were encouraged to share information on the following during their introductions: (1) name and gender; (2) US state and/or country of origin; (3) current geographic location; (4) major; (5) degree(s) earned; (6) professional background; (7) strengths in learning design, curriculum development, or multimedia production; (8) hobbies and/or interests; (9) dream job or career goals; and (10) something that they have never done but that would like to do in the near future not necessarily related with their profession (e.g., sky diving, travel to a special location, and work as a volunteer). It was understood that individuals would only share the information and media that they would feel comfortable to share with the learning community.

This activity let students' personalities shine and cultivated a sense of belonging, as shown in Fig. 4. Members of the learning community were expected not only to read/view their peers' introductions but also to interact with each other. They could comment on a common hobby or interest, share a relevant resource, etc.

Work as a Member of a Geographically Distributed Design Team

It is guaranteed that, as potential instructional designers, students will not work in isolation; rather, they will be members of a larger team of subject matter experts, developers/coders, and other designers that may be geographically distributed. Making the major assignment a team project was not the most popular design decision, but the process used to create the design teams helped to alleviate some of the issues. One of the major issues students had with working as members of a design team was that they hardly knew anyone in the class, which was exacerbated by the fact of the course being offered online. Students were not going to be able to meet face-to-face in a physical space. However, the extensive introductions that I encouraged and modeled (see section "Contribute to Elevate Social Presence") made the team formation process less difficult and more seamless. Students were asked to self-select their team members by signing up in the learning management system to a particular group. There were not any guidelines to follow during team formation other than my strong recommendation to keep teams as heterogenous as possible in regard to work experience, background, gender, age, interests, geographic location, etc. But again, this was only a recommendation and not a mandatory criterion for team formation. Therefore, only a few teams followed it.

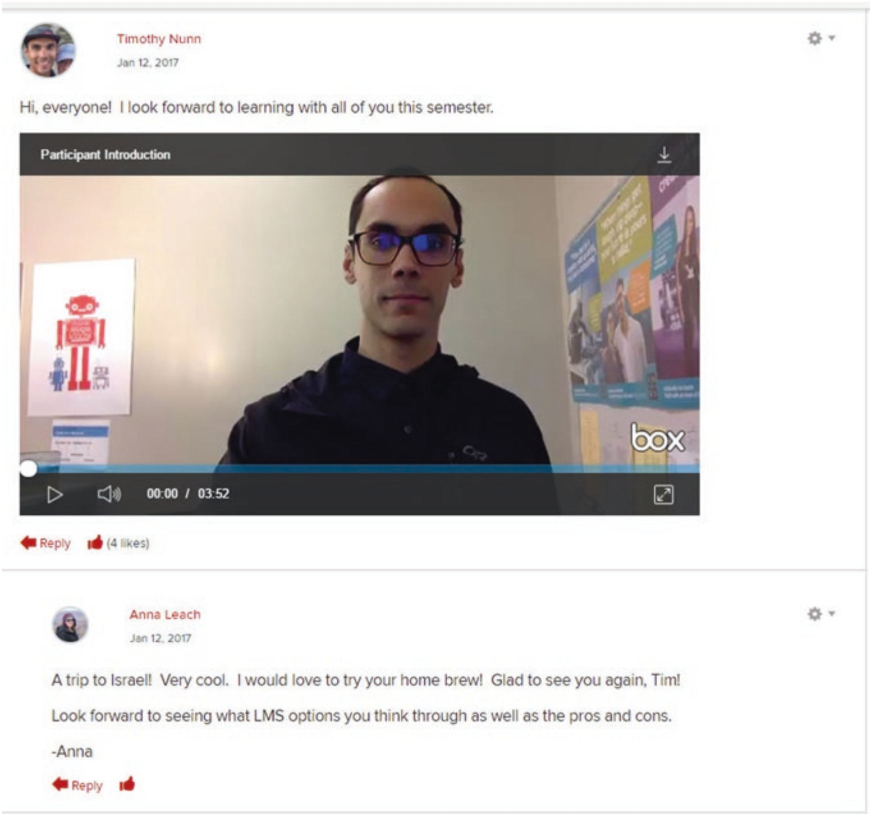

Fig. 4 Screenshot of one of the students' introductions and peer response (with students' permission)

The students formed five design teams (three to four team members each) and tackled five different instructional problems that they identified.

The Applied Learning Design team project was the major assignment for the course, as it was worth 125 grade points, or 62.5% of the final grade. The high percentage toward the total grade stressed the importance of the project to course completion. However, the grade was distributed across six different mini-assignments to allow student to take in the instructor's feedback and improve their performance between stages. The mini-assignments were:

1. A learning analysis document (20 points). Students submitted an analysis of the learners, content, and context for their instruction and offered a rationale for the need for instruction and a background for the problem to be addressed. This document also provided a detailed description of the processes that were used to complete the various analyses and presented the main findings, including the instruments that were used to collect data.

2. A live class presentation of the analysis results (10 points). This presentation was a mandatory activity, which consisted of a 2-hour live session on Adobe Connect scheduled in the evening. In case students could not attend the session, they would need to agree with their design teams on a makeup activity, for example, recording their part of the presentation, which would be played during the day/ time of the presentation.
3. A learning design blueprint (20 points). This document consisted of a careful specification of the design features of the instruction. It included (a) the objectives of the instruction and overall purpose for instruction; (b) the instructional design approach/model used; (c) major components of the instruction and their sequence; (d) activities to be used in the instruction, including feedback strategies; and (e) motivational strategies to be used in the instruction.
4. The development of a learning product that addressed the educational problem identified (30 points). Students were encouraged to be creative at this stage of the learning process and to be rigorous and thoughtful as they used the learning design blueprint to guide their development. The instructional materials could take several formats: printed, live workshop, electronic/online, blended, etc.
5. An evaluation with real learners of the learning product (10 points). Students were required to try out the educational materials with a small sample of learners (4 to 6) that represented their target audience and create a 2- to 5-minute video excerpt of their test. The purpose of the video clip was to provide evidence that an instructional tryout was implemented. Only a small sample of learners was required since recruiting a large sample would be a challenge for some of the teams and distract them from the main purpose of the project: learning the process of designing instruction by applying it into a project that addressed a real educational problem.
6. A live class presentation of the learning products and main evaluative results (15 points).
7. A final report that described the educational materials and examined the decisions that were made throughout the learning design process. Results and recommendations based on the tryout findings were also expected in this report (20 points).

With regard to grading, not everyone on the team received the same grade. At the end of the project, team members were required to submit a review that described the contributions of each individual team member (including themselves) in regard to participation (e.g., encouraged others to participate and considered other points of view), dependability (e.g., all that was promised was delivered on time), and ability to share (e.g., did an equal amount of work compared to others or did much less work compared to others). This information along with my own observations throughout the development of the project helped me to account for any variations in grade within the same team.

A reflective final paper was not assigned to the students; however, they were able to reflect on the learning experience on their final reports and in numerous online discussions. Looking back, I now realize that this was a design trade-off: requiring from the students more reflective tasks or a successful completion of a complex learning design project? As I work on the next iteration of this online learning experience, I will definitely create more opportunities for deeper reflection and to gather evidence of transformation and learning from completing the design projects. For example, ask the design teams to keep a design blog that will consist of a continuous record of their thinking, studying, and learning as well as a repository for new ideas, observations, and examples of learning design processes that they will collect throughout the course. Students will also describe on their blogs their feelings from working together in a geographically distributed design team, why they select the design problem they did, and how they may apply what they learn in the future.

Two nonmandatory live consultations with the instructor via Adobe Connect were also available to the design teams to address issues, clarify project specifications, and define the next steps. Eighty percent of the students in the class participated on these sessions.

Address Real Educational Problems

Design teams were asked to identify a real educational problem to address in their projects. The following instructions were given to students: "your team will identify an educational problem that requires instruction as a solution, meaning that it is not a performance problem. This problem should be relevant to you and your team. As a result, the team needs to spend some time negotiating the problem to address" since reaching consensus was strongly recommended. Examples of educational problems were provided such as cyberbullying in low achievement schools and financial education for single mothers. The OpenIDEO challenges (https://challenges.openideo.com/challenge) were also suggested as inspirational starting points. Additionally, teams were encouraged to find educational problems in their own communities.

In terms of guidance provided to help students select educational problems, it was suggested to start with a background research of the issue they wanted to tackle followed by a problem statement. The purpose of this initial research, besides learning more about the problem itself, was to provide concrete evidence when describing the problem and its significance.

Below are two examples of the problems that were addressed by the students as part of their applied learning design project. The problems were identified by the design teams, and the solutions/instructional materials were also produced by the students. The instructor guided the design teams throughout the learning design process.

Lack of Skills on Survey Design for Educational Research Graduate students in the college of education come to the research methodology center (RMC) for information, consultation, and guidance in the construction of surveys. Badly designed surveys generate invalid results that if taken seriously can lead to disastrous consequences. For example, results of poor-designed surveys when leading decision and policy making about teaching and learning practices have important social implications and the potential to negatively impact populations and communities.

The solution created included the establishment of a partnership with RMC and the design team to create a resource that supported college of education graduate students on creating high-quality survey research. The Questionnaire Question Construction (IoQC) learning experience was the result of this partnership. It included a set of three online modules deployed as a Canvas public course, on the following topics: (1) “What Is an Effective Survey Questionnaire?” (2) “What Is an Effective Questionnaire Item?” and (3) “Culminating Practice in Survey ExChange.” One of the most innovative features created from scratch is a platform called “Survey ExChange,” on which community organizations and educators could post requests for questionnaire development and graduate students taking IoQC could volunteer to fulfill them as shown in Fig. 5. The design team envisioned the following “Survey ExChange” application scenario:

1. IoQC learners create profiles to “Survey ExChange” (post their resume and a sample questionnaire).
2. Community organizations look through the profiles and contact a suitable learner/volunteer to propose a specific project.
3. The learner/volunteer chooses whether or not to accept the project.
4. If a match is made, the volunteer and community organization collaborate on creating the survey.
5. The completed survey undergoes a rigorous peer review process to ensure quality.

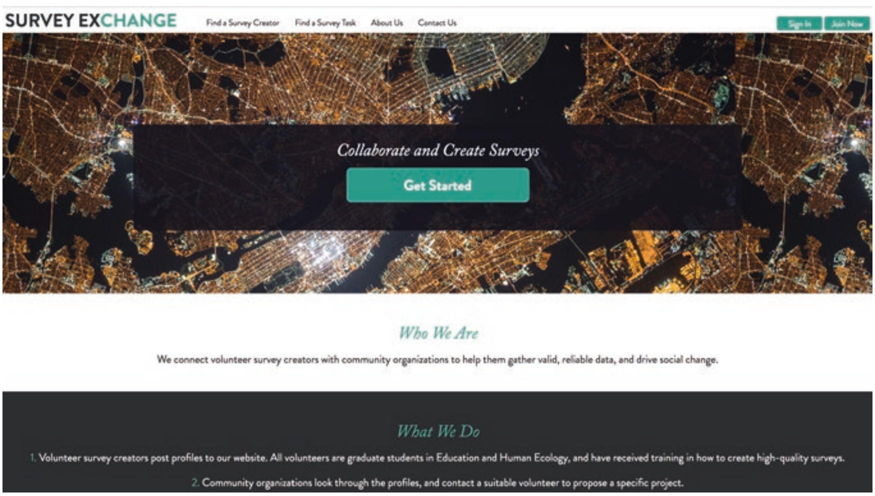

Fig. 5 Screenshot of “Survey ExChange” working prototype

Additionally, the design team envisioned themselves involved in different capacities such as soliciting and coordinating moderators, advertising the "Survey ExChange" platform, recruiting community organizations, and coordinating the peer review process.

Need to Transform Academic Curriculum Vitae (CV) to Meet Nonacademic Positions' Requirements According to the National Association of Colleges and Employers (2016), the number of graduate students seeking to apply for nonacademic jobs after graduation has been steadily increasing with a high receptivity of advanced degrees in the nonacademic job market. Additionally, employers are combing a candidate's CV for evidence of leadership, ability to work in a team, and problem-solving skills. However, many colleges and universities do not offer career exploration and preparation assistance at the graduate level, leaving graduates to their faculty advisors' limited experience on working outside academia and lack of training in how to provide guidance about how to search for a nonacademic job.

The proposed solution aimed to address the severe shortage of career preparation resources for graduate students at the university and to create instruction on how to transform an existing academic CV into an employer-friendly resume for nonacademic job searching. The result was an e-learning experience, "Transforming your CV into a Resume: A Guide for Graduate Students" (https://u.osu.edu/rvscv/), which consisted of three major components (see Fig. 6):

1. Learn – a short video (1–5 minutes) introduced and explained each major topic (e.g., "formatting" addresses why it is important to format a resume differently from a CV and tips to format the document appropriately).
2. Toolkit – additional digital content curated by the design team in partnership with subject matter experts was offered since learners' need to craft a resume for nonacademic job searching was varied. For example, some learners might need or desire additional information to help them develop the best document possible.
3. Apply – learners were encouraged to apply the information to their own CVs and to transform them into resumes as they moved along through the e-learning modules. Leading/prompting questions were included to encourage learners to take action.

In future iterations, the design team hoped to include interactive comments so that subject content experts could periodically address questions about specific topics. Another suggestion for improvement was to link the learners to experts who would review the resume and provide feedback. The e-learning experience would feature a space where learners could upload their transformed CV for feedback. The expert would then contact the learner to set up a date and time to video chat with the learner and share what was working well and what needed to be changed on the document. To offer a holistic resume transformation experience, industry and human resources partners could provide additional feedback and tips to the learners as well as peers.

As I reflect on this case of experiential learning, I need to confess that I have never anticipated the massive amount of work and time commitment that it required. Not only I had to provide substantive feedback on every project delivery to each

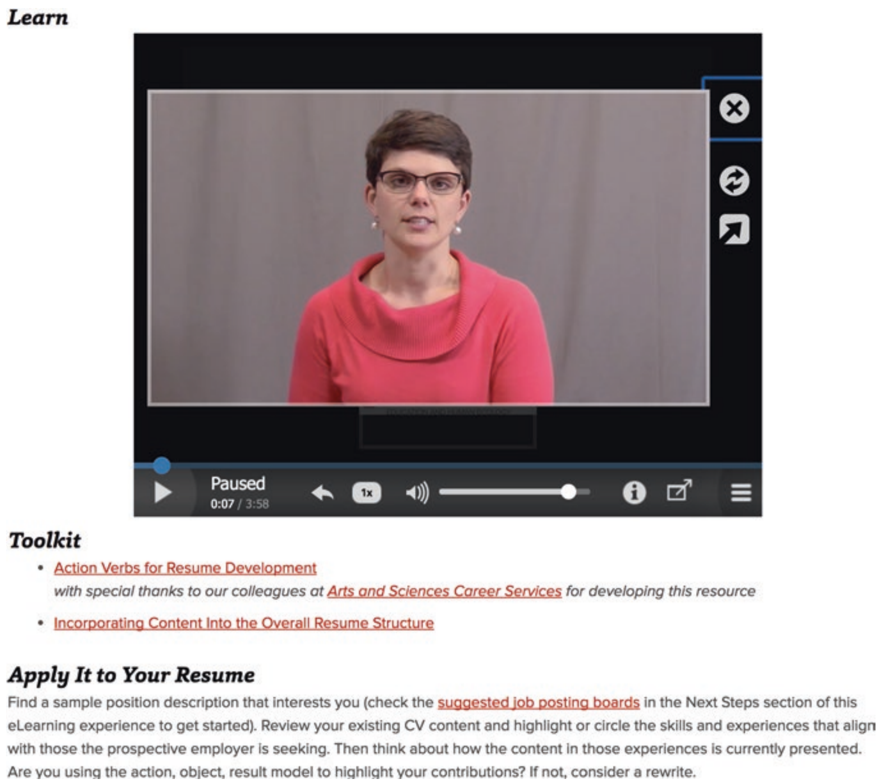

Fig. 6 Screenshot of "Transforming Your CV into a Resume: A Guide for Graduate Students" (with student's permission)

design team but also I had to be a relentless mentor for each design team due to the complexity of the design projects and the distributed nature of the work. For the next course design iteration, I would like to invite a practitioner mentor to the online class that could contribute to the mentoring of the design teams. This person will need to be an experienced learning designer with a passion for mentoring emerging designers and willing to work with design teams at a distance. I believe that finding the practitioner mentor will be a challenge in itself, but one that I am willing to take. Both students and I will benefit from this person's experiences and perspectives on learning design as someone actively engaged in the field.

Explore Entrepreneurial Opportunities

"Applied Learning Design" offered online discussions with guest speakers who discussed entrepreneurship, product development, and consulting experience. The following discussion shows how students engaged with the university's technology commercialization officer (referred here as C.) and learned about the process of

Table 1 Week 14: Start-ups in educational technology (online activity)

A 5-minute closed-captioning video with the technology commercialization officer introducing the university office that works with researchers (graduate students, post-docs, and faculty members) across the university to translate academic inventions into commercial products is available for view. C. kindly agreed to be the guest speaker for this class. He was asked the following questions:
1. What does university's technology commercialization do?
2. What do I need to get started?
3. Please describe the process of "commercialization" and "licensing."
4. What happens with the revenue generated from these activities?
5. What can I do with the revenue generated?
6. If I decide to commercialize my product, how long would the entire process take?
7. If I successfully commercialize my idea, who does it belong to?
8. Besides the potential for revenue, why would I want to do this?
After viewing the video, please complete the following:
Think about three questions you would like to ask C. if you had the chance of meeting with him. Type your questions on your computer as you watch the video or after viewing the video.
Share your questions with your peers by creating a post to this discussion (text-based, video, or audio). Only after posting your questions you should read/view/listen to your peers' questions and react to them as you think is appropriate. (It's fine if there are repeated questions.)
Post your questions here as a reply and then use this forum to discuss each other's participation and get C.'s answers and insights.

educational products' commercialization and licensing. This online discussion took place on week 14 under the topic "Start-ups in educational technology."

C. talked to the class via a pre-recorded video and addressed questions, ranging from "What does University's Technology Commercialization do?" to "What happens with the revenue generated from these activities?" (See Table 1.)

After viewing the video, students were asked to post three questions that they would like to ask C. He was added to the course as an "Observer" and was able to interact with the students by addressing their questions directly on the discussion board. (See Table 2 for an example.) This activity introduced students to university's software disclosure form necessary to file an invention to the commercialization office.

When exploring entrepreneurial opportunities in this course, it was important not only to expose students to alternative careers in learning design but also to facilitate the understanding of entrepreneurial thinking – that is, the concept of entrepreneurship as "a way of life, and a need driven desire to create and innovate" (Kao et al., 2002, p. 29). In other words, students were encouraged to apply what they learned in this one course into endeavors that live beyond the class.

Table 2 Week 14: Start-ups in educational technology (participants' interaction)

S. wrote (April 16, 2017):
C., Thank you for sharing the important work completed by your office. Here are a few questions for you:
Obviously, technology is the primary type of product that your office works with. What if a faculty member or researcher writes a book about some of the learning and research – does your office assist with the marketing of this type of innovation?
Does the innovator have rights to improve or amend the innovation in the future without having to share additional revenue?
How does your office compare with other universities in terms of revenue it has made from commercializing innovations?
Thank you!
C.'s response (April 17, 2017):
Hi S.,
It sounds like in the book scenario that would be a work of authorship and the ownership would rest with the author. In that case the creator is the lead on marketing.
Let's assume that we are talking about a "widget" instead of a work of authorship. The inventor always has rights to continue their research. If the next invention is an improvement, then it would still be reviewed according to the policy.
While revenue is an important metric, it is not the only. Other significant metrics include invention disclosures, number of start-ups, number of engaged faculty, etc.

Join a Professional Community

This online course was designed as a community of learning design practice. Students, as vital members of this community, were required to provide critiques to their peers' work and suggestions for improvement and share their insights outside their design teams on moving the learning design projects forward. As a result, peer feedback was requested during the live class presentation of the learning products and main evaluative results. The drive behind this activity was to propel the learning products into a next phase that would continue after the course was over. The intent was to gather initial feedback from the community to move projects into a potential phase of licensing or commercialization. An initial draft of the peer feedback form is shown in Fig. 7.

As mentioned before, the members of this community were also responsible for curating digital resources on learning design and contribute to a digital knowledge base that would exist beyond the course and be of use to other online communities.

Were the Design Decisions Impactful?

The following section discusses the design decisions for "Applied Learning Design" that worked particularly well in the context of the online master of learning technologies and with the group of graduate students enrolled in the course, based on observations during the cycle of course design, development, and implementation.

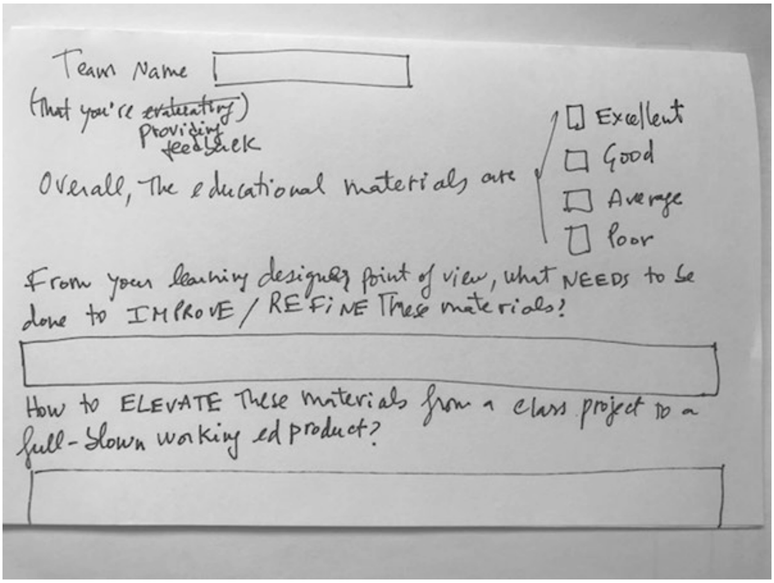

Fig. 7 Peer feedback form initial draft

Students working as members of geographically distributed teams on addressing a real educational problem have benefited the design teams, their peers, and their surrounding communities and personal networks. Real-world implementation beyond the course is an indication of the impact of these design decisions. The RMC is adding the IoQC learning experience to their educational repository and making the instruction available to all researchers on-campus, including graduate students. Likewise, "Transforming your CV into a Resume: A Guide for Graduate Students" is under review to be adopted by the university's career counseling and support services. The director of these services had identified this topic as one in the pipeline for development and incorporation into a larger university initiative. This initiative aims to offer a series of self-guided career modules that assist college students in learning more about themselves and choosing a major(s)/careers, applying to grad school, and preparing to enter the workforce as responsible, global citizens.

Secondly, the effort to strengthen entrepreneurial thinking led to several outcomes. Students became very serious about disseminating their work and taking the solutions created to the next step. Several other learning design projects evolved beyond "Applied Learning Design," but, since they are not explored in detail in this chapter, they will only be briefly mentioned. For example, one of the projects involved the redesign of an online module for a newly created online master of healthcare innovation program offered at the college of nursing. This work was transformed into an educational technology conference proposal. Another project sought to provide fifth-grade students with a mental framework for understanding the distinctions between valid, reliable news items and "fake news," or biased, unreliable information on the Internet. It is going to be implemented to 220 fifth graders with the buy-in of the school media specialist and administration. Moreover, in the individual project, one of the students chose to write about backward design and used this assignment as a catalyst to express her perspectives on backward design when applied to nursing education. She turned it into a manuscript and submitted it to a prominent nursing journal. The article has been published and is available online.

In terms of overall instructional effectiveness, the student evaluation of instruction generated reliable and valid evidence. With a 60% response rate, all of the survey items' responses were above the department mean, with an overall average of 4.6 (response scale was Likert-type with "5" being high and "1" being low). Some of the students' comments read: "Very supportive and caring demeanor. Enjoyed the real-world experts and the expertise that they shared;" "[the instructor] does a really nice job meeting students where they are. She has a great way of helping build students confidence while challenging them at the same time."

Difficulties Encountered During the Design Case's Enactment

Creating an augmented online course that included real-world practice of learning design processes and small-scale implementation of learning solutions made it necessary to bridge the digital and physical world. This crossover proved to be one of the major difficulties of teaching the course. Online students are not used to having to conduct academic work outside the boundaries of the learning management system. To be successful in this online learning experience, students had to "burst their bubble" and venture into their local communities and surrounding networks. To make things harder, they had to do it as part of a design team whose members they could not meet face-to-face, at least in most cases. In addition, the notion of designing and developing a learning product and learning about commercialization and licensing posed an exciting challenge, but at the same time many of the students felt that it was an insurmountable one.

Along these lines, one of the rejected design decisions was the requirement for students to fill out the university's standard mutual confidential/nondisclosure agreement with the ultimate intent of having all design teams file an invention disclosure to the university's technology commercialization office. The purpose of submitting this documentation was to expedite the negotiation process and establish a record and systematic support for graduate students who wanted to explore the commercialization of their learning products. It was found that this type of agreement should only be an option to investigate after the course was completed and not a course requirement as initially defined. Such requirements added more pressure to an already complex learning design project and demotivated the students who were not confident or were not interested in following an entrepreneurial path as part of their careers. Students were appreciative of being exposed to the commercialization and licensing processes at the university and interacting with other educational technologists who started their own companies and/or created learning products, but they did not want to be required to follow this path.

Another difficulty encountered during the course was the need to rethink my role as educator. The students demonstrated so much initiative and ownership of their Applied Learning Design projects that I had to rethink my role as online educator. I had to learn how to step aside and act as a curator and facilitator of the learning experience. My major roles were building confidence, encouraging students to develop better ways of addressing pressing educational problems, and establishing deeper connections between the course content and the rewards and challenges of practicing learning design.

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Expanding the Reach to First-Generation Students: A Collaborative Learning Experience Between Criminology Students in Sweden and the United States

Julaine M. Fowlin, Carina Gallo, and My Lilja

Introduction

To design is to consider contextual variables and make decisions within those parameters to achieve desired outcomes. Don't we all wish we lived in a world with unlimited resources and no constraints to our solutions? Yet, resource constraints make the field of instructional design and technology intriguing and a continuous problem-solving cycle. In this case, we were bounded by the limitations of distance/time, available technology, institutional policies, and learner characteristics. We were motivated by the potential learning gains of having students immersed in criminology theory exploration through the lenses of two distinctly different national contexts. Boling (2010) states that "at heart, the design case is a description of a real artifact or experience that has been intentionally designed" (p. 2). In describing this design case, we hope to make the precedent (embedded knowledge) of our experiences explicit enough for others to make informed decisions about the applicability of this design to their respective contexts (Boling, 2010).

In recent years, there have been several funding initiatives geared at increasing the number of students who participate in study abroad programs. Among these initiatives are the 100,000 Strong in the Americas and Generation Study Abroad. The 100,000 Strong in the Americas US Department of State (n.d.) website states that:

J. M. Fowlin (✉)
Harrison School of Pharmacy, Auburn University, Auburn, AL, USA
e-mail: jfowlin@auburn.edu

C. Gallo
Department of Criminal Justice Studies, San Francisco State University,
San Francisco, CA, USA

M. Lilja
Department of Criminology, Malmö University, Malmö, Sweden

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> In today's interconnected, technology-driven world, quality education alone is not enough. We need to be more internationally-aware and cross-culturally adept. We need a generation of leaders who can reach across borders. For this, students need a broad base of skills and experiences, including exposure to other countries and cultures. (para. 1).

This "exposure to other countries and cultures" is often done through study abroad programs which are often costly and not accessible to some populations. First-generation students and students of color are heavily underrepresented in study abroad programs (Picard, Bernardino, & Ehigiator, 2009; Thrush & Victorino, 2016). In a longitudinal study, Terenzini, Springer, Yaeger, Pascarella, and Nora (1996) found that the most significant difference between traditional college students and first-generation students was lower family income and being Hispanic. They are also more likely to work while attending school. Thus, Rausch's (2017) conclusion that lack of funding is one of the primary reasons first-generation students do not participate in study abroad programs is not surprising. Rausch (2017) asserts that first-generation college students must also contend with social and cultural challenges for study abroad programs to succeed. First-generation students tend not to perceive study abroad programs as accessible or beneficial and often think they may delay graduation (Rausch, 2017).

One option to expand access to study abroad programs is to encourage institutions to participate in initiatives like the 100,000 Strong in the Americas. However, these funding opportunities can be competitive and limited. Institutions must therefore explore alternatives and exploit technological affordances that can help overcome constraints of distance and foster collaborative learning. This was the impetus for the design case we present. In this chapter, we present a case where computer-supported collaborative learning (CSCL) was used to provide first-generation students with an opportunity to explore the application of criminology theory in an authentic international context, with opportunities for social and cross-cultural engagement.[1] The learning design was developed to facilitate collaboration between criminology students and faculty from a US and a Swedish university. The two universities will from now on be named "the US University" and "the Swedish University." Fifteen criminology undergraduate students participated in the project. The collaboration gave students an opportunity to harness similar benefits to a study abroad program without the financial burden. The project was grounded in instructional design theories of CSCL and best practices for cross-cultural team collaboration to create an engaging and collaborative learning environment. The design offered students a unique learning opportunity to broaden their understanding of applying criminology theories in two distinct national settings (Gallo et al., 2018). We present the design case through design decisions, implementation outcomes, a rich description of the context, and a holistic reflective view from the instructional designer, faculty, and learner perspectives.

[1] The current project has also been described and analyzed in the article "Gaining a global criminal justice perspective: a computer supported collaboration between students in the United States and Sweden" (Gallo, Fowlin, & Lilja, 2018).

This case is interesting to designers and researchers on several levels. First is the subject matter of criminology, and first-generation participants introduce complex variables in the instructional design process. The case highlights how various technological affordances combined with sound instructional design can allow us to meet complex educational needs. Second, faculty may avoid CSCL because it is a challenging design. This case provides an example that CSCL designs can be done and are worth the effort. Third, we share examples of course materials and screenshots that researchers, educators, and practitioners can use to guide the design of similar learning designs.

The Design Team

Two faculty members (Drs. Gallo and Lilja) and one instructional designer (Dr. Fowlin) comprised the design team. Carina Gallo is currently an Assistant Professor at the Department of Criminal Justice Studies at San Francisco State University. At the time the project was implemented, she was an Assistant Professor of Criminology and the Criminology Program Coordinator at Holy Names University in the United States. Carina's scholarship addresses historical and international trends in crime and welfare policies, with particular attention to how policies and laws intending to support underrepresented and marginalized groups have developed over the last century. Carina is dedicated to exploring and applying innovative teaching practices such as cross-cultural learning. She is interested in how technology can enhance student learning and globalize the curriculum. My Lilja is a Senior Lecturer in the Department of Criminology at Malmö University in Sweden. She is also one of the founders and former Director of the Criminology Program at the University of Gävle in Sweden. She has been teaching criminology for over 15 years and has taught at Stockholm University, the Police Academy, and the University of Gävle. Her research interests are drug and alcohol policy and misuse and youth crime. Julaine Fowlin is currently the Director of Faculty Development at the Harrison School of Pharmacy, Auburn University. When this project was implemented, Dr. Fowlin was the Instructional Designer at Holy Names University. Her research interests include curriculum reform, knowledge management, distributed cognition in teams, and design and development of innovative performance improvement experiences. We will now describe the context that resulted in the conception of the learning design.

Design Conception and Background

It all started in January 2015 when Dr. Gallo shared with Dr. Fowlin the success she had with doing a social work online collaboration with students from the United States and Sweden in 2009. Dr. Gallo wondered if she could harness similar results in the Criminology Program at the US University in partnership with her colleague, Dr. Lilja, from the Swedish University. The collaboration would be between students enrolled in a criminology theory course, which is one of the most challenging courses for students to complete. Both faculty members thought that the students could benefit from an authentic experience where they can learn with students in another country. Dr. Gallo was envisioning an implementation in Fall, 2015. A study abroad program was not feasible for both institutions at the time due to lack of funding and the short time constraint. Dr. Gallo shared with Dr. Fowlin that in her previous experience having an established professional relationship with a collaborating faculty was helpful, and she was confident that we could plan and implement the project the following semester. In her previous project, Dr. Gallo had the support of an instructional designer in the delivery phase of the course. This time she wanted to collaborate with an instructional designer in the planning phase.

Dr. Fowlin's "instructional design" interests were piqued at the possibility of designing a cross-cultural learning experience with two highly motivated faculty members. In her analysis, she discovered this was more than just a collaboration between two groups of students from two countries. In the field of criminal justice, the collaboration was a strategic learning opportunity, as the United States and Sweden are often considered polar opposites regarding criminal justice policies and practices in westernized societies. The United States often represents a punitive criminal justice model and has one of the highest incarceration rates in the world. Sweden has low incarceration rates and is often characterized by strong beliefs in crime prevention and rehabilitation (Gallo & Elias, 2016). One critical difference between the two universities is that the US University is located in a high-crime area and the Swedish University in a low-crime area. The disparity between the two countries/cities and their policies provided a rich and authentic context for learning about differences in criminal justice policy and practice (Gallo et al., 2018).

Other institutional differences included that the US University is a small, private, nonprofit, Catholic university with a total student population of 650, while the Swedish University is a midsize public university with an average student population of 14,700. Despite these differences, both universities have a diverse student body that includes first-generation and underrepresented students. The two universities also have significantly more incoming study abroad students than outgoing study abroad students. This is in line with the findings that underrepresented and first-generation students, which make up a large part of the student populations at the two universities, tend not to participate in study abroad programs due to lack of funding and awareness of the perceived value (Picard et al., 2009; Rausch, 2017; Thrush & Victorino, 2016).

Theoretical Foundation

After getting the full instructional design context and background information from Drs. Gallo and Lilja, Dr. Fowlin began putting the pieces together regarding the type of learning experience we wanted to afford within the constraints of, for example, time and place. Dr. Fowlin was inspired by her academic training and an article she read on case-based learning by Choi, Hong, Park, and Lee (2013). The article included a diagram that clearly illustrated alignment with design decisions and theoretical principles, and she strived for a similar alignment. Theories of situated learning and community of practice also applied, but we needed a framework that would guide collaboration with technology. CSCL proved to be an ideal framework as it is not based on one theory but a collection of theories, including theories we considered individually, such as sociocultural learning, situated learning, communities of practice, and distributed cognition (Lipponen, 2002; Ludvigsen & Mørch, 2010; Stahl, Koschmann, & Suthers, 2006; Stahl, 2002).

The hallmark of CSCL is learning or collaborative knowledge-building through interaction supported by technology (Lipponen, 2010; Stahl, 2002), which involves the processes of contributing and attending to the contributions of others (Wise, Hausknecht, & Zhao, 2014). CSCL is active learning and student-centered; it creates an environment where students can reflect on their thinking and assumptions (Kirschner, 2001). Through the collaboration on authentic and problem-solving tasks, students negotiate meaning and develop a shared understanding, which leads to deeper level learning, enhanced critical thinking, and greater retention of knowledge (Kreijns, Kirschner, & Jochems, 2003). Using technology allows for broader access to people and information. Technology also facilitates knowledge creation in ways that may not be possible without it (Hoadley, Honwad, & Tamminga, 2010), and knowledge and expertise are distributed among participants (Lipponen, 2010). The computer-supported collaborative learning (CSCL) framework would provide an alternative to study abroad and expand access for first-generation students.

Dr. Fowlin did a literature review on CSCL and cross-cultural teams, which she presented to Drs. Lilja and Gallo. It was vital that they understood the characteristics of the design and the value. The synthesis of the literature review included the following:

- CSCL consists of three main components, technological, social, and educational. The learning experience design should account for all three (Chen, Caropreso, Hsu, & Yang, 2012; Kirschner, Strijbos, Kreijns, & Beers, 2004).
- Technology should have collaborative affordances and foster interaction, including the ability to communicate, share resources, collaborate on a shared task, and build a sense of community (Jeong & Hmelo-Silver, 2016). However, having the technology alone is not enough; collaboration must be intentionally built in the design and students must be scaffolded on how to collaborate (Chen et al., 2012; Jeong & Hmelo-Silver, 2016; Kirschner et al., 2004; Kreijns et al., 2003).
- Genuine interdependence is essential for successful collaboration (Kirschner et al., 2004; Salomon, 1992). This requires the creation of an authentic need for

students to collaborate where they have to interact, exchange information, and discuss concepts to come to a shared understanding of what is needed to achieve the desired goals and outcomes. It also requires that team roles are divided in a way where each person contributes in a meaningful way to accomplish tasks.

- The social aspect of CSCL should foster a sense of community or social presence and development of trust (Kreijns et al., 2003). Students should feel comfortable sharing differing views and coming to a shared consensus (Osman & Herring, 2007). Social interaction plays an essential role in cross-cultural teams, and students prefer to have more background knowledge of each other's cultures and context (Yang, Yu, Chen, & Huang, 2014).
- Cultural context can affect how participants behave in an online collaborative environment and can ultimately affect learning (Chen, Hsu, & Caropreso, 2005).
- Certain team challenges are unique to cross-cultural teams, such as the myth that a lack of language fluency would imply lack of competence, as well as cultural preferences for implicit or explicit communication (Behfar, Kern, & Brett, 2006).
- The learning task should have three dimensions: task ownership, task character, and task control (Kirschner et al., 2004). (1) Task ownership – students assume ownership of the task through both individual accountability and genuine/positive interdependence. (2) Task character – the task is relevant to students and allows for problem-solving. (3) Task control – students determine strategies to complete tasks and delegate roles.
- Teaching presence is an important element of CSCL (Osman & Herring, 2007; Stegmann, Wecker, Weinberger, & Fischer, 2012; Wise et al., 2014) and refers to the role that faculty members play in orchestrating the learning experience. Faculty members must actively ensure that learners engage in meaningful discourse and offer prompts to trigger reflection and challenge assumptions. This is often done through modeling, scaffolding, and providing feedback (Lazakidou & Retalis, 2010).
- Both faculty and students must overcome the constraints of communicating synchronously across time zones and giving feedback promptly. They also need to have patience, technological skills, and language proficiency. Agreeing on standards and procedures of collaboration across institutions can be time-consuming (Yang et al., 2014).

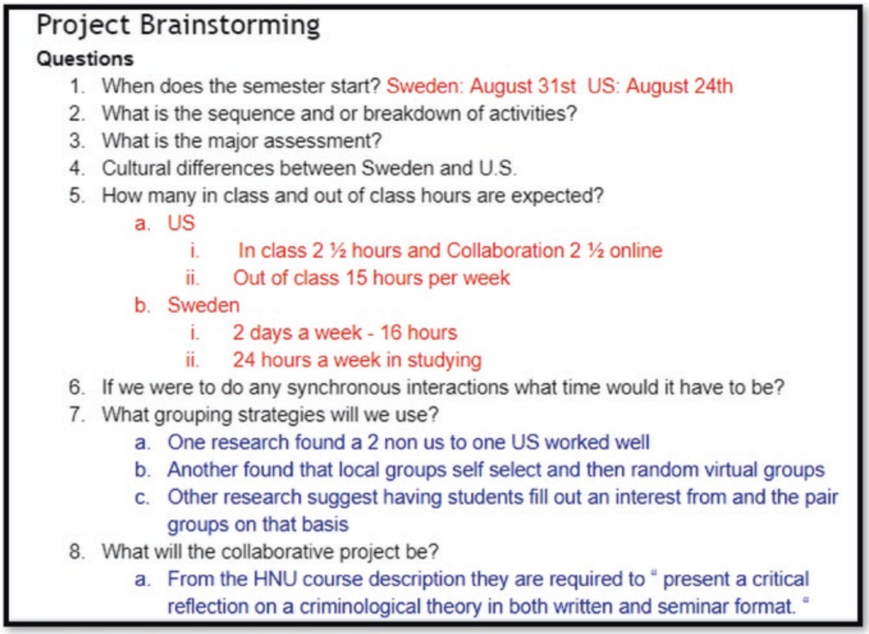
After learning about CSCL, we agreed that CSCL was a suitable framework for the learning goals and would work well with the characteristics of a first-generation population. Dr. Gallo also noted that projects where criminology students in different countries collaborate in online environments, were not common, and CSCL is also not well documented in the criminal justice education literature. This was an opportunity to contribute to the field of criminal justice education.

Planning and Key Decision-Making

After having shared understanding regarding the theoretical framework, we started designing the learning experience. This was around five months before the implementation of the course. The instructional design experience mirrored the students' learning experiences. Our planning meetings took place on Skype, and we had to deal with similar collaborative challenges as the students would encounter, such as time differences. Dr. Fowlin started to make notes of things that contributed to us working well together, intending to use these as guidance for the students. For example, the best time for us to meet was between 9:00 am and 11:00 am Pacific Standard time, which was between 6:00 pm and 8:00 pm Swedish time. Having the meetings via Skype allowed us to establish rapport quickly. We decided that synchronous means of communication may help facilitate student discussions. We also recommended to the students the meeting times we used for our collaboration. During the planning phase, Dr. Fowlin discovered that Sweden had more holidays than the United States. Additionally, in her view, Swedish people tended to take their holidays seriously and adopt a more strict "no work during holidays" approach than she was used to in the United States. Dr. Fowlin therefore adjusted deadlines to keep Dr. Lilja's Swedish holidays in mind, and she thought this would be an excellent example of a cultural difference to share with students. She encouraged Drs. Gallo and Lilja to think about intentionality and alignment in the design, ensuring that we integrated guidance from the literature on CSCL. In the design, we often get caught up with the uniqueness of the experience we forget the purpose. We started the project by agreeing on the core outcomes and then did a backward timeline. This process involved a lot of brainstorming to come to a shared understanding. Below are examples of the brainstorming questions that helped us to achieve shared consensus, and Fig. 1 is an excerpt from one of our brainstorming session notes:

- When does the semester start for each institution?
- What is the sequence and or breakdown of activities?
- What is the major assessment?
- What are the cultural differences and similarities between Sweden and the United States?
- How many in-class and out-of-class hours are expected?
- If we were to do any synchronous interactions, what time would it have to be?
- What grouping strategies will we use?
- What will the collaborative project be?
- What will be the shared content that both groups will get exposed to?

Dr. Fowlin saw her role in these meetings as "knowledge elicitor," that is, through questioning she got the faculty members to articulate the value of this experience for criminology students. In the first formal meeting, we agreed on these learning outcomes: (1) Describe and compare central criminological theories regarding the causes of crime and societal responses to crime, (2) explain the epistemological background of these theories and analyze how different theories relate to each other,



Project Brainstorming

Questions

1. When does the semester start? Sweden: August 31st US: August 24th
2. What is the sequence and or breakdown of activities?
3. What is the major assessment?
4. Cultural differences between Sweden and U.S.
5. How many in class and out of class hours are expected?
   a. US
      i. In class 2 ½ hours and Collaboration 2 ½ online
      ii. Out of class 15 hours per week
   b. Sweden
      i. 2 days a week - 16 hours
      ii. 24 hours a week in studying
6. If we were to do any synchronous interactions what time would it have to be?
7. What grouping strategies will we use?
   a. One research found a 2 non us to one US worked well
   b. Another found that local groups self select and then random virtual groups
   c. Other research suggest having students fill out an interest from and the pair groups on that basis
8. What will the collaborative project be?
   a. From the HNU course description they are required to " present a critical reflection on a criminological theory in both written and seminar format. "

Fig. 1 Excerpt from a brainstorming session note

(3) apply various criminological theories to different types of empirical material, (4) discuss historical trends in criminology and crime policy in the United States and Sweden, (5) collaborate in cross-cultural teams to complete a shared task, and (6) communicate orally and in writing effectively.

After we had come to a shared understanding of the outcomes, we revisited the evidence from the literature about the type of learning that CSCL affords and what was needed for successful implementation. Dr. Gallo also shared her previous experience, where students in Sweden and the United States collaborated in an online environment. From there we mapped activities, assessments, and materials to the learning outcomes, on a course, program, and institutional level. We then embarked on the journey of explicit intentional and aligned design.

Institutional-Level Decision-Making

In our brainstorming session, we realized we had to contend with two significant institutional differences. The first difference was that participation in the project was mandatory for the US students, but had to be voluntary for the Swedish students.

Fig. 2 Flyer used to recruit Swedish students to participate in the project

Swedish is the instructional language in the Criminology Program at the Swedish University; hence the Swedish students could not be required to participate in an English-taught course. Besides, the collaborative component was a major percentage of the grade for US students, while the collaboration had a lesser impact on the Swedish students' grades. We decided that we needed a recruitment strategy for the Swedish students. About two months before the semester started, we created an invitation flyer (see Fig. 2), and Dr. Lilja sent an email invitation to the criminology students at the Swedish University to participate in the project. Voluntary participation meant that the Swedish students were intrinsically motivated to participate, helping us to avoid one group not taking the collaboration seriously because the experience was a low stake for them.

The second institutional challenge was that the US course started one week earlier than the Swedish course. Moreover, the US course was seven weeks and Swedish was five weeks. After looking at the dates and comparing the syllabi of the courses, Drs. Gallo and Lilja decided that it was best to make the collaboration last four weeks as Swedish students needed their last week for exams. To ensure that both groups of students met institutional requirements the collaboration was only one aspect of the course.

Task Design and Technology

After we agreed on the learning outcomes and the theoretical foundation of the project, we designed the assessments and learning activities. The students needed opportunities to work in small and large groups. Reflection is also a vital aspect of CSCL. With this in mind, we created these assignments: (1) written discussion forums, (2) group research paper, and (3) video meetings and reflective journals. We chose Blackboard as the learning management system (LMS) as both groups of students were familiar with this system. The US University hosted the experience given Dr. Fowlin was on-site to give support and could give the Swedish students access to Blackboard. The wiki, discussion forum, and journal tools in Blackboard, Skype, and Google Hangouts provided the affordances that were needed for the video meetings. We summarized the assignments for each week in tables on Blackboard (see Fig. 3).

Written discussion forums, which were due on Tuesdays, were based on the assigned readings. We gave students specific questions, and they were required to respond substantially to their peers' contributions. A rubric guided the process and explained what constitutes a substantial response.

The group research paper aimed at student task ownership (accountability and interdependence), control (directing one's own learning), and character (authentic task). We achieved these aims by allowing students to work in mixed groups (both US and Swedish students) to complete a criminology comparison theory project. Students were required to set up weekly group synchronous web conference meetings, using technology of their choice (we recommended Skype or Google Hangouts). All video meetings had to take place by Thursday of each week. The goal of the meeting was to discuss the readings and the group paper. We gave students guidelines for each meeting to help them complete the group research paper on time. The students wrote the group paper using the wiki tool, which allowed faculty to give constructive feedback during the learning process and to see the contribution of each student.

In the reflective journals, which were due on Fridays, students were prompted to reflect on the video meetings, the week's discussions, and the strategies they were using to complete the group paper. Journaling aimed to enhance the students'

Week 2		
Aug. 31- Sept. 4	Please note that you are expected to read Akers & Sellers (Chapters 2, 3, and 7) this week and Earn your **Collaborator Badge** by completing the **Connection Zone**.	
	Sept. 1	Written discussion 1 (Personal introduction)
	Sept. 3	Video Meeting 1 (Strategy for group paper)
	Sept. 4	Journal 1

Fig. 3 Summary of assignments week 2 of the project

metacognitive skills, since they wrote about how they were learning, not only about what they were learning. The journals were private to encourage students to express themselves freely; i.e., the students could not read each other's journals. Only the design team and the student who wrote the entry had access to the journal. Examples of reflective journal prompt questions were:

- How did you feel during the collaborative video meeting?
- What happened during the collaborative video meeting?
- What did you like most about the collaboration and the readings?
- What did you learn from the collaboration and the readings?
- In what way do you think the discussions relate to the readings?
- What strategies did you and your group use to ensure that the goals of the collaborative video meeting were accomplished?
- What would you change or what would you do differently?

Social Interaction and Sense of Community

After addressing educational and technological aspects, we explored how we could foster a sense of community and give students the support they needed to collaborate. From the literature we knew that the collaborative component had to be explicit and students preferred to learn about each other prior to the course. To prepare for a brainstorming session, Dr. Fowlin did some research on the differences between Sweden and the United States, for example, in relation to culture differences. She also reflected on her personal experiences as a member of our cross-cultural design collaborative experience. The outcome of our meeting was a Blackboard lesson module titled "Connection Zone" that provided explicit instructions on collaboration and an orientation to the two countries (see Fig. 4).

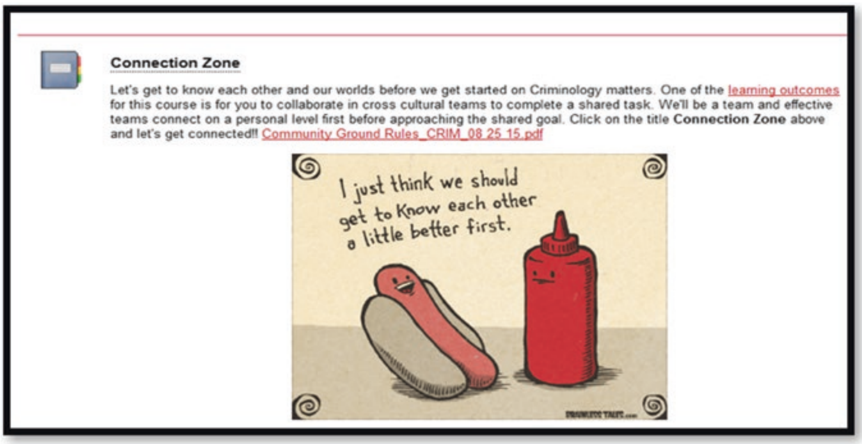


Fig. 4 Introduction to the Connection Zone

Maria Concastra, a student from the US won a scholarship to a Swedish university. Maria did a lot of reading about Sweden, it's people and its culture. She was excited to learn about the great environmental work that they have been doing, similarly to California, where she is from; such as one has to pay for bags at the grocery store to reduce waste and encourage greater use of recyclable bags. With this similarity along with her love for coffee Maria was sure she was all set for the trip and would blend in quite well. However, despite her preparation several confusing and frustrating incidents occurred during her first weeks in Sweden.

Maria was so excited to meet her host family (Per Andersson, Birgitta Andersson, and Annika Andersson) and see their beautiful home. When she arrived they were already at the airport waiting for her. She enjoyed the scenery and the conversation in the car. When they reached the residence after Mrs Andersson opened the door Maria hurried inside to see the beautiful interior decoration. Her excitement was short lived as the room became quiet and everyone stared at her. She wondered what had gone wrong, until Mr Andersson said in a very serious voice…"*Where do you think you're going with your shoes on?*

The second incident was when Maria had a group assignment. She always liked to get things done way in advance however, the assignment was given just before the Midsummer (a big Swedish holiday) Maria sent several emails to her peer Anita and received no response. She was very angry and wanted to work alone, so she sent an email to the instructor who did not respond either. To make matters worst at 7:00pm that night she felt for a sandwich and went to the near by grocery store which was closed. Maria was so frustrated she just went to her room and cried.

Fig. 5 Example of scenario-based activity

We used a scenario-based approach with discussions and a *video presentation* (https://tinyurl.com/connectionzone). One scenario included the Swedish norms of not wearing shoes as well as not working during holidays (see Fig. 5).

We used the LMS quiz feature to allow students to respond to open-ended questions related to the scenario. Students were instructed that there were no right or wrong answers and that the scenario would help them get an idea of some cultural differences and similarities. Follow-up questions were geared at addressing the scenario from both the US and Swedish perspectives. The following were some of the questions based on the scenario.

- What motivated Mr. Andersson and the rest of Maria's host family to react the way they did to Maria wearing her shoe inside?
- What attitudes or values appear to be important in Swedish society based on her group member and instructor's nonresponse and the stores closing at 6:00 pm?
- What attitudes or values appear to be important to the US society based on Maria's reaction of anger to the nonresponse she received?
- What could have been done differently to avoid these cross-cultural misunderstandings?

In addition, students were given links to resources to read more about the two universities.

We also created formal "ground rules" (https://tinyurl.com/CrimRules) and included a social forum called "Fika" to represent the Swedish tradition of "having coffee and pastry." See Fig. 6 for a screenshot of the Fika forum.

We hoped that assigning the forum a Swedish name would help the Swedish students to have a sense of belonging, given they were asked to step out of their language comfort zones. Students were instructed to use "Fika" as an open forum to share non-course-related information about themselves and/or where they live. To

Fig. 6 Screenshot of introduction to the Fika forum

Fig. 7 Screenshot of video introduction

help with fostering a sense of community and provide a personal welcome, Dr. Fowlin created a *video tour* (https://tinyurl.com/CrimVideoTour) of the course. We sent a link of the video to the students via email prior to the start of the course. We also posted a link to the video tour on Blackboard. The tone of the video was friendly and aimed at sparking students' enthusiasm and calming any anxiety. She began the video with a personal introduction and noted that the students would embark on a similar collaborative experience as we did to create the course and it will be a fun experience (see Fig. 7, for a screenshot of Dr. Fowlin's enthusiastic greeting).

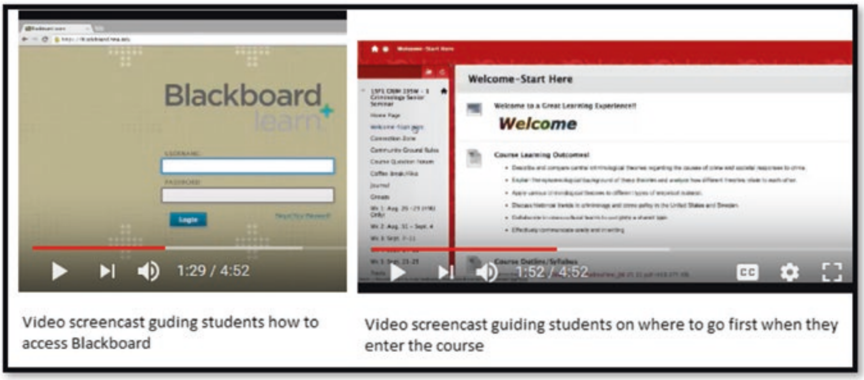


Fig. 8 Screenshot of video segments guiding students from accessing Blackboard to navigating the course

After, Dr. Fowlin used screen capture to provide a virtual tour of the course, from logging in to the LMS to describing various sections of the course. She also provided recommendations for the order in which they should navigate the course (see Fig. 8).

We believed the newness of this experience could make the average student anxious, and the level of anxiety would probably be higher for first-generation students. We wanted to give the students as much support as possible. As it was just as crucial for students to interact with us, as it was for them to interact with each other, we included a picture of ourselves and shared both professional and personal details on Blackboard, such as our favorite songs. We thought of creating personal video introductions, but time did not allow. We also saw the written personal introductions as an opportunity to model what we wanted students to do when we asked them to introduce themselves at the beginning of the course.

Incentive and Feedback

We discussed ways to get feedback from students on different sections of the course. We talked about only asking each group during the face-to-face class times; however, students may not feel comfortable sharing feedback in a large group. Technology came to our rescue in the form of DropThought, an application that enabled learners to give formative feedback to faculty using their phones or computers. DropThought integrated with Blackboard and allowed students to give regular feedback on specific experiences in a quick and easy way. See Fig. 9 for a screenshot of DropThought.

This enabled the team to improve the course in real time continuously. For example, some students reported that they did not fully understand the grading criteria for the group paper, and we were able to provide global guidance in an announcement explaining how the rubric would be used to evaluate the outcome of their collaborative

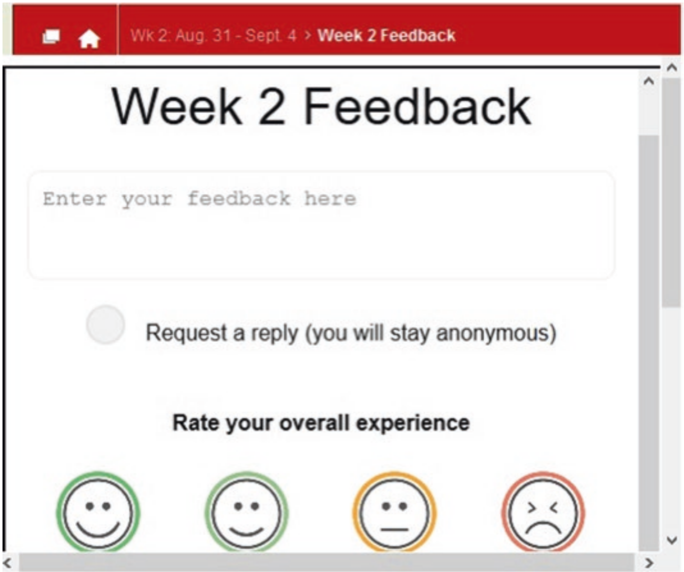
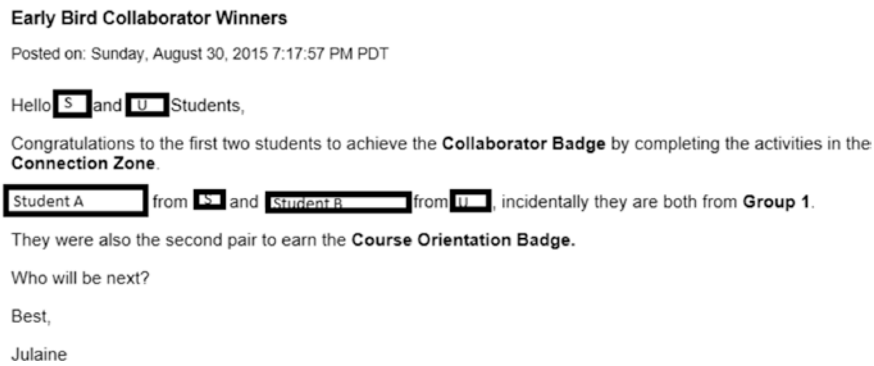


Fig. 9 Screenshot of DropThought feedback form integrated in Blackboard


Early Bird Collaborator Winners

Posted on: Sunday, August 30, 2015 7:17:57 PM PDT

Hello S and U Students,

Congratulations to the first two students to achieve the **Collaborator Badge** by completing the activities in the **Connection Zone**.

Student A from S and Student B from U, incidentally they are both from **Group 1**.

They were also the second pair to earn the **Course Orientation Badge.**

Who will be next?

Best,

Julaine

Fig. 10 Screenshot of announcement congratulating students who earned a badge

work and evidence of individual effort. We also used Blackboard's course analytics on participation and engagement, as it was crucial that students watched the video tour and participated in the Connection Zone. Besides, we tracked and rewarded student progress through a badging system in the LMS. The system automatically awarded a badge when a student completed designated sections. Students could earn two badges: a Course Orientation badge for completing the Welcome-Start Here section and a Collaborator badge for completing the Connection Zone activities. We used the announcement feature to publicly acknowledge the first group of students to earn each badge. See Fig. 10 for an example of announcement (student and institution names are anonymized).

Table 1 Summary of success factors from the literature aligned with the design decisions in the project

Success factors	Design decisions
Student task ownership	Group paper
Technology affordance and matching	Skype: Team video meetings Journal: Reflection on team meetings Discussion forum: Group interaction and critical analysis Wiki: Group collaboration Badging: Motivation and task accomplishment tracking
Shared understanding of each other and goals	Course video tour "Connection Zone" module on collaboration and orientation to cultures Introduction activity
Sense of community	Community Ground Rules Social Forum (Fika) Students required to respond with substantial comment to peers Active involvement of both faculty
Faculty scaffold/teaching presence, modeling, and fading	Weekly reminders and frequent check-ins Summary and clarification of discussion points Detailed rubrics and guidelines

Finally, we planned to scaffold the delivery of the course through weekly reminders, frequent check-ins with groups, and summaries and clarifications of discussion points. This would help establish teaching presence and keep the momentum of the collaboration. Drs. Gallo and Lilja thought it would be best if they alternated weeks scaffolding the students. That way the students would interact with both faculty members. Table 1 shows the alignment between the findings from the CSCL and cross-cultural collaboration literature and our design decisions.

Implementation

In the previous sections, we outlined the theoretical underpinnings, planning, design decisions, and outcomes. In this section, we give an overview of the challenges and successes through interweaving related excerpts from students' reflective journals.

Challenges

Coincidentally, the number of students who volunteered from the Swedish University was equal to the number of students who enrolled in the criminology course from the US University, so we had four groups with two students from each country.

Apart from that, we did not use any specific matching strategy to formulate the groups. When the US students started the course, all students had been placed in groups, and a list of names and email addresses was available on Blackboard. Dr. Fowlin physically attended the first class at the US university, where she gave the students an overview of the collaboration. The US students decided that a representative of each group would initiate contact with the Swedish students. Dr. Gallo and Dr. Fowlin gave the students an example of language they could use. For example, she suggested that they should include in their communications how excited they were to collaborate and initiate the scheduling of the first meeting. We coached them in seeing themselves as residents of the "host country" in a study abroad program and assured them we would be there for them.

We encountered challenges the very first week, when the US University had a power outage. In the first journal entry one US student stated:

> As you may know, [the US University] experienced a school-wide power outage that made the internet unavailable to us. Because of this, we were unable to have our video chat with the students from [the Swedish University]. This saddened me because I was really looking forward to talking with students from another country and hearing their views on the subject of criminology.

Some groups figured out alternative ways to communicate with each other as we learned through one Swedish students' journal entry:

> Although the Wi-Fi was down at [the US University] the entire week my group and I managed to video chat on Thursday morning at 8 am U.S. Pacific time. During our video meeting, we were able to come up with a plan for the remainder of the weeks we have left. We figured out a plan on how to deal with the paper and what parts we will be covering individually and together as a group. As well as the paper we discussed strategies on how to read and discuss the text during our weekly meetings. It all went good with my group meeting this week.

After hearing about the challenges that some groups experienced, we wondered why some students had found alternatives to communicate with each other and others had not. We found out that one explanation was that a few students could use their cellular data plan instead of the Wi-Fi. However, most students at the US University relied almost entirely on the Wi-Fi provided by the university. They had no or a limited data plan on their phones. We had not anticipated the loss of Wi-Fi, nor that the students would have constraints finding alternative options. Upon remembering the constraints of our student population, we understood why some did not explore alternatives. As soon as we discovered what was happening, we helped the US students by giving them access to wired connections in Dr. Fowlin's office.

At the end of each week, we had a debriefing meeting via Skype where we collaboratively decided what to include in the weekly wrap-up email for students. For example, Dr. Gallo wrapped up the first week with an email recognizing two students that earned their badges for completing the course orientation session. She also reminded students of the tasks they needed to complete in the following week. One Swedish student expressed the lessons learned in the first week in this way:

> What I have learned about the collaboration this week is that factors that we cannot influence, like technical difficulties, may cause temporary issues and delays. I have also learned that we have to accept that it can happen, that it is nobody's fault, that everyone is trying their best, and that it does not help to get frustrated over it. Eventually, the problems will be solved, and we will become more experienced.

In the second week we faced another unforeseen challenge, a US student dropped the course leaving one group with three students, but the group remained focused, as expressed in this US student's journal entry:

> Overall this meeting was good. The only problem is that we only have 3 people in our group and it's kind of hard to split the group work because we each have a ton load more than the other groups. I will talk to my group and figure out a proposal with a solution to make this project a bit less stressing.

Drs. Gallo and Lilja talked about possible solutions but decided that having one less member did not warrant a change in the group's goals, as the groups should work on all sections as a group rather than individual ownership of a particular section.

Another challenge included the time zone difference between Sweden and the United States (9 hours). We expected that the students would have challenges setting video meeting times, and we gave students suggested times that worked well for our collaborative meetings. We did not account for discussion posting times though. For example, we had a cutoff date for making postings, but we needed to build in a cutoff time as well to allow both groups to post within their time zones and have time to give feedback as one Swedish student noted:

> Something I wish would be different is that since we in Sweden is nine hours before it's hard to get the chance to reply on any American students threads since it should be done the same day. The reply should be due the day after. Since this is a collaboration, I would like to have the possibility to reply to what the Americans writes to.

One surprise in the project was that the students did not use the social forum "Fika." Dr. Gallo's 2009 project included a similar social forum, which the students used frequently. One explanation for this difference can be that the current project included a synchronous component, which mitigated the need for an asynchronous social forum. Some technologies that the students used in the current project, such as WhatsApp and Facebook chat, did not exist or were not used as often back in 2009. We also noted that some topics that would have been appropriate for Fika were included in the personal introductions, as well as the reflection narratives. In the personal introductions, students shared photographs of their locations and included embedded videos of their favorite songs. Drs. Gallo and Lilja also used the announcement feature to add a social element. For example, Dr. Gallo shared a photograph of the airport when she was on her way to the European Society of Criminology's annual meeting in Porto in Portugal. This finding alludes to the fact that a social element is important for both students and faculty. However, a defined social forum may not be necessary in cases where students have access to social media technologies that can be repurposed for educational purposes or when other features of the course foster social discourse.

Successes

Despite the challenges, overall students expressed that they had a great experience. Based on students' reflections, the experience was both intellectually and socially enriching. Socially, students shared how much they enjoyed getting to know about each other and the culture in each country. For example, one Swedish student shared in the first journal entry:

> What I liked the most this week about the collaboration has to be the personal introductions. It was very exciting to read about people in another country and culture and to learn about their personal interests and life goals.

Another student from the US University shared how they hope to visit Sweden one day:

> I also really enjoyed getting to know the other two girls from Sweden, they were fun to chat with and work on this paper with. This was a new experience for all of us and we came into the course not knowing what to expect and we came out with more knowledge on criminological theories, as well as improving our communication skills. I truly believe this is going to help us in the real world when we go out and have a proper job. In addition, the girls in our group from [the Swedish University] are much older than me and I was able to learn more about their real jobs, the criminal justice system, and different perspectives on crime. Overall, this collaboration was a great experience for me. I got to learn about another country and how things work not only in the criminal justice system but as well as many other cultural factors. I hope to visit Sweden one day, things seem more about equality over there and that is something I really appreciate and respect.

One big surprise was that language was not a barrier in the collaboration, which both students at both universities shared in their journal entries. One Swedish student shared:

> It's always a bit nerve-racking to talk to people that have English as their main language. But I guess that makes it easier for them to understand English that is far from perfect. There was actually no big problem with the language barrier in the meeting.

A US student noted that "Video chatting with them [the Swedish students] was really easy and fun because surprisingly their English was very good so that was not an issue." Students had mixed feelings about having mandatory video meetings. One US student expressed they would change this aspect of the course:

> The only thing I would change about this course is to not make the video meetings mandatory because as we all know, technology has a way to always mess up when we need it, and with the 9 hour time difference between us and our busy schedules as college students (athletes too), it is difficult to set up a time where everyone is free for the meeting.

However, other students wrote that the video meetings made a difference in the collaboration. In the quote below, a US student remarked how nice it was to put a "face with a name":

> Another reason as to why this week has gone so well is because we finally got to have our video conference with the Swedish students. It was really nice to finally put a face with a name. I felt that it was a great experience being able to talk with them face to face over skype.

Another student from the Swedish University seems to have mixed feelings about the video meetings, but seems to settle on that they were helpful:

> This week we had our first group video meeting, since we experienced technical difficulties last week. It felt a bit strange during the meeting to have the camera on, instead of just the sound. But I guess that is a good learning experience as well, and I felt like we got another connection than we would have had if only writing to each other in forums or by using group message.

Intellectually, the students were learning from each other and co-creating knowledge. One Swedish University student wrote about the weekly discussion forums:

> I've learned some more about feminist theories, which I find interesting, and life-course theories. The weekly discussions were very good this week. I find it interesting how people look so very differently on feminist theories and on reasons behind and effects of patriarchal structures in society. Even in the discussions I think you can sometimes see how patriarchal structures affect you unconsciously in the way people think and reason when reading each other's posts.

Another student from the US University expressed how valuable the experience was for them.

> I wouldn't change anything my group did, even though if was tough at first to get in contact with them due to the wifi here at school we managed to work things out and meet whenever possible. It was such a pleasure to be able to do something like this to end my college career. Also being able to meet two awesome people in a totally different country and collaborate to do work from our own place. We worked very hard in the work we did each makes everything at the end much better knowing that we finished everything on time and plus it was some great teamwork.

This project was one of the most fulfilling design experiences that we have ever had. We were all intrinsically motivated to do this project, and it made a big difference. This project was not an official assignment for either of us, but we all had a passion for enhancing the teaching and learning experiences of students. We had to meet a lot and figure out the challenges. At the end of the experience, Drs. Gallo and Lilja articulated how valuable it was to work with an instructional designer. A key success factor in this design case was that the makeup of the team included the expertise to create the social, technological, and educational aspects of CSCL. The faculty (Drs. Gallo and Lilja) thought that the greatest sense of accomplishment was the collaborative knowledge-building that occurred, especially using the wiki. They were amazed at the level of group interaction, reflection, problem-solving, and critical thinking. Additionally, faculty thought the process was mutually beneficial to their professional development as it was for the students' intellectual development.

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Reinventing Military Science in Higher Education: Using Service Learning and Cloud Computing to Develop Future Leaders

Robert Monk, Carrie Lewis Miller, and Hunter King

Introduction

The Army Reserve Officers' Training Corps (ROTC) is an elective program available at many colleges and universities that offers students both scholarship opportunities and leadership training for those interested in continuing to Armed Forces service. Historically, the ROTC courses and training prepare candidates for a career as an officer in the military. Courses in leadership, military history, and physical fitness are some of the key components of these programs. Taught by battalion leaders who are generally officers in a corresponding military branch, military science courses give students a chance to wear a uniform, push themselves physically, and learn critical thinking and problem-solving skills while learning about the branch of the military they are considering as a career. The rise of the digital age and the increasing number of online courses available at post-secondary institutions have inspired academic technology and pedagogy researchers to explore how these changes in our learning environments influence shifts in traditional pedagogy and teaching and learning preferences within ROTC and military science courses. The following design case describes one such meeting of digital technology and traditional pedagogy through the lens of two massive service-learning projects.

R. Monk
Prescott College, Prescott, AZ, USA
e-mail: robert.monk@prescott.edu

C. L. Miller (✉) · H. King
Minnesota State University, Mankato, Mankato, MN, USA
e-mail: Carrie.Miller@mnsu.edu; Hunter.King@mnsu.edu

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Design Scenario

Curriculum Model

Benedictine University (BenU) at Mesa, a small branch campus of a Catholic institution based in the Midwest, opened in Fall 2013 with a small group of students interested in participating in the Army Reserve Officers' Training Corps (ROTC). It is unusual that an ROTC affiliation would begin at a startup satellite campus during its opening year; however, the BenU Mesa campus is a unique one in that the entire campus is lecture-free and that the objectives of this campus are closely aligned with the objectives of Cadet Command, the organizational unit that oversees ROTC programming. The student interest combined with the curriculum model made it an appealing exception to the rule, and a small cohort was created under the Sun Devil Battalion stationed at Arizona State University, a large research institution in a neighboring city from the BenU Mesa campus. The courses offered were military science (MIS) 101, *introduction to the military*, MIS 102, *land navigation, first aid, and survival*.

The curriculum at BenU Mesa relies on a combination of the flipped classroom model and problem-based learning to promote critical thinking skills and active learning. Incoming Fall 2013 students participated in regular technology workshops to familiarize themselves with the most cutting-edge tools and technologies available. This technology-enhanced campus supports the kind of collaborative learning and critical thinking skills that are requisite to the development of great Army officers and leaders, and this idea is the catalyst that created such a quick and effective partnership between BenU Mesa and the ROTC Department at Arizona State University (ASU).

The ROTC curriculum is largely focused on personal development, teamwork, and understanding the function of the Army (Fig. 1). The course objectives are broad, and some are difficult to teach through traditional lecture, *Explain the importance of being a model citizen as an Army officer,* for example. An instructor could try to teach this through case study or lecture, but a far more effective method is to get students out of the classroom and be seen by the community as model citizens (Johnson, 2010).

In the summer prior to the inaugural term at BenU, the university held a workshop for incoming faculty that introduced the fundamentals of problem-based learning (PBL), given by the authors of the book *The Practice of Problem-based Learning*, José Amador, Libby Miles, and C.B. Peters. During the workshop, faculty members practiced designing and implementing curriculum using the PBL model. Following the workshop, the ROTC instructor began to consider how he might develop a syllabus following the PBL methodology that also meets the course objectives required by Cadet Command. The instructor realized that the personal development, teamwork, and officership objectives could be met by solving one big "problem": the planning and execution of a service project. As part of education in the Benedictine tradition, students at Benedictine University must complete

Leadership
- Understand the importance of leadership and personal challenge

Personal Development
- Explain the importance of goal setting and time management
- Define the basic elements of stress and stress management
- Identify benefits of healthy nutrition and diet in a personal fitness program
- Develop short & long-term goals for a personal health and fitness program

Values and Ethics
- Explain the Warrior Ethos
- List and define the Seven Army Values

Officership
- Explain the importance of being a model citizen as an Army officer
- React to passing colors, National music, and approaching officers
- Identify Army customs, courtesies, and Cadet rank structure
- Understand the impact of different cultures on leader development

Tactics and Techniques
- Identify symbols and colors on a military map
- Work effectively in teams with fellow Cadets

Fig. 1 MIS 101 course objectives from Cadet Command

service-learning hours every academic year. It was this program element that led to an innovative, service-based leadership training using Cloud technology to collaborate, coordinate, train, and plan for a large-scale service-learning project.

Working with an instructional designer as a pedagogical resource and technology guide, the ROTC instructor created an organized framework for material delivery and cadet collaboration using Google Sites and Google Docs. The students would design, propose, and execute a large-scale service-learning project in the city of Mesa, near the BenU campus.

Design Elements

Service Learning

Service learning is an instruction method that combines civic service in the community with academic instruction in a reflective and responsible manner. Going beyond volunteer work, service learning adds a content-related component and requires the student to connect what they are learning in class to what they are doing to serve their community at large (Heiselt & Wolverton, 2009). Many instructors cooperatively build service-learning projects with their students and civic or community leaders to provide the most authentic learning experience that emphasizes elements of the curriculum or topic being studied (Dymond, Neeper, & Fones, 2010). Benedictine University's long history of community service coupled with their commitment for developing problem-based learning environments for students set the stage for the development of a novel, community service project for a military science course aimed at teaching leadership and project management skills.

Studies have shown that students who participate in service-learning curriculum demonstrate higher levels of civic responsibility, social involvement, and awareness of social injustice (Dooley, 2007; Myers-Lipton, 1998). Effective service-learning experiences do require planning on the part of the instructor. In addition to careful project and site selection for the service-learning experience, instructors must be cognizant of their students' affective preparation for the experience, in addition to their cognitive preparation (Dooley, 2007). To encourage course fidelity and higher learning, it was important for the students to have opportunities for reflective practice and safe spaces in order for them to process the information they gained from the service-learning experience. In addition, the service-learning experience tied into the military curriculum in a meaningful way, providing students with a way to authentically practice the skills, knowledge, or behaviors that the course intended them to achieve.

Problem-Based Learning

The United States (U.S.) Army, and combat situations in particular, are amazing problem-generating machines and, therefore, provide many problem-solving opportunities for officers. From an Army officer's first day on the job, there is an expectation that the officer is capable of researching, critical thinking, and problem-solving. Officers in the field quickly learn that they are no longer in college where they simply receive a block of instruction and recite the answers on an exam to be successful. Once in the field, they are in an environment where they are expected to figure out solutions to problems, make mistakes, and learn from them. In the field, there are an endless stream of problems that are triaged and solved daily, sometimes with life and death consequences at stake. Whether the student is a young lieutenant (entry-level commissioned officer), a senior non-commissioned officer (an enlisted officer that has moved up the ranks by promotion, lower in rank to a lieutenant), or a brand new private (lowest Army rank, held by newly enlisted recruits), giving a learner guidance and then sending them off to succeed or fail develop their wisdom quickly.

Veterans who exit service and enter higher education are often classified as self-directed, adult learners who demonstrate managerial or leadership skills, who may have intercultural expertise, who exhibit high levels of intrinsic motivation, who have a strong organizational commitment and sense of community, and who are able to adapt to changing situations (Starr-Glass, 2011). These characteristics, although general, speak to the level of problem-solving and just-in-time PBL military personnel receive during their time of service. By incorporating PBL into premilitary service programs, such as ROTC, it better prepares cadets to perform well and succeed during their time of service and beyond.

Because PBL was a mandate for the BenU campus courses and because PBL and problem-solving are integral parts of the Army experience and the ROTC curriculum, the instructor chose PBL as the driving force behind the service-learning experience. The instructor wanted the students to solve a real-life problem while providing a service to the community.

Traditional PBL in academics requires the use of an ill-structured problem that allows students to explore the content through the solving of that problem. The instructor acts as a "guide-on-the-side" to answer questions and redirect students when necessary (Amador, Miles, & Peters, 2006). As an active learning technique, PBL can quickly engage students with the respective content in addition to creating opportunities for students to practice critical thinking skills. However, novel teaching methods that account for generational pedagogy shifts do not come without their limitations. One such limitation of PBL is acclimating students to having less structure and reliance on the instructor, compared to the more traditionally designed course~~s~~ (Miller, 2016). In the case presented here, the instructor felt that the students completing this service-learning project had to have structure to complete the project successfully. In addition, they needed to familiarize themselves with the military structures, methods, and policies that being part of the ROTC program entailed. The instructor decided that the problem-based learning used in combination with the service-learning project could not follow traditional PBL methods with the "ill-structured" problem. In this case, the instructor still acted as a "guide-on-the-side," and the students were provided with a framework within which they would operate and choose their service-learning project, although the instructor was more directly involved with mentoring and providing interventions than he would have been under a more traditional PBL model.

Service-Learning Project Design and Learning Outcomes

Service Project Design

Since the military science courses at both universities were representative of traditional ROTC curriculum, service projects were desired that would allow students to develop the core principles of personal development, teamwork, and officership. In addition, to incorporate the Benedictine principle of community (e.g., call for service to the common good and respect for the individual), service projects within the community that housed BenU Mesa were considered ideal by the instructor. Since the student audience for this project consisted of incoming freshman students new to the ROTC program, one intended benefit from the chosen methods of PBL and service learning involved increasing cadet confidence as they successfully solved problems and participated in a successful, large-scale community service project. Another intentional design objective was successful collaboration between diverse groups of students, similar to actual military operations. To simulate real military experience, students would have to coordinate cadet deployment, movement, responsibilities, and work at a distance, working together to insure project success. As the instructor had direct experience with this type of project management in military operations, he felt confident that the service-learning project would be ideal for helping the students develop the needed skills.

In order to give students ownership over their service-learning experience and yet still develop the core ROTC principles, the instructor constructed project guidelines and constraints but left the choice and implementation of the project to the students. The groups of freshman cadets were split into three sections by the instructor: two larger sections held at ASU and had between 12 and 40 students, five students at BenU, and 50 cadets enrolled in freshman MIS 101.

As dictated by Cadet Command, first semester outcomes focused largely on basic Army values and concepts, while the second semester covered more technical aspects of the Army, such as Army writing styles and the Army Operations Order process (OPORD), a formal plan given to subordinates that divides a military operation into a summary of the situation, the mission of the military unit responsible for the operation, and the supporting activities that the unit will conduct. Each of the two semesters aimed to achieve different outcomes, which allowed the instructor to design two differing service project concepts in addition to making design changes based on reflections from the previous semester. As planned, the success of the first semester's project instilled confidence and experience in the student's ability to plan and work together. These outcomes enabled the second semester project to surpass the first in terms of complexity and autonomy of the student leadership. Both service projects varied in scope, complexity, and desired learning outcomes.

Technology Tool Decisions

According to a recent Pew research poll, the use of social media and technology, in general, has seen stark increases over the past decade (Lenhart, Smith, Anderson, Duggan, & Perrin, 2015), occasioning an opportunity for instructional designers and higher education faculty to integrate technology in their course design, with the aim to encourage collaboration and engagement among learners. The use of digital technologies to transform collaborative learning experiences opens the door for students to learn from each other as well as from their instructor, in a truly social constructivist environment (Rowe, Bozalek, & Frantz, 2013).

One challenge for the instructor, as it related to the ROTC curriculum, was uniting cadet units at two different campuses and providing a structure for them to work collaboratively on one large service project. Because both campuses used different email and learning management platforms, the instructional designer suggested that Google products in combination with a common LMS might be the best fit for creating an open, collaborative structure to provide course materials and organize the project.

BenU and ASU both use separate and unique learning management systems (Desire2Learn and Blackboard, respectively). This made posting information to both classes and collaboration between schools both time-consuming and challenging for the instructor. The instructor solved this challenge by using Edmodo (a third-party free learning management system suggested by the instructional designer) and Google collaboration tools (Google Drive and Google Sites) as systems to coordinate student efforts and post assignments outside of the regular in-class meetings.

Students from both campuses were able to review the semester assignments and quiz study guides for the semester in the shared Google Drive. A file in the shared Google Drive also showed students a breakdown of all available points for the semester and their current grade (available anonymously using Google Sheets).

The majority of student assignments were completed online and submitted to the instructor via Google Forms. In addition to assignments and quizzes, Google Forms were also used to conduct anonymous peer evaluations and after-action reviews (lessons learned). These evaluations helped the instructor to individualize feedback to each cadet regarding their perceived contributions to the class and the overall project.

Fall 2013: Mesa Community Revitalization

A service-learning project designed by the instructor using both PBL and service-learning theories along with objectives of Cadet Command was introduced to the students enrolled in MIS 101 at both universities in the Fall 2013 semester. The students would find, plan, organize, and execute the project by the end of the semester using standard military planning and operations procedures. Through the planning and execution of the project, the ROTC students spent time experiencing fundamentals of the following course objectives:

- Leadership – by working as team supervisors and project managers.
- Personal development – by soliciting self- and peer feedback throughout the process.
- Values and ethics – by researching needs within the community and committing to help.
- Officership – by practicing command and control and decision-making.

At the beginning of the first semester, the majority of the classes were broken up into groups of between four and five students, with one large team of seven. The instructor chose these team sizes because the Army arranges teams of soldiers in similar sizes to maintain an effective span of control. When practical, the instructor tried to replicate the conditions that soldiers generally experience in the Army.

Each group was given the following broad guidance: “As a group, develop a Service Project Proposal Video. Your video will outline your project proposal idea and demonstrate how your proposal successfully meets [at least half of] the course objectives and [all of] the constraints [listed below].”

Teams were provided with four project parameters, which included:

1. The project must benefit more than 100 community members.
2. The project will occur near the Downtown Mesa area [near the BenU campus].
3. The project will occur sometime between December 2 and 10, 2013.
4. The project must include some local leaders (government or organization).

The instructor chose these parameters for various reasons. The first requirement, to benefit 100 community members, was made to ensure that the scope of the project was large enough to necessitate sufficient planning, resourcing, involvement of community leaders, and so that upon successful completion, the cadets would feel a greater sense of accomplishment than if the project had a smaller scope. The second requirement, to hold the project near the BenU campus, was implemented in an effort to ensure that the larger ASU cadet population would be motivated to work with the smaller BenU population who were more familiar with the needs and opportunities in the Mesa area. The instructor was concerned that holding the first project near the ASU campus might marginalize the smaller BenU team. Holding the first project near the BenU campus would make it more likely that the ASU team would involve and include the BenU cadets. The third requirement, to hold the project during the first full week of December, was made to ensure that there would be maximum time for planning and preparation. The final requirement, to involve local community and government leaders, was intended to help the cadets gain confidence working with leaders from outside agencies. Throughout a military officer's career, it is likely that they will be paired with leaders in various government agencies or with peers from other militaries or nations. The instructor felt that this would be a helpful first step to build confidence. A more tangible and underestimated benefit from this requirement was the help that local leaders provided in the form of resources and ideas. These requirements were a very important part of the project framework. All of the requirements chosen, except the date range, did result in a very positive outcome.

Freshman students went out into the community, looked for project opportunities, and then developed proposals that they posted on YouTube for the class to watch. Once the class members reviewed each submission, they selected the best projects. To guide the class in making their decision, the instructor demonstrated how the Army uses the seven-step Military Decision-Making Process (MDMP), and then he developed an exercise for the class to follow the same methodology to select the best plans. The MDMP is used by the military in both active and training operations and is viewed as a problem-solving tool for almost any situation requiring action. Heiselt and Wolverton (2009) and Reese (2019) explains, "The MDMP facilitates interaction among the commander, staff, and subordinate headquarters throughout the operations process. It provides a structure for the staff to work collectively and produce a coordinated plan" (p. iii).

After students from the MIS 101 class researched local concerns and developed proposals, the winning proposals were sent to local community leaders via email to be voted on. Local leaders picked the Mesa Community Revitalization Project, and the students began work on setting goals and developing a plan as soon as they received the notification emails.

Once the winning proposal was selected, that team was appointed as the management team, and through various other exercises, the class was divided into nine teams each with specific planning and execution responsibilities. Each week project progress, challenges, and plans were discussed and revised.

The ROTC students met with the city council of Mesa, Arizona, as part of the project discovery process. In the Mesa area, a number of low-income neighborhoods were in need of painting, graffiti and trash removal, and basic landscape maintenance. The scope of the project area was defined to seven blocks in a high-need area of Downtown Mesa.

An example of how the students were able to use real Army planning methods to facilitate the project is shown below (Fig. 2). The format of the figure below was adopted from the plan that the instructor actually used to prepare a military transportation company for deployment to Afghanistan. The instructor worked with the management team in pre-class meetings to give them guidance and then watched them brief their plan to the rest of the classes and their subordinate team leaders.

The freshman students met with a city councilman on a regular basis throughout the project for resources and guidance, attended a town hall meeting to raise awareness in the community and recruit local volunteers, held three fundraising events to raise money for supplies, and solicited help from local businesses for donations and

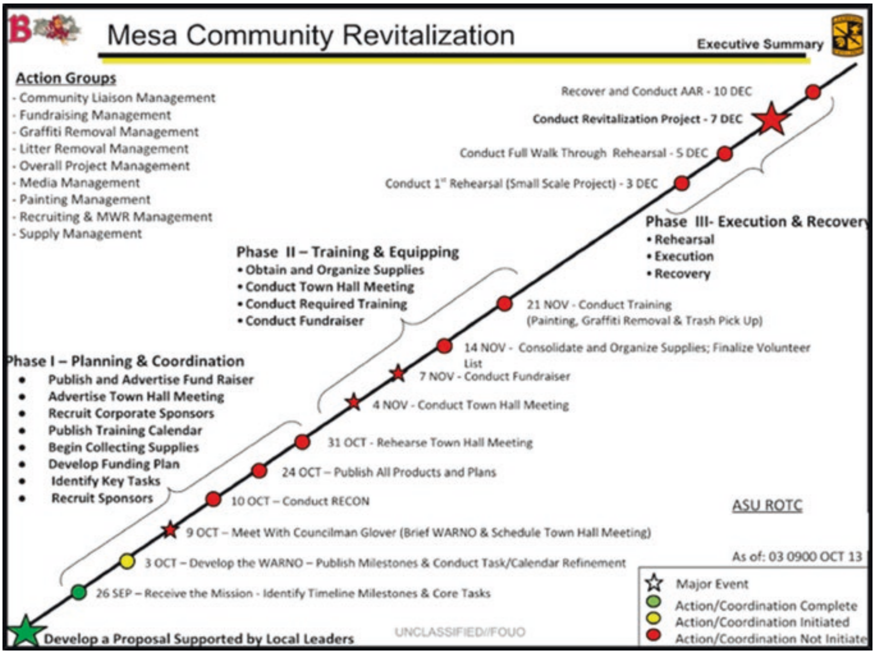

Fig. 2 Mesa Community Revitalization Project planning document

services such as trash removal. They also worked with the city of Mesa volunteer management division to coordinate tools and supplies loaned by the city and to gain guidance on contacting the residents of the target neighborhoods. Just like young lieutenants in the military, these cadets learned by jumping right in. They hit many roadblocks; some groups failed to meet their milestones, but in the end, they came together to make the mission happen. Through solving the problem and completing the service-learning project, the cadets practiced the ROTC core principles of personal development, teamwork, and officership.

On the day of the event, the freshman students managed more than 100 volunteers. They ran a command post (CP), a central base for mission operations. In the military, the CP is the main hub of information and operations to any mission. The CP maintains communication, a flow of information, and control of assets vital to mission completion. Generally, the CP is located in a central location to the mission that is protected yet maintains a line of sight for communication. It is the central nervous system of any operation. In this service-learning scenario, the freshman students used the CP to manage the painting of an entire home, the painting of more than 200 curbs, and the removal of more than 20 truckloads of debris and trash from several homes throughout the community.

In the months leading up to the event, the students also learned how to use various Google collaboration tools and techniques to synchronize the three separate classes. The instructor and teams used both Google products and the Edmodo site to communicate with each other outside of regular class meetings. The individual classes had face-to-face meeting times to communicate with the instructor and each other, but not the other teams. This communication had to be done electronically.

More than achieving the course objectives, this group of civilian freshman students grew into a cohesive military unit. They understood military terms like "leadership, goal setting, time management, values, and officership" to a degree that couldn't quite be reached from only sitting in a classroom. Figures 3 and 4 show the storyboard summaries of each project.

Spring 2014: Operation Smoke the Kids

The Spring 2014 semester mission was to conduct a service project recruiting event that would (1) raise awareness of the ROTC program among high school students and (2) raise awareness and funds for a military affiliated charity. The name of the second project, selected by the cadets, is a nod to the Army's common use of the term "smoke" when referring to exhausting and strenuous workouts. By the time that the second project was beginning, the class had a huge success behind them and an optimistic and eager challenge ahead.

For this second project, the instructor began with a different approach when designing the management scheme. During the first iteration, both the student and faculty were new to each other and to the idea of a service project. By the end of the first term, the instructor had a better idea of which students might be best suited to

Fig. 3 Summary of the Mesa Community Revitalization Project

Fig. 4 Summary of the Operation Smoke the Kids project

act as upper management (like Army commissioned officers). Just prior to the start of the term, the instructor asked his first-choice project manager if they would take on the role and the student agreed. The instructor worked with the new student project manager to build a management team of four people. The size of the management team was chosen to replicate the instructor's experience in a typical Army unit structured to maximize span of control. This way of structuring teams (as opposed to having a few large teams) also results in more leadership opportunities for students in the class.

Additionally, based on feedback from the previous project, the instructor assigned an upperclassman cadet officer to each team to act as a mentor and to ensure that the upperclassmen in the ROTC program were aware of what the freshman class was planning. The intent with the mentoring element was to increase communication and oversight from the upperclassmen as well as to bring more experienced cadets into the project to demonstrate leadership and collaboration techniques, similar to the instructor's experience when deployed and on military operations. This pairing with a mentor greatly increased oversight and helped to facilitate the project as cadets then had both role models and additional avenues of communicating with the command structure.

Once the management team was set, the instructor outlined their mission and gave them time to organize their thoughts and prepare a presentation to the class. After the management team presented the class mission, the instructor dismissed the majority of the class and asked for anyone interested in a team leadership role to stay behind.

The volunteer team leaders worked with the management team for the remainder of the class period to exchange contact information and to establish a convenient meeting time for the management team and team leaders. These meetings usually occurred a day before class, and it was a very helpful time for preparing the agenda and priorities for the upcoming class.

Another interesting decision that the management team made was to disband the finance team and move their team leader into the management group. The cadets decided to make this change because the finance team had a few significant manpower requirements, but the majority of the time, they only required one person to make the arrangements. Once the finance team leader was added to the management team, they were able easily get support from the team leaders when full class support was required. This decision was of particular interest, because it showed that the cadets were paying attention to the efficiency of their organization and that they identified the need to reorganize and shift resources. This kind of organizational assessment and management is something that Army officers do on a regular basis, but it is not something that the instructor had taught or that he was anticipating. This restructuring was a smart move that improved overall efficiency and demonstrated that service learning can lead to skill development beyond the scope of the main course objectives.

The instructor noticed a big difference in the type of involvement required between semesters. During the first semester, the instructor dealt much more in the plan details and team management. During the second semester, the MIS 102 class was much more autonomous and more capable of identifying and solving problems without needing as much instructor guidance or intervention. During the second project, the instructor would pass observations and concerns to the management team with less direct supervision required.

The final project result was a "Leadership and Warrior Skills Challenge Event." During the planning of the project, the freshman class contacted more than 100 school administrators to invite high school students from across the valley to attend the competition. They developed competition standards and sent training videos to participating students in order to prepare them for the challenge. In addition to high school students and VIPs from the Veterans Center, students also coordinated for the Maricopa County Attorney Bill Montgomery to speak and officiate the competition.

The purpose of this service-learning project was to demonstrate and exercise the fundamentals of leadership and teamwork as the cadets collaborated, planned, and executed a project that was a great win for the Army, the Arizona State University, the Pat Tillman Veterans Center, and the dozens of high school students that learned about each of those organizations.

The freshman class organized into 14 teams and managed several planning sessions to ensure mission success. Each team made contributions to the overall success of the project. Through the class' hard work and the generosity of local companies and leaders, the majority of food and water was donated to the cause. Chick-fil-A, in particular, donated more than 100 meals at no cost. The class also invited Fox 10 news to provide live coverage during the competition.

Throughout the semester, cadets developed an Army Operations Order (OPORD) totaling more than 100 pages with all included maps and diagrams. Each team was responsible for a particular Annex or Appendix. The teams briefed the instructor on their progress during four separate In-Progress Review (IPRs) and finished by conducting a Concept of Operations (CONOP) brief, a common military procedure used to synchronize several military units prior to large and complex operations, prior to the event.

Not only did the cadets exceed the curriculum requirements, but they also introduced dozens of high school students to ROTC while raising more than $4800 and awareness for a local military charity. On the day of the event after the competition was complete, the cadet project manager publicly handed a check for more than $4800 to the director of the Pat Tillman Veterans Center on behalf of the students of the Sun Devil Battalion.

Project Feasibility and Over-/Underestimating Capabilities

A critical concern and consideration from the beginning of either project was the ultimate feasibility of completing the project on time and in a satisfactory manner. The instructor and students were trying something new inspired by the principles of problem-based learning and service learning. There was no guarantee that the project would be successful, but even if the class didn't achieve all of its goals, there would have been many lessons learned along the way.

In an attempt to mitigate the possibility that students might over- or underestimate their capabilities, the instructor asked questions of feasibility often or when plans seemed vague or not fully thought-out and made interventions when necessary.

An example intervention was implemented during the first project with the "litter removal team." The initial plan was for the students to send out a flyer stating that the group would be conducting free, junk, and debris removal for any homeowners that requested it. There were more than 300 homes in our project area. While the group had planned for a lot of volunteer labor, there were not many vehicles (trucks or trailers) available for debris removal, and the instructor wanted to avoid the risk and control challenges that would occur with such a large vehicular operation. The management team was advised to consider focusing all of their effort on a few large debris removal projects as opposed to many smaller projects at dozens of residences. By working with the contacts at the city of Mesa, the students were able to select a few high-need resident homes on which the group could focus.

An example of underestimating the outcomes the students could reach that almost occurred took place during the second project. When the instructor learned that the management team planned to raise $4200 for the Pat Tillman Veterans Center, he was initially concerned. Raising $4200 in 3 months seemed to be a high goal. The finance manager and management team were familiar with the technique that they planned to use, and they were confident in their abilities. The instructor told them to aim for $4200 but to make sure that the Pat Tillman Veterans Center understood that the money was not guaranteed. The instructor was concerned that the students would fall short of their ultimate goal, but everyone was pleasantly surprised when the students raised $4800 coming in $600 over the goal.

Span of Control

Another challenge during the first project that benefited from faculty intervention was a personnel conflict within the "supply team." After a few weeks into the project, one of the student team leaders came to the instructor with frustrations about their group. The complaint was that "no one on his team was doing anything." When the instructor spoke with the team members, their consensus was that their team leader did everything and didn't trust them with anything important. Over the course of the next few weeks, the instructor worked with that manager and his team to try and make them more functional. While part of the problem within that team was personality driven, the instructor felt that the problems were exacerbated by the size of the team. When the team was established, it was initially assigned seven members (the most of any team). This decision was made because their mission was expected to require more cadets that the other teams. Three years of experience conducting these service-learning projects has taught the instructor that teams are most functional at sizes of between two to four.

In the later projects, the students were introduced to the concept of span and control as a consideration when building teams. Below is how the Army defines span and control in Field Manual 6–0:

> Span of control refers to the number of subordinate units under a single commander. This number depends on the situation and may vary. As a rule, commanders can effectively command two to six subordinate units. Allocating subordinate commanders to more units gives them greater flexibility and increases options and combinations. However, increasing the number of subordinate units increases the number of decisions commanders have to make. This slows down the reaction time among decision makers. (Department of the Army, 2014).

Initially, the instructor did not give much thought to span of control, but as the projects grew in complexity, it turned out to be a significant consideration in project planning. When setting the teams, if the instructor noticed five or more people in a group, he would question if it was necessary. For example, during initial planning, if a task seemed like it required an eight-member team to complete, the instructor would ask for students to think of a way to break the task down into two sub-tasks and then form two teams each with a leader. This reduced span of control not only helps each leader better control their teams, but it also opens up another leadership position within the class. Whenever able, maximizing the number of leaders adds to the ability of the students to learn and demonstrate leadership skills in support of the course learning objectives.

Outcomes

Fall 2013 Mesa Community Service Project

The desired learning outcomes of the first project included exposing students to leadership opportunities and familiarizing them with the Army values through community service and partnership with community organizations. The class was able to partner with the city of Mesa and many other organizations to help achieve this objective. These partnerships provided students with logistics and training support. The city of Mesa, in particular, has a volunteer management office that supplied the class with tools, training, and access to a town meeting to recruit community volunteers. Initially the instructor encouraged student partnership with local leaders with the idea of exposing students to civil leadership, but the partnership turned out to be an extremely helpful and fruitful venture for both the city of Mesa and the ROTC students.

Spring 2014 Operation Smoke the Kids

The desired learning outcomes for the second project were more focused on military planning, communication, and small group leadership as directed by Cadet Command. During the first project, the instructor was much more engaged assisting in the planning and resourcing of the project. During the second project, students were much more independent and were able to solve many more problems on their own. The instructor noticed a shift in the type of input that they provided had changed from a more hands-on coaching role into more of a mentorship role. This shift is reminiscent of a shift that often happens for new leaders in the military. As superior officers feel more confident in their subordinate leaders' capabilities, their leadership style tends to evolve from a coaching style to a style that is closer to mentorship.

Service-Learning Project Revision

Reflections on the Project

1. *Project Timing* – This was an oversight during the first project. When the instructor initially gave a timeline for the project, he scheduled it for the week between students last class and their final exams. This was particularly bad timing for first-term freshman students. Many students complained that they had major project responsibilities during the week that they should be studying for their first ever college finals. This also led to the instructor being required to clean and turn in all of the supplies back to the city. Once the instructor learned how disruptive it was for students to help during finals week, he worked hard to ensure that after the project, no students had anything left to take care of. In subsequent projects, the instructor scheduled the project with sufficient time to be fully completed before the last class of the semester, so that class could be spent reviewing the lessons learned and beginning initial plans for the following semester.
2. *Assign Upperclassman Mentors* – During the first project the instructor did not assign any mentors and he acted as lead mentor for all groups. Student feedback from the after-action review of the first project was clear: they felt lost and unsure of what to do and where to go at many times. The project was successful, but during a student's first semester in ROTC and oftentimes first exposure to leadership roles, it turned out to be very helpful to have mentorship assistance. During the second semester, the instructor assigned a senior cadet to each team. The senior was meant to help provide ideas and resources to the underclassmen cadets. With each team having a mentor, it greatly increased the instructor's flexibility and increased the capabilities and knowledge of the teams and was a valuable experience for the seniors offering to help.
3. *Small Team Sizes* – A design conclusion reached by the instructor for these types of service-learning projects is to use smaller, more structured teams. Whenever possible, the more teams, the better. Particularly, if you have enough upperclassman mentors to give every team one, the opportunity for mentorship increases. As was seen in the second semester project, the more team leaders that you have, the more leadership opportunities that exist. The ultimate goal of both projects was to produce leaders, which was more effectively done when there was a leadership role model in the form of the upperclassman in the group. Additionally, establishing a "chain of command" is fundamental to how the military works and is fundamental to these types of service projects with widespread groups of students. Practicing command and control in a controlled environment where failure is an acceptable method of learning is invaluable. The more levels of leadership and opportunities to lead that you can produce, the better. Finally, span of control is an important factor for new leaders in the ROTC programs. Setting the tasks and managing more than four people at time can be overwhelming for a new leader. Bringing in more experienced leaders, such as the upperclassmen, was a great solution to both keep the freshman students from becoming overwhelmed and to provide examples of leadership techniques.

Future of ROTC and Instructional Design

The combination of the ROTC/instructional design collaboration, the strong organization using Google products by the instructor, and the unique element of a service-learning project completed across multiple universities should make it an interesting design case for both faculty and instructional designers. The potential for research on the scholarship of teaching and learning with this design case and framework is immense.

There are many similarities between the logistics and planning strategies seen in the military and the process with which an instructional designer approaches a design project. From this collaboration in planning, organization, and execution of a service-learning experience that relied heavily on Cloud technology, the instructional designer learned many techniques that could be applied to her own organizational setting. The ideas of considering *span of control* or of completing *after-action reports* are not concepts instructional designers generally find in service-learning literature. However, controlling group size and creating opportunities for reflective practice are often built into learning experiences by instructional designers on a regular basis. Opening up a collaborative opportunity between an instructional designer and an ROTC instructor broadened both of our vocabulary and our design practice by the exchange of techniques and ideas.

Through the design and completion of this project, both instructor and instructional designer concluded that service learning is a valuable and effective method in increasing involvement within a community and in developing leadership and teamwork skills. The use of technology was critical to the success of these projects, and the instructional designer continues to use the artifacts built by the ROTC instructor as models of collaboration and coordination of service-learning projects and problem-based learning activities.

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An Activity-based Design Case for Step-by-step Teaching of Programming to Secondary School Students

Ali Kürşat Erümit

This design case describes the process we used to design lesson plans to support secondary students to develop problem-solving, reflective thinking, critical thinking, and algorithmic thinking skills. We identified topics for programming and steps for teaching algorithmic thinking and then designed activities and lesson plans for these topics. We made revisions based on expert and teacher feedback and formative testing with students to ensure the lessons and activities are suitable for typical class periods and appropriate for students' cognitive levels.

How the Idea Came Up

I was first inspired by the research literature after identifying an apparent gap. The studies I reviewed describe what should be done, but not how to do it (Futschek, 2006; Zsakó & Szlávi, 2012). Relevant studies offer some activities, but these are not connected to each other in a coherent curriculum. The literature suggests that learning programming improves students' problem-solving skills (Bergersen & Gustafsson, 2011), positively affects cognitive learning (Grover & Pea, 2013), develops high-level thinking skills of students (Kafai & Burke, 2014), increases motivation (Akpınar & Altun, 2014), enhances creative thinking skills (Kobsiripat, 2015), and supports algorithmic thinking (Futschek & Moschitz, 2010). The literature provides evidence of both affective and cognitive benefits from programming activities. However, they give few clues on how to implement these activities in schools.

A. K. Erümit (✉)
Trabzon University, Fatih Education Faculty, Computer Education and Information Technologies Department, Trabzon, Turkey

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I decided to tackle this gap with students in a 16-week graduate course I was teaching, *Algorithmic Thinking and Programming Training in Schools* (AT&PT). I focused the course around the question "What should activities be like for developing algorithmic thinking skills of secondary school students?" Guided by this question, I set the course goal as designing a model for teaching programming at secondary level and developing activities and lesson plans according to this model. After defining the problem and understanding the needs, we completed the design in 10 weeks, during which we held 6-hour face-to-face weekly meetings, besides individual work and online meetings. Weekly discussions focused on our findings obtained in the literature review, what to do next, planning for the following week, and distributing tasks among group members. Our design timeline is illustrated in Fig. 1.

Forming the Design Group

I informed students who were enrolled in my course that I was looking for students with experience, skills, and knowledge in programming, teaching methods—especially in public schools, preparing lesson plans and activities, reviewing literature, and conducting interviews and qualitative analysis. Only one student had experience teaching in public schools, while the rest of the designers had all the other qualifications (Table 1).

Although they had many of the qualifications, I knew they would need to learn more about programming instruction; I therefore assigned readings that highlighted practical examples of both computer-based and non-computer-based activities. I particularly assigned papers that investigated algorithmic thinking skills in non-computer environments, because I wanted them to understand that algorithmic thinking is a skill which can be developed independently of computers and in the course of daily life. I also wanted them to understand that algorithmic thinking skills can be improved without using a computer as a part of the computer instruction lesson.

Defining the Problem and Understanding Needs

Because few of us had public school experience, we knew we also needed to identify the constraints of teaching in a classroom and understand learner needs. We interviewed teachers to determine what they pay most attention in preparing a lesson plan in public schools. We got opinions of nearly 150 teachers by means of a survey that asked, "What do you pay attention to when preparing a lesson plan?" After each of the designers evaluated the responses separately, we met and reached consensus on three main elements. We found out that we needed to prepare lesson plans that were suitable for cognitive levels of the students, that fit the duration of

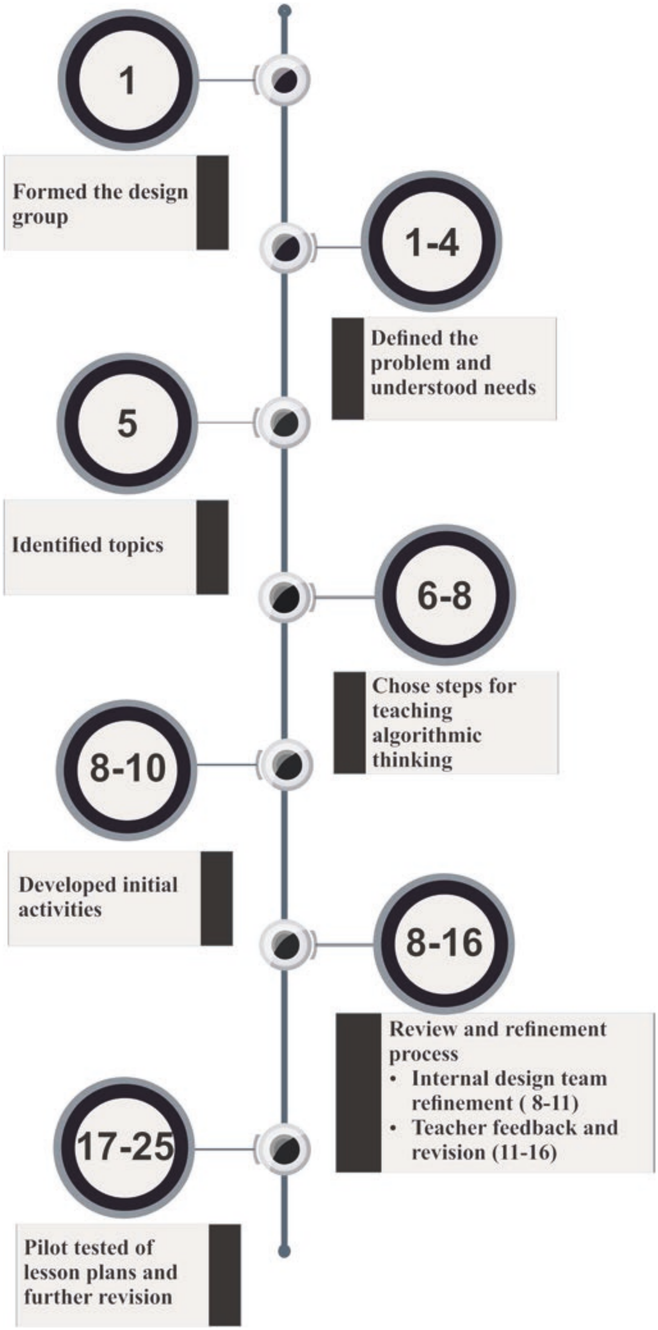

Fig. 1 Timeline of our design processes; numbers indicate the week in which the activity occurred

Table 1 Design group information; all members contributed their expertise

Group members	Gender	Title/level of education	Experience	Postgraduate graduation	Role
Kerem	Male	Assistant professor	21 years of experience in programming and 14 years of experience in programming education	Computer teaching	Planning, coordination, evaluation
Yahya	Male	Lecturer-PhD student	17 years of experience in programming and 14 years in programming education	Computer teaching	Literature review to identify the steps for teaching algorithmic thinking
Semra	Female	PhD student	8 years of experience in programming	Computer education and instructional technology	Literature review to identify topics; *algorithm* lesson plan
Ceren	Female	Master's student	6 years of experience in programming	Computer education and instructional technology	*Conditions* and *variables* lesson plans
Hüseyin	Male	Master's student	6 years of experience in programming	Computer education and instructional technology	*Loops* and *description of the programming environment* lesson plans

the class period, and that fit the physical possibilities of the classroom. These criteria became the framework for evaluating the suitability of lesson plans and activities. For instance, we had to shorten or divide some activities because of the class period duration, although we had initially intended to make them longer. We also planned the activities so that they could be done in the narrow classrooms.

Although we referred to various sources to understand learning needs, we relied primarily on the *Information Technologies and Software Course Curriculum* published in 2017 by the Turkish Ministry of National Education (MoNE). This resource provided the rationale for the topics and objectives. With the aid of expert and teachers' views, we sought to align the lesson plans with the student and instructional setting characteristics.

After Dilara identified possible topics by reviewing the literature, we divided the topics up, and I selected readings for each student based on their topic. Because each designer focused on different topics, they could inspire each other and bring different perspectives when evaluating each other. Since we studied each lesson plan in detail, they were able to justify their decisions.

To guide the design process, I posed questions during the fourth week of the course:

- How can algorithmic thinking be improved without using a computer?
- What features should activities for developing algorithmic thinking have?
- How can we integrate these activities into programming instruction?
- Is it possible to plan activities related to programming education without computers?
- What programming topics should be included for secondary school students (aged 10–15)?
- Is there a certain sequence that works best in programming instruction?
- What are the steps in programming instruction for secondary school students (aged 10–15) in reference to various definitions?
- What should classroom activities with and without computers be like?
- What should lesson plans for this process be like?

Identifying Topics for Lesson Plans

We analyzed 15 existing secondary education courses and activities that included programming education to identify possible topics. Programs ranged from a few hours to an academic year, with seven programs lasting one semester or longer. We reviewed programs described in publications (e.g., Grover, Pea, & Cooper, 2015) and as described by organizations (e.g., Association for Computing Machinery, Harran University, iD Programming Academy, etc.). The topics included an introduction to computer science as a field, algorithms and programs, loops, functions and operations, algorithms, data representation, Boolean logic, conditions, variables and constants, models, and robotics. Variables and constants, conditions, loops, and functions were the most common topics. In our design, we included the following topics: the concept of algorithm, description of the programming environment, variables, conditions, and loops. We also covered programming environment setup, software and programming concepts, and algorithmic thinking.

Choosing Steps for Teaching Algorithmic Thinking

Algorithmic thinking is considered as one of the most important skills for programming instruction. According to Futschek (2006), algorithmic thinking consists of various sub-skills related to structuring and understanding. These sub-skills include the abilities to analyze a given problem, fully express a problem, produce a strategy for a given problem, create an accurate algorithm for a problem using strategies, think in all possible situations, and increase the efficiency of an algorithm. We reviewed algorithmic thinking steps in various studies. Garner (2003), Szántó (2002), and the Committee on Logic Education (2017) grouped several of the steps together, thus reducing the total number of steps. As a result, they provided less detail, making these less useful for teaching. Vasconcelos (2007) and Futschek

(2006) placed a lot of focus on understanding and explaining the problem, at the expense of other aspects. Zsakó and Szlávi (2012) provided sequential ordering that made pedagogical sense, moving from simple to complex. For example, the step of encoding with the help of the programming language is introduced in the fifth step. In other models, the encoding step comes earlier; it is important that encoding be started only after the problem is fully understood and analyzed and a solution is reached through analysis and synthesis. We therefore decided to adapt and elaborate the algorithmic thinking steps introduced by Zsakó and Szlávi (2012), and we describe how we scaffolded each step.

Acknowledgment of the problem consists of recognizing the problem to be solved, understanding what is to be done and what is not to be done, and providing reasoning for these. The teacher describes the scenario and the rules to the students and the distributes the *problem acknowledgment table* specific to the activity for guidance and evaluation. The students fill out this table, answering basic questions about the activity. The table is designed to make it easier for students to understand the problem by distinguishing what is needed to solve the problem using the given details. Their answers are utilized by the teacher to find out whether the students could understand the problem or not.

Identifying strategies consists of selecting and implementing an algorithm and monitoring what happens in the meantime, taking notes, and paying attention to what would happen in the next step. The teacher distributes and strategy identification table prepared specifically for the activity. The students are asked to write their own strategy in this table. In the case of group work, students must fill in the table as a group. Variables related to the problem are in this table, and students are required to write the values that can be taken by these variables in different situations.

Reviewing strategies includes checking that each part of the algorithm runs, understanding what the parts are, why they are divided into those parts, and how those parts work during the problem-solving process. This requires the ability to read algorithms, which means understanding a complex algorithm built by someone else using the programming language. The ability to notice and explain the objectives of the parts that make up the program and their relationships to each other are important skills at this step. On the board, the teacher writes the different results reached by students. The strategies are discussed, and the most appropriate strategies are identified as a class.

Creating the algorithm includes abstraction and analogy skills. Abstraction refers to omitting unnecessary and insignificant information from the problem to explain it correctly and thus reduce the complexity. Analogy means matching a new concept, event or object with a familiar one. Each group (or person) is asked to write the algorithm for their strategy on a piece of paper. The teacher calls for volunteer students to animate the activity in front of the class. The student(s) read(s) their algorithm. Identified strategies are animated in class. The activities are performed without computer up to this step, while a computer is used in the following steps. Based on my experience, students benefit from guiding questions such as:

- What information is given in the problem?
- What is the desired target?
- What is expected to happen when the solution is applied? Which operations will be applied in what order?
- What kind of data structures, variables, and constants should be used?
- How will the program be divided into smaller subprograms? Is it possible to divide the program into subprograms to facilitate problem-solving? If appropriate, what will the relationship between subprograms be like? Can it be divided into subprograms in relation with input, output, and operation types?

Running the Algorithm This step is about performing or encoding an algorithm in any programming environment. For this reason, it is necessary to learn the programming environment and to use the programming language attributed to that environment. Students need to understand the general features of a programming environment for running/operating programs and how programs are encoded. Based on my experience of 21 years in programming along with 14 years in programming education, I can say that coding an algorithm requires a high level of thinking skills and thus is not much enjoyed by students. Because coding involves understanding and appropriately using the terms that express this algorithm beyond understanding the algorithm. Thus, coding requires thinking about the problem holistically and understanding the role of each part in the whole. Each code block must be evaluated in relation to the function of the preceding and subsequent commands. The programming environment helps with debugging; however, we need to rely not only on the programming environment but also on our analytical ability, which is required to correct the error. The teacher presents the finished version of the application that is supposed to be undertaken by the students in Scratch. Then, the teacher gives students materials in Scratch (character drawings, objects, etc.) and they try to do the coding in Scratch. The teacher shows students the correct coding. In the case of using more than one application, the process is repeated.

Editing and modifying the algorithm requires higher skills than writing a new algorithm because it is necessary to understand the way the programmer was thinking and writing. The teacher shows the students an application similar to an incorrect code structure and explains what the program should be like when in operation. The teacher then gives the Scratch application with incorrect code structure to the students. The students study the algorithm to detect the error and evaluate it. They change and rearrange the code blocks. They check whether the code blocks are working. The teacher shows the correct coding structure by adjusting it according to the directions of the students.

Designing complex algorithms involves dividing the algorithm into sub-targets and designing with the help of systematic planning if the problem cannot be solved in one step, which is common in modern projects. At this stage, the teacher only provides the necessary directions and explanations in class. The teacher identifies students' tasks and responsibilities. Students design a new algorithm and code it in a programming language.

Developing Initial Activities

Having identified topics for lesson plans and steps for teaching algorithmic thinking, we sought to plan both computer-aided and non-computer activities. Classical programming activities usually involve writing code for computerization of mathematical examples (factorial finding, prime number finding, Fibonacci sequence, equation solution), meaning the student needs mathematics knowledge first. This approach—used often with adults—is difficult for younger learners. In our review of existing curricula, we noted that activities included identifying bugs in programs, using block coding like Scratch (including setup, sound, pen and color control, detection, control block, events, data and operators), and programming, with a few including non-computer programming activities. Most included introductory instruction and application, such as problem-based learning or game design. We noted that analogical activities were common for younger learners.

Thus, we decided to plan activities around analogies. We selected this type of activity to ensure students would relate the concepts to their daily lives. When learning abstract subjects such as programming and algorithms, analogies can enhance motivation by making it easier for students to access the topic. We developed non-computer and computer-aided activities, thinking that the former would enable students to express themselves through games in class and to be exposed to other views and notice different strategies.

We developed the activities and scenarios in a distributed manner (Table 1). Each team member drafted activities and scenarios following literature reviews and their own ideas. We discussed the draft activities and scenarios and shaped them collaboratively at meetings (Table 2). During the meetings at that stage, we debated how and when to use computer-aided and non-computer activities in the classroom. We also considered how to tailor lesson plans to fit the class duration and students' cognitive levels. In Turkey, a standard lesson is 40 minutes in the sixth-grade level. We knew that schools differed in achievement levels, and therefore we sought to prepare lessons suitable to a range of cognitive levels. We therefore reviewed existing sixth-grade lesson plans used in schools with different achievement levels. These helped us adjust both duration and cognitive level of our lesson plans.

Review and Refinement Process

Internal Design Team Refinement

At weekly meetings, each designer presented the lesson plan they had prepared and the whole team evaluated it. We provided feedback using the criteria we had previously determined (i.e., time, size of classes, cognitive level, and physical borders of classes). The presenter defended their design by answering the questions asked. In this way, we made a collective decision on what needed to be done in the design. We

Table 2 Activities and scenarios by lesson

Activity	Scenario
Algorithm lesson	
Help the shepherd	There is a shepherd, wolf, weed, and sheep all together. They want to cross the river by boat. Can you help the shepherd?
I find the cities	Ayşe is a survey engineer. She is supposed to place cities A, B, C, D, and E around a circular lake. The distances between these cities are given.
Weaver birds	There are two weaver birds, one male and the other female bird. They want to build three nests. The birds can spend as much time as they want for each nest. How soon can the birds build all three nests?
Let's recognize the programming environment lesson	
Leisure time activity	Following a brief introduction, students use scratch. The teacher checks students' ability to drag the code block to the code area; add a character to the screen; change the screen background; change the character costume; animate the character; and prepare a basic activity.
Variables lesson	
Buying fruit	Ali's mother asks him to buy the maximum amount of fruit he can for 50 TL. There are apples, bananas, and oranges.
I choose fruit game	The teacher writes names of fruit on paper and asks students to come to the front and represent the fruit. Another student reads the algorithm they wrote and calls the students representing the fruit to act out their strategy. For example, they pick five people representing 5 kg of apples, two students for 2 kg of bananas, and another student for 1 kg of oranges. Finally, they explain Ali's money, the fruit basket, and kg values represent the variables; the price of 1 kg of fruit is an example of the constant value, and fruit names represent string values, while prices and weights are integer data.
My fruit basket scratch app	First, students calculate the fixed price for three kinds of fruit with an externally inputted kg value. They introduce the variable of money and calculate how many apples, bananas, and oranges can be bought. A new variable named fruit basket is created, and the kg values for all the fruit in the basket are summed up. Finally, the total amount (kg) of fruit bought is shown on the screen.
Conditions lesson	
Map activity	Ali and Ayşe live in Gebze, but they want to go to their grandmother by bus on summer vacation. They want to say goodbye to their friends before they depart. They make an arrangement to meet their friends at Sultanahmet Square. Can you show them the shortest way to Sultanahmet and then the bus station?
Colorful steps game	For in-class animation of the best strategy selected, the teacher places cartons labeled with route stops on the classroom floor. One student starts at the first stop on the route and another gives a command. To simulate *if/if not* structures, if the command is right, the student walking on the stops goes back to their desk, and the student who was giving commands takes a turn to follow the stops.
Loops lesson	
Ali playing a game	Ali would like to play a car racing game with yellow, green, red, and blue cars and four types of road (asphalt, soil, sand, and gravel). Racing starts on the soil road. To win the game, Ali has to select the cars completing ten tours as quickly as possible. Can you help Ali do this?

(continued)

Table 2 (continued)

Activity	Scenario
Auto racing in-class animation	Four students hold up the four road types and one student acts as the car. The teacher gives the blue, green, red, and yellow cartons to that student, who then demonstrates the color required by their strategy from one point to another, and another, and so forth, until they complete one tour. Students learn to associate the tour with the concept of loop.
My fuel amount	Students are asked to enter a quantity of fuel for the car in a previously created scratch game. The amount of fuel is decreased by one level. The students are told to keep the car moving on the screen until they run out of fuel.
Auto racing scratch app	The students apply strategies from previous scratch activities to ensure the car completes ten tours and switches colors.

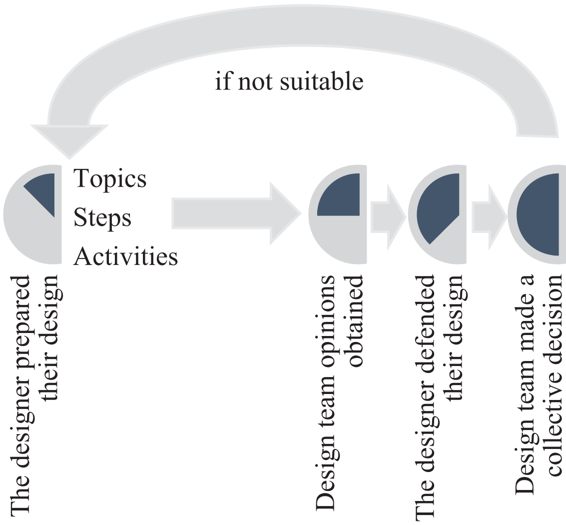

Fig. 2 Our preparation and revision process

re-evaluated the design at the following week's meeting and repeated this process until we reached consensus (Fig. 2).

For example, in reviewing an activity for *loops*, Dilara and I raised a criticism regarding the shape of the map saying, "The racetrack is too small, so the movement of the vehicle is stuck in a narrow area. It may be difficult for the student to program in this case." Ali said, "There seems to be no variety of roads on the racetrack." As a result, Güven changed the racetrack into a square in order to depict different types of roads more easily and to build a wider area. At the next meeting, when Güven presented the amended design, Ali, Dilara, and Ayşegül argued it seemed too difficult for the students to code. Güven replied that the latter design did not contain many differences in coding. Therefore, we re-evaluated the coding from the first design. As a design group, when we realized that the codes were difficult for the students from the outset, we decided to make the coding easier. We recommended

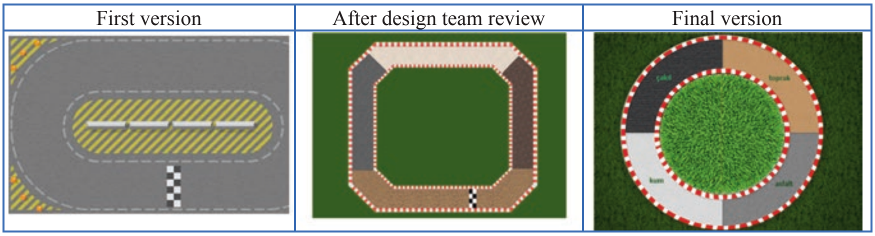

Fig. 3 Modifications to the racetrack map

programming a circular track with an angle change of only 1 unit each time for convenience. The following week, we agreed and approved the revisions (Fig. 3).

We faced a few disagreements along the way. Kürşat, Ali, and Güven argued that instructions and tasks needed to be defined clearly in advance so that classroom implementation can go smoothly and with fidelity across classes. However, Dilara and Ayşegül argued that teachers and students should play it by ear and have the flexibility to make preparations and consider all the drawbacks that may arise in advance. Although we found both views to have value, we decided to clearly define the implementation instructions and teacher/student tasks because lesson plans are to be applied in crowded classes within a limited period of time and we wanted common learning to take place.

Teacher Feedback and Revision

After we revised the lesson plans based on our own expert review, we interviewed ten *information technology and software* teachers (five female, 6–14 years' experience programming, 1–4 years' experience teaching programming) about the lesson plans. For 6 weeks, we interviewed the teachers and made revisions until they approved the lesson plans, about three times each. We made the revisions related to variables, conditions, and loops. We held semi-structured interviews. I arranged the interviews with the teachers, some of whom were my former students and others were teachers I had met during outreach. This allowed me to use my personal experience to select teachers whom I believed would be capable of providing professional evaluation of our designs. Each designer presented their design in about 1 hour and received teachers' views. The same teachers watched all the presentations and shared their feedback. The designers audio-recorded the interviews, which we later listened to collectively and identified concerns to be addressed. Revisions made based on teacher feedback were checked at the next meeting (Table 3).

Variables We updated the time allocated for the algorithm operation step to 40 minutes since the teachers stated that it would be more efficient for students to take an hour lesson for the Scratch application regarding the concept of variables. We likewise updated the time allocated for editing and modifying the algorithm as

Table 3 Primary revisions for each lesson plan. Following expert review, we detailed student and teacher activities for many lessons

Activity	After expert review	After teacher review	After implementation
Algorithm lesson			
Help the shepherd		Increased duration from 10 to 40 minutes	Visual replaced with picture showing both banks. Directions added
I find the cities Weaver birds	Numbers added to map corresponding to new data table	Increased duration from 15 to 40 minutes	Removed from lesson plan Weaver birds scenario created
Let's recognize scratch lesson			
Leisure time activity	Sample checklist added. A visual called *Routing steps* added	Scratch program setup omitted	Web address for sample projects changed. Criterion for adding sound omitted
Conditions lesson			
Map	To fit secondary level, map simplified three times enriched with visuals, number of stops reduced		
Maze map game; scratch app	Checkered background added for character to move step by step across the squares	Background with a smaller number of larger squares. Motion commands prepared in advance to reduce coding and encourage use of *if conditional*. Calculation tasks omitted to make game less complex	Game screen simplified. The students were given the code blocks that they could write a code inside that block only
Loops lesson			
Ali playing a game	Chart of car speeds in different tracks omitted, except for table of seconds. New operation added for the time lost by cars while passing from one track to another	The operation was omitted for the time lost by cars while passing from one track to another	The operation was added back for the time lost by cars while passing from one track to another
My fuel amount and auto racing scratch apps	Racing track shape made circular. Screens added to introduce app and index the cars	Implementation codes simplified. Screens for introduction and indexing the cars were omitted	

20 minutes. The teachers suggested giving a longer time for students to edit codes and find the error. They stated that some students could be quick enough to complete the activity in 10 minutes but that 20 minutes would be more appropriate for the entire class. We updated the time allocated for the entire lesson plan as 160 minutes thinking that the time given for the steps should be more flexible.

Conditions In the Scratch app *Map*, we prepared motion commands in advance so the students' encoding task could be moderated. We edited it to encourage using *if* conditionals only. Our aim here was to encourage students to write the commands related to the topics only. We updated the time allocated for the lesson plan as 160 minutes for efficient performance of computer-aided and non-computer steps and taking plenty of time. To precede the app *Map*, we inserted a simpler application called "question-answer" because the teachers pointed out that the map application was a bit too difficult as a first example, so it seemed sensible to introduce a simpler application first.

Loops In the problem status, we omitted the loss of time by cars while passing from one track to another. The teachers stated that it might be above students' cognitive levels. Thus, we decided to test the application after removing the feature. We edited the Scratch application (amount of fuel) codes resulting in simpler codes. In the first draft, there was "nested loop," positioning, and "if…then" code blocks. After the teachers' opinions, we omitted these codes and prepared the code structure using the "if …. then, forever" code block only. We removed the introduction screen and insertion and withdrawal of the cars from the sequence from the application. It was stated by teachers that it could be too heavy for students, especially as a first example. Although the introduction and addition to the list (sequence) were readily available, it was noted that it would be very difficult to use the list (sequence) in rotation of the cars (Fig. 4).

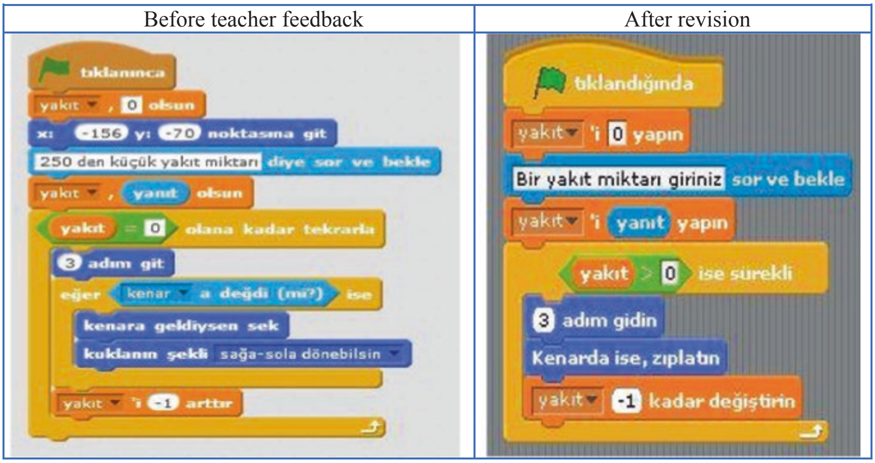

Fig. 4 Modifications to *loops*

Pilot Testing of Lesson Plans and Further Revision

After we completed the design process, we decided to pilot test all the lesson plans in a real classroom environment. Our intention was to find out whether the students could do the activities and whether the activities were a good fit for the class time and overcrowded classrooms.

The pilot test was carried out in 9 weeks with 40 sixth-grade students (19 males, 21 females). The teacher had previously participated in our interview process and had shown great interest in the design process from start to end. We chose the school for two main reasons. First, the teacher is experienced in teaching and, specifically, teaching programming to junior high school students. Second, the school is equipped with the necessary laboratory facilities to perform computer applications.

Only designer Güven attended the pilot test, as having the entire team attend would have been too crowded and distracting. Güven met weekly with the teacher prior to pilot testing to ensure she understood the lesson plans. The fact that she was willing to implement our draft lesson plans, activities, and teaching methods meant extra workload. Though this was not really difficult, it took some time. Had she been unwilling to do this, the activities might not have gone as well as they did. Likewise, had the teacher had not understood the activity, the motivation of the students could have decreased during the lesson.

Güven also took notes during implementation and met with the teacher after each class. Güven also interviewed students about the activities and the course of the lesson. Later, we evaluated the data and used it to improve and adjust the design accordingly. Overall, the students had fun with the activities. They reported that they enjoyed the activities and the classes were more efficient as a result. When the students encountered problems, they had more fun even though it was challenging.

On the other hand, some challenges were noted during implementation. First of all, the computers and the Internet infrastructure were not adequate. As soon as the students started practicing on Scratch simultaneously, the program started slowing down. The speed was slow while dragging and dropping code blocks, which negatively affected students' work.

Another shortcoming was the crowded classroom, which brought about difficulties because the teacher could hardly reach some students. Her dedicated efforts seemed to leave a positive impact on students, increasing their motivation and providing continuity. As in the case of any innovation in educational contexts, the teacher was the key to implementation of our design. Our teacher made significant contributions, from agreeing to implement draft lesson plans to ensuring the lessons went as intended, and thus helped us reflect on the design in a sound way.

After implementing, the most notable modification made by the design group was related to the cognitive level of students. For example, the group removed the *I find the cities* activity because it was difficult for the students and it was not suitable for the length of the class. To increase the suitability of the activities for the cognitive levels of students and to ensure implementation in the classroom environment, we modified the way in which the activities were implemented; in the games *I* *choose fruit* and *Colorful Steps* games, we simplified the materials to facilitate implementation in overcrowded classes.

Concluding Thoughts

We described the steps of a design for teaching programming and reported our experiences in this process. We determined the topics for programming, set up the steps for teaching algorithmic thinking, prepared and implemented the activities, and drew a general design framework for programming instruction, taking into account the cognitive levels of secondary school students, applicability in class in terms of physical facilities and crowded groups, and lesson duration. The finalized lesson plans comprise 9 weeks of lessons, with two 40-minute class periods per week. For all the activities, the teacher asks questions related to the concept from the previous lesson in the review section to refresh their memory, asks students questions from daily life related to the topic, and explains the relationship between the materials for motivation. In the lesson plans, we defined tasks for teachers and students and provided the necessary directions. In addition, we designed materials that can be used by teachers, who may make modifications to activities as required by cognitive levels of students, time, and physical facilities.

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Supports for Digital Science Games: Visualizing and Mapping Analogies

Wendy Martin, Megan Silander, Katherine McMillan Culp, Cornelia Brunner, and John Parris

Integrating Digital Games into Instruction to Dislodge Science Misconceptions

More than 10 years ago, our team—consisting of instructional designers, game developers, science education experts, and researchers—began work on a set of four digital science games and instructional materials for middle-school educators. Collectively called *Possible Worlds*, with funding from the US Department of Education's Institute of Education Sciences (Award # R305C080022), and later the National Science Foundation (DRL-1252382), we were motivated by the desire to provide teachers with engaging and easy-to-use resources to help students overcome persistent science misconceptions and gain a deeper understanding of abstract science concepts that can be difficult to visualize. For example, students often struggle to understand the concept that a solid material like plant matter can be made from a liquid (water) and a gas (carbon dioxide). Students (and adults) who cannot imagine processes that take place at the molecular level are likely to hold the misconception that plants "eat" a solid material such as soil and transform that into plant matter, another solid material.

We believed that digital games were particularly well-suited for helping students build an implicit understanding of the invisible forces and interactions underlying difficult science concepts because (1) they encourage players to imagine different realities as they enter into a world of novel rules and situations and (2) they motivate players to gain mastery of those rules and persist through frustration as they solve

W. Martin (✉) · M. Silander · J. Parris
Education Development Center, New York, NY, USA
e-mail: wmartin@edc.org

K. M. Culp · C. Brunner
New York Hall of Science, Corona, NY, USA

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game challenges (Gee, 2007). We planned to leverage these affordances to create fanciful environments and experiences, analogous to abstract scientific phenomena, that would challenge students' assumptions and present new rules that they would need to master to succeed in the gameworld.

We also wanted to make games that were scalable, that teachers and students could use easily in their classrooms, despite limited time and technical resources. Therefore, we felt that games should focus specifically on misconceptions that normal instruction and curricula tend not to dispel. To help integrate the games into classroom teaching, we intended to design instructional materials that teachers could use to highlight the analogies between the game visualizations and the concepts the games target. We hoped that our games would create compelling, shared experiences that teachers could draw upon using our instructional materials to help middle-school students overcome the misconceptions that prevent them from comprehending abstract concepts that are essential for higher level science.

Initial Rationale for the Design of the Digital Games and Instructional Materials

The initial rationale for our approach to *Possible Worlds* rested on three elements that we felt would be critical to ensure students would learn from using the games: that the games would need to engage students, address a persistent educational challenge (science misconceptions), and be easily scalable and therefore adaptable for use in a variety of classroom contexts that likely vary in access to technology, curriculum requirements, student achievement levels, and teacher expertise and comfort with technology. To meet these needs, we felt we needed to create materials that were engaging, simple, flexible, and targeted to the specific problem. Therefore, we planned to design easy-to-use digital games that provided students with playful visualizations representing abstract concepts and phenomena and instructional materials that enabled teachers to draw explicit analogies between the game visualizations and the science concepts. We hoped that the game experience would be compelling enough to counter the intuitive pull of misconceptions as well as the abstract nature of the phenomena. We also wanted to create materials that could be used by teachers with no support from us to ensure use of the products beyond our grant period.

At the time that we began designing the *Possible Worlds* games and materials, there was great enthusiasm in the educational community about drawing on what commercial game designers do to create experiences that are motivating (Gee, 2007; Squire, 2006). Many of the game-based learning initiatives that were being discussed in the research literature were designed to be used in place of existing curricular units (notably *River City* [Ketelhut, 2007] and *Quest: Atlantis* [Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007]). While we agreed that digital games had the potential to create exciting and memorable learning experiences for students, we also suspected that most schools did not have the capacity to replace full curricular units with digital games. Our plan in 2008 was to build on the lessons learned from those initiatives and create a series of four relatively simple games based on familiar game mechanics (such as puzzle, platformer, and first-person shooter) that would be easy for students to play and that could be integrated into teachers' existing curricula to help them teach only those concepts that students tend to find particularly challenging. We also planned to develop instructional materials that connected the games to those science concepts. The choice to include simple, short games was grounded in our understanding of the challenges teachers face when attempting to integrate complicated digital interventions into teaching and learning—that teachers lack time and technical expertise, that they need help understanding *how* to incorporate technology into instruction, that their curriculum constrains their choices, and that students do not have sufficient access to technology (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Culp, Honey, & Mandinach, 2005; Edelson, Gordin, & Pea, 1999; Honey, Culp, & Carrigg, 2000). We planned to design the four games and associated materials so that teachers could select those that were aligned with the existing curricular units that they taught. The games were not intended to replace teachers' curricula, but to supplement it. We believed this was more consistent with how teachers might actually use digital games, increasing the likelihood that the games would be accessible and feasible for teachers to implement.

Our original vision was to make games for the Nintendo DS, which, at the time, had a very large install base among middle-school-aged students. This project began prior to the release of the iPad and before it was commonplace for middle-school students to have smartphones. The Nintendo DS provided a familiar portable platform for digital games that would be easy for students to play at home. Because our goal was to work within the constraints of typical schools, we did not want to design games that required a great deal of instructional time or developer involvement to implement. Rather, we wanted to have students play the games as homework and use precious instructional time for teachers to make connections between gameplay and targeted science concepts using the instructional materials we would design.

We decided to design visualizations in the digital games that were analogous to abstract science concepts because a great deal of research has demonstrated that drawing analogies between familiar concepts and novel ones is an effective method for building a solid and lasting understanding of those novel concepts (Gentner, 1983; Gentner, Loewenstein, & Thompson, 2003; Gentner & Smith, 2012). Our design challenge was to create game-based visualizations that were age- and curriculum-appropriate analogies of the concepts at the core of our target misconceptions and to integrate them into games that were compelling to play. Unlike simulations, the visualizations would not be illustrations of the concepts—such as watering a plant to make it grow. Rather, the games would use familiar game mechanics designed to give the player a visceral experience (e.g., "shooting" molecules apart with sunlight and putting the component parts of the molecule together like a puzzle to form glucose) that acts as an analogical source to the target concept—for example, the molecular process of photosynthesis.

From the start of the design process, we had in mind that teachers would need to be supported with materials that would guide them in integrating the student's digital gameplay experiences into regular classroom instruction, as well as limited professional development in the use of the games and materials. Therefore, in parallel with the digital game design, we developed a suite of materials that would enable teachers to connect student gameplay with the conceptual learning that we aimed to help students achieve.

The Design Process

The first priority for this project was to build a team with the expertise necessary to develop four different games that would each have visually realized worlds and characters that would inhabit them but that would also be educationally sound. First, we had an instructional designer with the expertise of a developmental psychologist who could create learning experiences aligned with instructional goals. Our game development partner, 1st Playable, brought years of commercial experience with licensed properties, including creating Nintendo DS games for Disney and Cartoon Network. They had expertise in art direction, character and graphic design, as well as designing mechanics and scoring systems that would make the games fun for middle-school students. Our team had science education experts to ensure the games were scientifically sound, to provide expertise about what middle-school science teachers typically teach, and to help design the instructional materials. We also had a production manager to coordinate the various aspects of the development process and researchers to test iterations of the paper mock-ups, digital games, and instructional materials with students and teachers.

The design and development process for each of the four games followed a similar pattern, although with each successive game the process became more efficient and integrated. First, the full team met with our advisory board, which included game designers as well as experts in science, developmental psychology, and educational media, to select the scientific misconception the game would target. We based our selections on a number of criteria. First, it had to be a persistent misconception identified in the research literature (e.g., we referenced Chi, 2008; Driver, Squires, Rushworth, & Wood-Robinson, 1994; Ozay & Oztas, 2003; Smith III, diSessa, & Roschelle, 1994). Second, the misconception had to be associated with topics addressed in typical middle-school science standards. This project predated the Next Generation Science Standards, so we used standards from New York and Massachusetts, where the research took place. Third, the team needed to be able to imagine a way to translate the abstract concept at the heart of the misconception into entertaining visuals and game mechanics. Fourth, there had to be potential for an engaging narrative into which the visuals and mechanics could be integrated.

The first game was based on the misconception described above—the belief that plants eat soil. The second game focused on misconceptions related to heredity—the idea that “dominant” genes are inherently better or more powerful than recessive genes and that inheritance of traits is not random or independent from what has happened before. The third game addressed the misconception that electricity is matter, and the fourth game focused on heat transfer and targeted the misconception that cold can be transferred just as heat is transferred.

After choosing each misconception to target, our science experts examined existing middle-school science curricula and standards that included the concepts related to the misconception and talked to science teachers to understand how they taught the concepts, what other digital and non-digital games or simulations they used, and how they could imagine integrating games into their instruction. Using this information, our instructional designer mocked up simple digital or paper-based games to serve as analogous visualizations of the concepts that students needed to understand in order to overcome the misconception. The researchers tested these mock-ups with students in after-school programs and provided rapid feedback about students' responses to the games to the instructional designer, who made revisions. The instructional designer then worked with the game developers to design the learning experiences and interactions that should be included in the prototype DS games. Based on these conversations, the developers created a game-design document to guide the production of the alpha, beta, and final versions of the games.

During the prototyping phase, the instructional designer, game developers, and science education expert met as a group weekly to review each iteration of the prototype and discussed the scientific content, instructional design, gameplay, and visual design. The researchers tested the prototypes with students. The production manager shared the user-testing feedback with the design team, who made changes in response. The designs typically required many iterations, especially with the first two games. With each new iteration the game developers produced, the instructional designer needed to ensure that the game mechanics, graphics, and larger game challenges did not undermine or contradict the analogy, and the science education expert needed to ensure that the game did not introduce scientifically inaccurate information or new misconceptions. At the same time, however, the team understood that the game developers had to have creative license to design games that were as entertaining as possible. The science education expert and the instructional designer also created or found classroom activities and materials that connected the digital game visualizations with the target science concepts. This collaborative process evolved over time, as the team members grew to trust each other and appreciate the various forms of expertise everyone brought to the enterprise.

The Evolution of the *Possible Worlds* Digital Game Design

One of the key components of the original project idea was that, in order to engage students in the game, we wanted to create games that did not look or feel like educational games but that seemed like real DS games that adolescents would want to play. In the beginning, our design team believed that meant that the larger game narrative goals did not have to be related to the core analogy we wanted players to learn. Rather, we planned to create analogous mini-games within the larger narrative that players would have to engage with multiple times to achieve the game goals. This repetition of the analogous mini-game would lead players to develop a deep, implicit understanding of that activity, which teachers could reference during instruction. Only if the game felt like a fun "real game" would players stay interested enough to be exposed to the analogous mini-game multiple times. However, with each successive game, we came to realize more and more that this bifurcation of fun narrative/analogous mini-game was not necessary. By the fourth game, the analogy had been completely integrated into the game narrative and goals.

During the process of developing the first game, *The Ruby Realm*, which addressed the misconception that plants eat soil and turn it into plant matter, prototyping began with testing a number of puzzle-like mini-games that attempted to provide a playful experience of interacting with the transformation of energy during photosynthesis. The main learning goal of the mini-games was to challenge misconceptions about the nature of photosynthesis by having students engage with mechanics, gameplay, and images that help them enact the process of using light energy to break apart carbon dioxide and water molecules and reconfigure them into a glucose molecule. The game developers tried out a number of different ways to visualize the atoms and molecules and different ways to break them apart and regroup them, such as using the DS stylus to separate the atoms from the molecules and then circle groups of them to form new molecules, as well as "shooting" molecules of water and carbon dioxide apart and completing a puzzle by dragging the resultant atoms to form the new molecule of glucose (Figs. 1 and 2). When we tested these two versions, the first-person shooter mechanic proved more popular with a range of students, perhaps because it is more familiar than the circling mechanic.

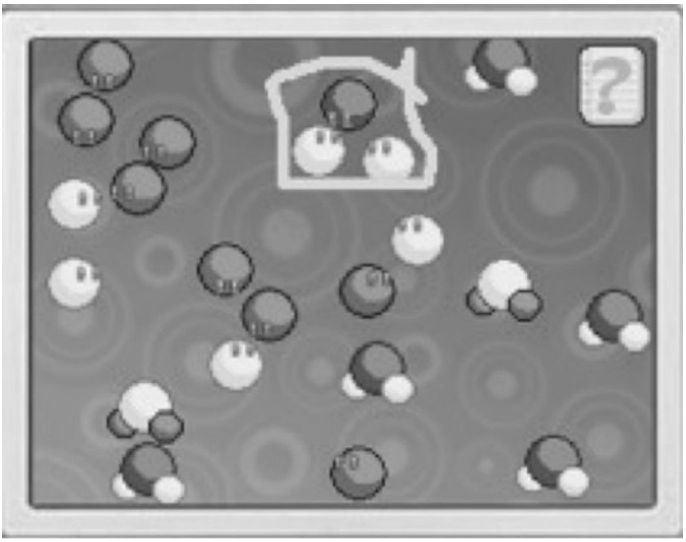

Fig. 1 Early iteration showing a circling mechanic to combine particles

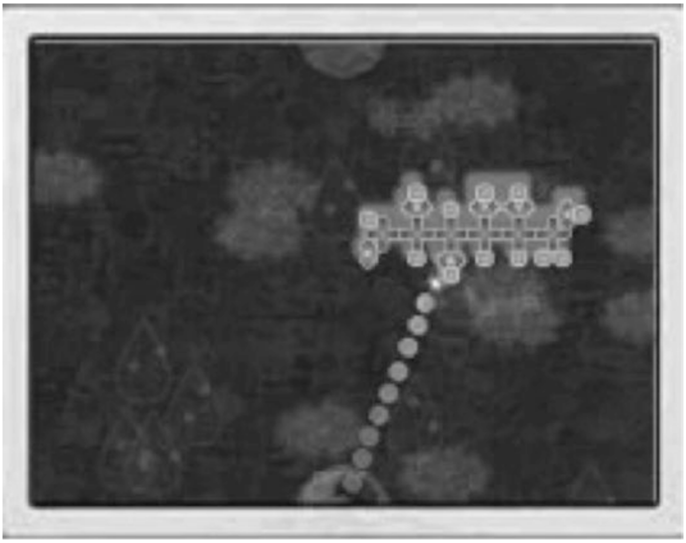

Fig. 2 Later iteration showing a shooting mechanic that directs energy toward particles

After the team agreed upon the design of the mini-game that served as the visual analogy to the concept, we conceived of a narrative surround. The first iteration of the photosynthesis game centered on the task of keeping a plant healthy. The game took advantage of the dual screen design of the DS; in an effort to aid a plant in its photosynthesis process, players shot apart and built molecules on the lower screen, while the resulting effects on a plant took place on the upper screen (Fig. 3). Although the team thought that the premise of caring for a plant would be engaging for our middle-school audience, we encountered two challenges. First our science experts objected that the game might give students the impression that plants controlled their own photosynthesis, creating a new misconception that plants have agency over this process. The second challenge with the prototype was engagement. When we tested this iteration with students, they enjoyed the action of shooting and building the molecules but were not very engaged by the "keeping a plant healthy" narrative.

At this point, we realized that our team lacked a crucial component—we did not have a storyteller who could make the game narratives compelling enough to keep students engaged. We were fortunate to find a writer with years of experience in developing children's media who could create interesting stories. Adding this person to the team transformed the photosynthesis game. Instead of keeping a plant healthy, the narrative centered on a group of kids who send a robot into a cave full of vampires to save their lost friends. At the time, vampires were popular in films and fiction aimed at our target middle-school-aged audience. In the game, titled *The Ruby Realm,* players control a robot called BioBot Bob, who relies on a process analogous to photosynthesis to produce the energy he needs to travel through a cave (Figs. 4 and 5). When players navigate Bob to a light shaft in the cave, they are able

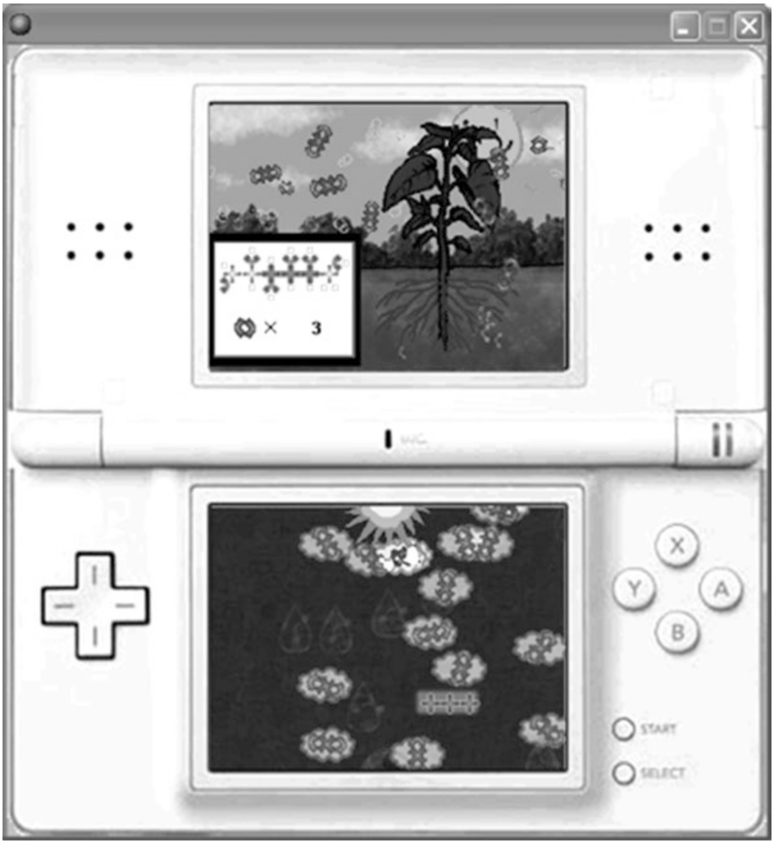

Fig. 3 Early DS game

to play the mini-game in which they break apart clouds (carbon dioxide) and droplets (water) into oxygen, hydrogen, and carbon atoms and then construct glucose (to give Bob energy), methanol (to fuel his jet pack), and tear gas (to ward off vampires). We hoped that having a robot engaged in an artificial form of photosynthesis would help students understand the process of breaking apart and putting together molecules, without having them believe that plants do this intentionally. When we tested this game with students, they were far more interested in playing through the levels than they were with the “keeping a plant healthy” game, which meant that they experienced the mini-game multiple times. In keeping with our initial belief, the mini-game was a task that students had to complete to achieve the game goals, but was not a main point in the narrative, which was to get through the cave to find friends and collect treasure.

For the second game, we sought to address the misconception that dominant traits are “stronger” or more desirable just because they are more likely to be expressed and the misconception that individual instances of a trait being expressed

Fig. 4 *The Ruby Realm* title screen

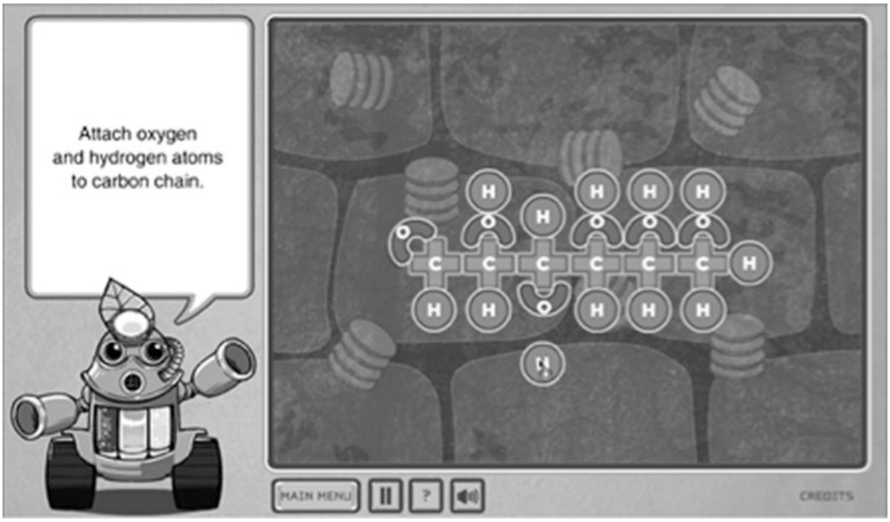

Fig. 5 BioBot replicator mini-game

are dependent on what came before (i.e., not random) just because there are overall patterns in the emergence of traits across a population over time. Therefore, we wanted to design a game in which players need to develop an understanding of randomness and dominance to help them achieve game goals. The instructional designer originally had the idea of using a pachinko machine/lottery mini-game to convey the idea of randomness and a rock-paper-scissors mini-game to convey the idea that different traits can be beneficial under different conditions.

Our writer and game developers took these ideas for analogous mini-games and extended them to the broader narrative and game goals, creating *RoboRiot*, a game about robots that become infected with a virus. The player must create a team of robots to disable infected robots so that the anti-virus software can be installed. There are a variety of environments in this world, and the robots have different basic "traits," such as fire, ice, water, and electricity. Each robot has two alleles—fire and water, for example—and the one that is functional or "expressed" determines its job. For example, a water robot is useful as a firefighter, a fire robot makes a good cook. Each type of robot is powerful against some robots and weaker in relation to others. The trick to winning the game is to deploy the robots so that they can "fix" the infected ones; this means that the robot sent to fix a specific infected robot has to be more powerful so that it can temporarily capture and reprogram it. To create a specific type of robot, the player can send two robots to a recycling machine and create a new one that has one allele from each of the original pair (Fig. 6). Because each allele is randomly selected, there is no way of predicting which two of the four alleles it will get, just as alleles from each parent are randomly selected in reproduction. We used robots again rather than biological creatures in this game to simplify heredity to something based on a single trait and to avoid the issue of biological reproduction. By using robots, which do not mate, have no life span, and exist to

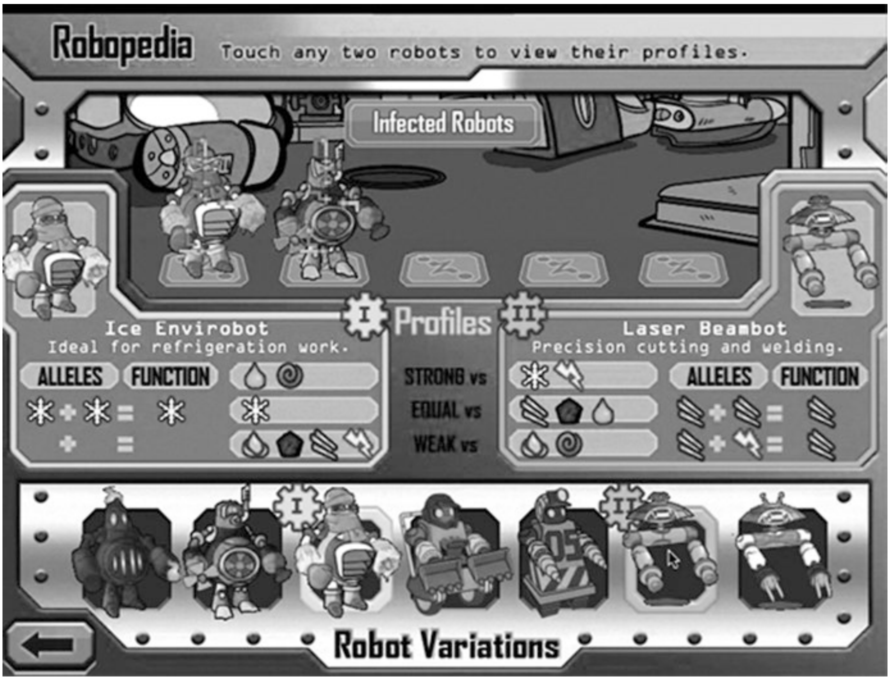

Fig. 6 *RoboRiot* "Robopedia" showing robot attributes

fulfill a single function, we could maintain our focus on the key ideas of random combinations and relative dominance.

The design team stayed with the original idea of an analogous mini-game that visualizes the concept of randomness (the recycling machine) but also saw the narrative potential of a rock-paper-scissors scenario, where different kinds of traits are valuable in different environments and in battle against other robots. Mastering the concept of relative dominance is important for developing a successful strategy for winning the whole game, not only a mini-game that a player needs to complete to get back to the action.

Our third game took on the misconception that electricity is matter rather than energy, a misconception often perpetuated by the common analogy of electricity flowing through wires like water through a hose. The design team's first idea was to visualize the flow of electrons jumping from positively to negatively charged atoms, but our science expert observed that the middle-school curriculum rarely treats electricity on an atomic level and that this approach might not be very useful in the classroom. Instead, the design team decided to use music as the central analogy for understanding electricity. Like electricity, music is not matter, but it can be a source of energy, at least metaphorically. To create the game *Monster Music*, the design team used an approach similar to that of game two, which combined an analogous mini-game that targeted one aspect of electricity (alignment of positive and negative charges) within a larger game narrative centered around the analogy of music as a source of energy. The premise of the game is that the player has to make musical recordings to reenergize the exhausted citizens of Harmonia, a platformer gameworld. The platformer is a widely used and popular commercial game genre dating back to Donkey Kong in the 1980s. Gameplay involves the player moving an avatar through a side-scrolling landscape of obstacles and surfaces that require jumping, ducking, and sliding to avoid danger and make forward progress. Selecting this genre was in keeping with our strategy of using game design patterns that were easily recognized by our target audience. Using these common platform mechanics, players move throughout this fanciful city looking for studios where they can make the recordings.

To record music, a player needs to complete an alignment puzzle mini-game in which they have to turn monster musicians situated in a grid in different directions so that they are holding hands (Fig. 7). Each monster has an open and closed hand, representing positive and negative charges. Before they are properly aligned, each monster makes a noise, but the sounds are incoherent. When the monsters are aligned, they make recognizable music together. Monsters were chosen as characters mainly on the basis of visual appeal, as many movies and children's media use cartoon monsters to represent strange but non-threatening forces. We thought this would work well for the premise of organizing a group of unruly musicians.

Our final game dealt with the misconception that cold can be transferred just as heat is transferred ("don't leave the refrigerator door open, you'll let out the cold!"). By the time this game was developed, the iPad had replaced the DS as a popular small, portable device, so we decided to develop the game for that platform. The larger touch screen of the iPad made it possible to create a navigation game with

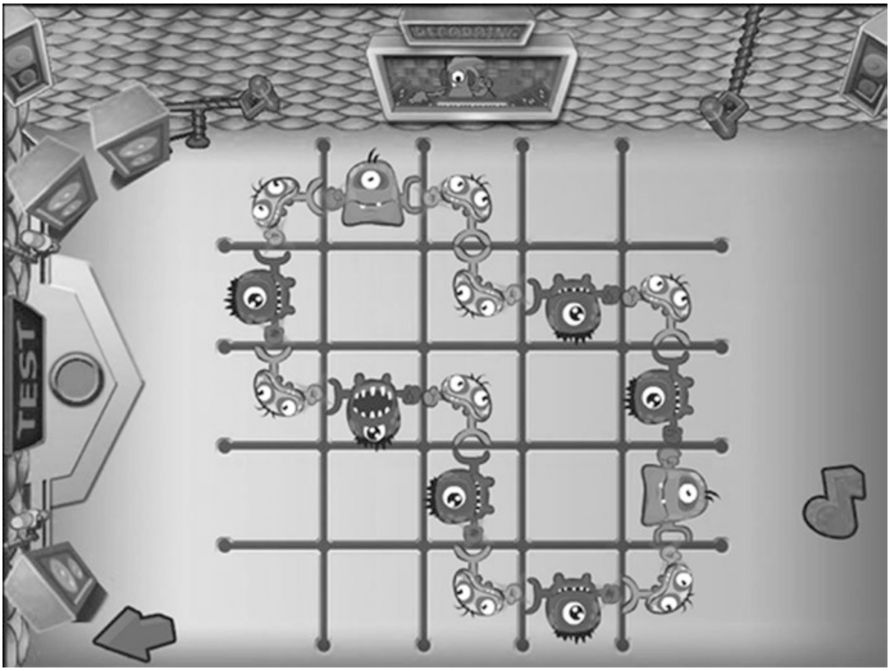

Fig. 7 *Monster Music* alignment puzzle

many different obstacles and places to move on a single screen, which would not have been possible on the smaller Nintendo DS screen. In addition to having more visual real estate to work with for game four, we also abandoned the notion that we needed analogous mini-games to visualize the concepts within the larger game narrative. Instead, with this game, *Galactic Gloop Zoo*, our design team had figured out how to move players through a leveled world that structured repetition of challenges analogous to heat transfer that were embedded in the narrative. We created a game with a story that centered on the need to distribute heat to achieve game goals by moving avatars around the screen and gaining and losing heat via radiation, convection, and conduction (Fig. 8).

The player is a zookeeper who cares for Gloops, blob-like creatures that interact with each other and the zookeeper avatar and have specific abilities that are activated based on their temperatures (which are indicated by color and animation). The player must solve each puzzle-based level by transferring heat energy to different Gloops using the three types of heat transfer. Visual cues such as arrows show that heat moves from a hotter object to a colder one, but not from colder to hotter, until the two objects reach thermal equilibrium, and the player can see the temperature of the avatar increase or decrease depending on what it is touching and for how long. As each level becomes more challenging, the player must make more precise temperature adjustments and strategically change the temperatures of the avatar and Gloops to solve puzzle challenges and achieve game goals. The final objective of

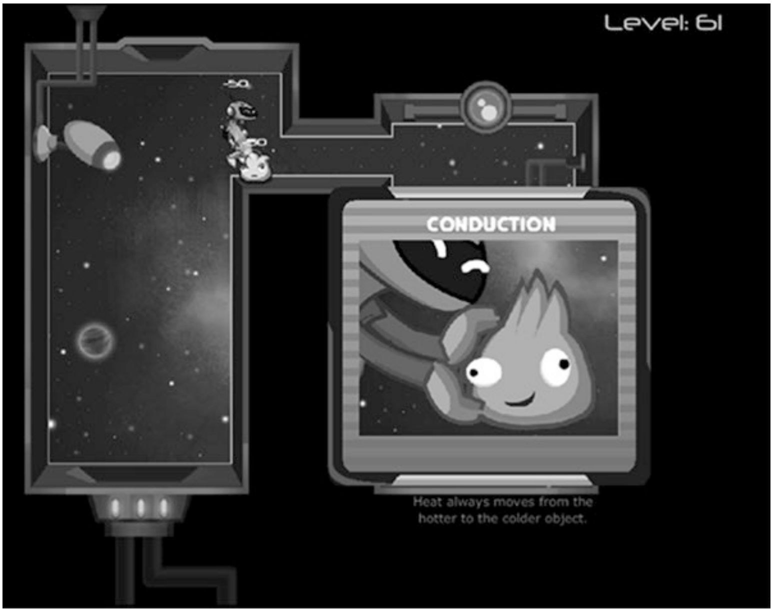

Fig. 8 *Galactic Gloop Zoo* screen showing conduction

each level is to raise or lower the temperature of an incubating egg so that it will hatch a group of baby Glooplings. With Galactic Gloop Zoo, our design team finally realized that we could create a compelling game narrative that itself was analogous to a challenging science concept, with game goals and strategies that required players to build a deeper understanding of that concept, rather than using analogous mini-games as the instructional tools within a more entertaining game narrative.

The Evolution of the Design of the *Possible Worlds* Instructional Materials

As noted above, from the very beginning we intended to create instructional materials to go along with the digital games to help teachers integrate them into their classroom teaching. This design decision was based on our years of experience working with teachers to use technology and our understanding (also reflected in the research literature) that children need scaffolding from adults in order to make sense of and learn from media-based experiences. Therefore, once the design team had a good sense of what each of the digital games was going to be like, the instructional designer and science expert, with input from teachers who participated in the early formative testing, created instructional sequences that included what we called "linking activities" to be used in conjunction with the games. The sequences stipulated the order in which certain components of instruction should occur and suggested ways to connect the game to the concepts. In our original sequences, we had students play the game as homework before receiving instruction about the subject matter. After students played the game, teachers then taught the subject matter the way they normally did. Afterward, they had students do a linking activity we provided that addressed the target concept, but which was a more typical classroom activity that did not involve technology. We incorporated linking activities in order to provide teachers with an experience that they could draw upon to explicitly connect the game analogy to the science concept it was intended to address. For example, in the case of *The Ruby Realm* photosynthesis game, we provided a kinesthetic activity in which students played the role of atoms forming water and carbon dioxide and then breaking up and reforming into glucose and oxygen. This activity allowed students to embody the exact process that they engaged in when they did the mini-game in which they broke apart water and carbon dioxide with light and put the atoms together to make glucose and then to talk about and make sense of the process together through classroom discussion.

We created other teacher support materials to encourage teachers to make references to features of the digital games during instructional time. We gave teachers instructional PowerPoint presentations that provided an overview of the specific target concepts that we addressed in the digital games. We also made it easy for teachers to share and reflect on specific visuals from the games. Because the first three games were designed for the Nintendo DS, a small handheld game console, they could not be projected to view as a class. It was also logistically unrealistic for teachers to have students open up the games and navigate to specific screens to support discussion. To respond to this challenge, we developed a web-based Flash version of the core mini-games that could be easily displayed for whole-class discussion.

We also knew that teachers needed to be very familiar with the specifics of the game in order to have the fluency to integrate them into instruction. This fluency would come from having time to play the game. We addressed this need by building a substantial amount of time (30 minutes) into the professional development for teachers to play the game. Therefore, even if they did not play the game again, we believed they would still be familiar enough with it to see how it related to the science concepts. In addition, the professional development demonstrated how the game images and mechanics were connected to concepts presented in the instructional PowerPoints.

We field-tested all four of our games and the related instructional materials in middle-school classrooms and conducted a randomized controlled trial (RCT) of *The Ruby Realm* (Culp, Martin, Clements, & Presser, 2015). We provided teachers with the games, handheld devices, linking activities, instructional sequences, and professional development. We designed our field test and RCT to collect evidence of whether and how teachers used the game and linking activities to make connections between the game analogies and instructional content and how students responded to the games and activities.

In the field tests and RCT, students reported that the games were fun (although not quite as fun as their favorite commercial games), and most played them to high levels, although up to 22% in the RCT did not play the game as homework; this may reflect a lack of interest in the game or the proportion of students who do not do homework in general. A critical finding was that the games were technically reliable and bug-free. However, we also learned that our instructional materials had not scaffolded discussion of the analogies between the games and science concepts. Teachers rarely referred to the game during instruction, and if they did, it was primarily to ask the students if they liked the game. A third important finding from this study related to student learning. Specifically, the results of the RCT found that student learning was moderated by teacher instructional quality—students who played the games did not learn more compared those who did not play the games unless they were taught by a high-quality teacher. This finding suggested to us that what needed changing was not the games but the instructional surround.

Instructional Material Design Guided by a New Theory: Analogy Mapping

The findings from the RCT and the field tests led us to a second project, funded by the National Science Foundation (DRL-1252382) that focused on the games that addressed topics related to energy transfer (*The Ruby Realm*, *Monster Music*, and *Galactic Gloop Zoo*). We investigated how to design materials and professional development that help teachers make more explicit connections between digital science games and science instruction. Because the *Possible Worlds* games were designed to be analogous to science concepts, we turned to the research literature to identify effective ways to support student learning with analogies. Most relevant was the research of Gentner and colleagues about analogical reasoning (1983, 1997, 2003, 2010, 2012) and Reese (2009) framing gameplay as the source for a series of relational analogies to be mapped to target concepts during instruction. However, our own research showed that creating digital games that were analogous to science concepts did not mean that teachers would reference them during instruction. To help us create better scaffolding materials for teachers, we drew upon the work of Richland, Zur, and Holyoak (2007), which offered practical guidance. Their research identified seven techniques teachers use to map analogies effectively during instruction:

1. Use a familiar source analog to compare to the target analog being taught.
2. Present the source analog visually.
3. Keep the source analog visible to learners during comparison with the target.
4. Use spatial cues to highlight the alignment between corresponding elements of the source and the target.
5. Use hand or arm gestures that signal an intended comparison.
6. Use mental imagery or visualizations.

Building upon this and later work by Richland and colleagues (Richland & Simms, 2015; Vendetti, Matlen, Richland & Bunge, 2015), and the guidance of Richland, who served as an advisor on this project, we redesigned the instructional sequences and created new instructional materials. One important difference in this project was that the games were now more easily accessible for a typical school. During the last year of the original *Possible Worlds* project, we transferred all of the games to Flash and created a website that made all of the games and instructional materials freely available. In addition, based on our finding that 22% of students did not play the game at home, we decided not to ask teachers to use the game as homework as we had done under the prior design, but rather had students play the game in class—before and after instruction in the science content. We provided professional development that focused specifically on the analogy mapping instructional techniques that Richland described. We also created two sets of PowerPoints that used game visuals to anchor student discussions about the games and analogies. The first PowerPoint was used after gameplay and gave students and teachers a chance to debrief about what they did in the game and to cement students' understanding of the game mechanics and goals. The second PowerPoint was used after science instruction and scaffolded analogy mapping between the game visuals and visuals showing the target science concepts. We placed the analogy mapping sequence after instruction based on feedback from Richland and other advisors, who noted that students would need some prior knowledge about the topic in order to make the analogies between the games and the concept of focus. We pilot-tested all of these materials with middle-school science teachers and students in low-income public middle schools and tweaked them over the course of the year based on teacher feedback and observations of classrooms and student interactions with the materials. We then conducted an exploratory comparison study in 11 classrooms in low-income communities. We found that the training and materials we provided helped teachers reference the analogies in their instruction (Fig. 9). Treatment teachers incorporated almost six times as many analogies as comparison teachers. We also found that students in the treatment classes performed better on assessments of energy transfer and electricity, suggesting that these techniques show promise in helping students learn the science concepts and overcome the misconceptions the games were designed to dislodge (Martin, Silander, & Rutter, 2019). We did not find that student assessment scores varied based on teacher quality, suggesting that the professional development and materials designed to scaffold analogy mapping enabled a wide range of teachers to integrate digital games effectively into instruction—in contrast to the findings from our previous design.

Fig. 9 Teacher using analogy mapping technique

Lessons Learned over Ten Years of Game and Materials Design and Development

This multiphase effort to help students overcome science misconceptions has provided us with important lessons about digital game design and the design of instructional materials to support the integration of games into instruction that our team will apply to future efforts.

Science can provide compelling rule systems for gameworlds Our team started this endeavor with the idea that digital games could help students dispel misconceptions in science because they encourage players to open their mind to new "possible worlds" that present novel challenges to overcome. We felt that it was essential that the games engaged students and that a compelling narrative was central to this engagement, particularly to hold their interest for sufficient time to support learning. We used the affordance of popular games to create fanciful visualizations that were analogous to difficult science concepts, thus opening up students' minds to the possibility of a world in which those analogous concepts hold true (in fact, the real world at the molecular level). However, in the beginning we were not confident enough in this theory to design a whole game around an analogy. Instead, we used mini-games that students had to play repeatedly to achieve game goals as the analogy source. These mini-games were situated within more conventional recreational game narratives and mechanics that we thought were necessary to actually engage middle-school-aged players. Over time, however, we became more comfortable with our design team's ability to make analogous visualizations that were both scientifically sound and narratively compelling. Similar to the experience reported by the team that created the Surge game series (Clark et al., 2016), we discovered that creating a "true game" that can achieve educational goals does require that we value imagery and mechanics found in popular recreational games over disciplinary representations of science concepts. We always held to the premise that digital game visualizations were good source analogies to target science concepts, but by game four we discovered that, in fact, a science concept such as heat transfer can serve as the basis of a rule system for a compelling gameworld, not just a mini-game within a conventional gameworld with more familiar rules, rewards, and obstacles.

Provide teachers with instructional materials and professional development that explicitly demonstrate how to integrate digital games into their teaching The design challenges we had to address to achieve our intended outcome of helping students dispel misconceptions were not limited to game design issues, but also encompassed the design of instructional materials and professional development experiences for teachers. From the beginning, we knew that students needed support to connect the game to real life in order to learn. However, our strategies changed over time. Our first attempt was not successful because we gave teachers all of the ingredients to make those connections except the most important part—the actual analogies. When we redesigned the instructional materials we asked ourselves, what analogies do we wish the teachers and students had made? Then we created instructional materials that, in fact, included those specific analogies, designing presentations that also included the visual supports necessary for teachers to use the analogy mapping techniques described by Richland and colleagues and that supported student discussion to further scaffold learning. Providing such explicit materials did not limit teachers' creativity. We saw teachers use a wide variety of teaching styles using these materials, from question and answer sessions, to small group work, to students coming to the board to point out connections.

This 10-year enterprise of iterative design, development, research, and redesign started with the ambitious goal of helping middle-school students overcome persistent science misconceptions. The reason the misconceptions persist (often into adulthood) is because standard science instruction does not dispel them. Innovative techniques are required for students to learn these difficult concepts. In the beginning, we thought that digital games designed to be analogous to science concepts, and instructional materials connecting the game visualizations to the concepts, could be the innovation that helped address this problem. What we found was that even carefully designed games and materials are not likely to have an effect on students unless they are purposefully leveraged by teachers as part of an explicit process of building robust understanding of complex concepts through gameplay, discussion, instruction, and reflection. Such work required innovative teaching and professional development combined with innovative digital game and materials design and the contributions of designers, developers, storytellers, researchers, and many educators and students along the way.FundingThis work was generously supported by the US Department of Education's Institute of Education Sciences (Award # R305C080022) and the National Science Foundation, Division of Research on Learning in Formal and Informal Settings (DRL-1252382).

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Design Case for Asynchronous Online Professional Development in Primary Grades Mathematics

Drew Polly and Christie Martin

Introduction

This design case shares the process of designing, implementing, and modifying asynchronous online mathematics professional development for elementary school teachers. Based on the recommendations of Boling (2010), we provide a rich description of the design decisions, experiences, and learning outcomes from our project. Further, informed by Smith (2010), this design case includes both typical sampling and critical case sampling. Specifically, we included typical design elements while also attempting to highlight aspects of the case that were very influential on the design and outcomes, such as the video excerpts of students that teachers had to analyze. This design case includes both data triangulation by examining artifacts from the designed professional development, teachers' work samples, and data that we collected during the project (Smith, 2010).

We begin by describing the overall context—a large grant-funded project focused on enhancing elementary teachers' skills and knowledge related to teaching mathematics. We then describe our design process, followed by examples and descriptions of the asynchronous professional development modules we designed. We close with a reflection on distinctive aspects of our design case.

D. Polly (✉)
University of North Carolina at Charlotte, Charlotte, NC, USA
e-mail: Drew.Polly@uncc.edu

C. Martin
University of South Carolina, Columbia, SC, USA

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Context

Purpose of the Design We designed online teacher professional development modules as part of a larger project funded by the North Carolina Department of Education Mathematics and Science Partnership grant program. The professional development experiences focused on supporting teachers' knowledge and skills related to using the Internet-based assessment tool *AMC Anywhere* (Math Perspectives, n.d.). The goals of the project were to support elementary school teachers to develop:

1. Knowledge of how young learners develop number sense skills.
2. Knowledge of mathematics related to number sense.
3. Skills and knowledge related to using the Internet-based formative assessment mathematics program *AMC Anywhere*.
4. Skills and knowledge related to using data from *AMC Anywhere* to plan mathematics instruction.

AMC Anywhere includes nine assessments intended to give teachers formative information about their students' understanding of number sense, which they can then use as they plan and implement targeted instruction with provided instructional materials (Didax, 2012). These assessments align to mathematics standards typically found between kindergarten and second grade. Teachers conduct the assessment one-on-one with each student. The assessment takes only a few minutes to complete. In some cases, teachers provide hands-on objects such as mathematics manipulatives for students to use in certain parts and then take them away to advance to a higher level of difficulty.

Figure 1 is a screenshot from the *Hiding Assessment*, which requires students to solve tasks related to addition and subtraction. In the task below, teachers ask students to identify numbers that can be added together to make a total of eight.

Like most Internet-based assessment tools, *AMC Anywhere* stores data and allows teachers to retrieve data per individual student or by class. School administrators and district leaders can access and organize data by grade, schools, or even entire school districts. Data from the progress report connects to related instructional materials, allowing teachers to have a direct course of action to provide instruction based on data.

Figure 2 is a sample student progress report, which allows teachers and others to view students' growth over time. The numbers listed in the top data row identify the number the student was finding addition combinations to; for example, 6 means that students were told that there were total of 6 counters, but only 4 were visible. They were then asked to determine how many counters were hiding. The ratings are given by the letters in the table: A means ready to apply, P means more practice is recommended, I means that explicit instruction is needed, and N means that the student is not ready for any work related to that number.

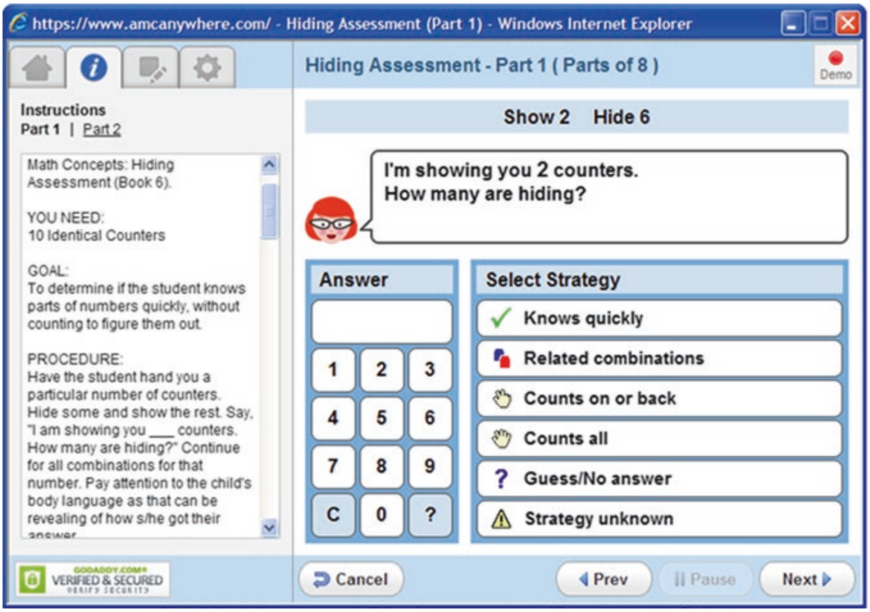

Fig. 1 Screenshot of *AMC Anywhere* Hiding Assessment

Critical Decisions in Our Design Process of the Professional Learning Experience

The professional development experiences, including face-to-face workshops and online experiences, were designed and implemented with 250 primary grade teachers in five school districts across North Carolina over a 3-year period. All participating teachers were using the same North Carolina mathematics standards, and all districts were using similar curricular resources that aligned with student-centered pedagogies. Teachers were recruited by district leaders, but all of them volunteered to participate in the project. In turn for participating, teachers received a stipend for summer work and the online modules, access to the online formative assessment tool for the duration of the grant, and a full set of instructional materials that aligned to the formative assessment tool.

During the summer, all teachers started their project work by participating in 40 hours of a summer workshop focused on using an Internet-based formative assessment mathematics program that they accessed via either a laptop computer or iPad. The workshops were district-specific, but teachers from different school buildings within a district worked together during the workshops.

The grant's guidelines required at least 40 hours of face-to-face workshops with teachers during the summer, but was open to how teachers completed 20 hours of professional learning experiences during the year. Based on our knowledge of teachers' busy schedules during the school year, we knew scheduling face-to-face

Hiding Assessment - Part 1: Identifies Missing Parts of Numbers with Models								
Date	3	4	5	6	7	8	9	10
10/11/2013		A	P	I				
02/20/2014		A	P+	P				
05/22/2014			A	I				

Hiding Assessment - Part 2: Identifies Missing Parts of Numbers without Models							
Date	4	5	6	7	8	9	10
10/11/2013	N						
02/20/2014	P	P					
05/22/2014	P+	P	A	P	P	P	P

Fig. 2 Student progress report from *AMC Anywhere*

workshops would be challenging. The project management team included project staff and district leaders, who were knowledgeable about the school contexts. We considered various possible options, including evening and weekend face-to-face workshops, synchronous online professional development, and asynchronous professional development.

The project included six different school districts across the state, all with different school contexts. Therefore, the project staff, which consisted of mathematics educators and graduate students, and district leaders reached consensus and decided that synchronous professional development activities—whether online or face-to-face—would not be as effective compared to asynchronous modules, which could be completed when teachers were ready to complete them with support from district leaders. One of our previous projects and other statewide efforts showed poor attendance in evening workshops, and school districts in this project were not willing to have teachers come to professional development during the school day, even if substitute teachers were paid for by the grant.

During the initial planning stages, project staff from three of the smaller school districts requested that professional development materials and modules be built so that teachers could complete them online or in person workshops being led by district leaders. The larger districts, however, wanted online materials only, since they logistically could not determine how to bring all of the teachers together to the same space. Further, the initial planning stage included the creator of the assessment tool, who was not familiar with anyone who had done online professional development related to the tool. As a result, there was some tension and uncertainty around whether or not online professional development during the year would be effective.

We framed modules around principles of effective professional development (Polly & Hannafin, 2010) and included classroom-based, job-embedded professional learning activities that teachers completed. After completing these activities, they submitted artifacts including written reflection as evidence of their work and learning. To this end, we opted to design asynchronous online professional development for all of the teachers. As a result, one of the next design decisions we faced was determining how to structure online professional development resources for the teachers. Since some teachers taught together in the same school or district, some teachers met together with other teachers and worked together in the same room on these activities. The three smaller districts made arrangements for teachers to come together to the district's central office to complete most aspects of the online modules together at the same time.

We conducted a needs analysis after the summer workshops to identify focal content. District leaders participated in a planning meeting where they stated their perceived needs for teachers who worked in their district. We also asked teachers on the last day of the face-to-face workshops to provide their opinion about concepts they wanted to learn more about. We found alignment between district leaders' and teachers' desires to participate in more professional learning activities focused on three areas: (1) structuring and organizing their classroom to collect formative assessment data; (2) analyzing formative assessment data after collected to identify students' needs; and (3) aligning the state mathematics standards, their mathematics curricular resources, and the formative assessment program. In year one of the project, the project leadership team, which included university faculty such as myself and district leaders, decided to design learning experiences that addressed all three of those needs. We designed the work to occur across the entire year.

In considering how to support teacher learning in the absence of synchronous meetings, we wanted learning experiences that would connect what they had learned in the summer workshop, focused on how to use the assessment tool, how to analyze data, and how to make instructional plans. We also were committed to a structure that created opportunities for teachers to dialogue with each other.

Since project staff and district leaders decided that the optimal format was for teachers to complete the professional learning experiences in an asynchronous manner, we saw a need to be explicit about the steps and processes related to analyzing the data they would collect using the *AMC Anywhere* tool. We elected to include video-based cases in the online modules. This process of watching a video and using the program to assess the student's performance is an experience teachers had completed five times during the summer professional development. By including the task of watching videos and assessing students who were in the video, we provided teachers with the opportunity to review what they learned during the summer and helped teachers refresh how to use the program before using it to assess their students' progress. We therefore also provided access to the video cases. As project staff and district leaders collaboratively planned the activities, they felt that teachers needed a heavily scaffolded and detailed template to help them with data analysis and creating instructional plans.

Lastly, when considering how to write and frame opportunities for teachers to reflect on their experiences, their teaching, and student learning, project staff and district leaders reached consensus that the reflections should focus on student learning instead of on teacher performance or teacher actions. This approach, all stakeholders felt, mitigated the potential that teachers would get defensive about their use of specific instructional strategies or curriculum resources. We also hoped it would focus teachers' work on students' growth in understanding of mathematics and attention on what they were noticing about their students while they were teaching.

Description of the Professional Development

The 20 hours of online experiences were divided into three modules, which were housed in a learning management system operated by the North Carolina Department of Education. Each module included a series of tasks (Table 1) that aligned to research-based, learner-centered approaches to teacher professional development (Garet, Porter, Desimone, Briman, & Yoon, 2001; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2009; Polly & Hannafin, 2010).

Table 1 Tasks in modules

Module	Time of year	Professional learning activities
Module 1	September–October	Solving mathematical tasks Watching videos and practicing analyzing students' mathematical understanding Assessing the whole class using the Internet-based formative assessment program Writing about assessment results, setting up classroom
Module 2	January–February	Solving mathematical tasks Watching videos and practicing analyzing students' mathematical understanding Assessing the whole class using the Internet-based formative assessment program Writing about assessment results Developing a differentiated instructional plan for a group of students based on data
Module 3	April–May	Solving mathematical tasks Watching videos and practicing analyzing students' mathematical understanding Assessing the whole class using the Internet-based formative assessment program Writing about assessment results Watching videos and read about number talks activities, try to do a number talk with students

We included three common tasks in each of the three modules: (1) video-based cases of students being assessed for teachers to watch and analyze, (2) scaffolded activities to support teachers' analysis of their students' data, and (3) opportunities for teachers to write about and reflect about their students' performance based on data they had collected. All of these focused on authentic classroom-based work and students' performance, which were primary goals of the project.

Video-Based Cases Each online module included video-based cases of students completing the same assessments that teachers were expected to administer to their own students. These cases scaffolded teachers to read a short two-page article about the content, to watch the video of students doing the mathematics assessment, and then to respond in writing to the video about students' performance. For instance, in Module 1, teachers first reread material from the summer workshop about strategies that children use to count a set of objects. They then watched two videos of two children counting a set of objects and used the *AMC Anywhere* online assessment program to assess students during the video. Figure 3 shows a screen capture of the video and prompts that teachers were expected to respond to.

Teachers wrote their responses in a threaded discussion so that they could interact and dialogue with each other about their observations and thoughts about the video. As teachers wrote their responses, design team members and graduate students facilitated the online discussion posts by responding to teachers and posing additional questions to continue the conversation. We found that while we designed the online threaded discussion to be a forum for ongoing dialogue, most teachers just posted the one required time. Even when we asked a follow-up question on the discussion forum no one responded.

Scaffolded Activities to Support Data Analysis We also incorporated tasks in each module to support teachers' effort to analyze their students' performance using data collected with the online *AMC Anywhere* program. These tasks, while similar to teachers' work during the face-to-face workshops, had a higher degree of authenticity since they were using the program to assess their own students in their class. Across the three modules, we focused on various skills related to data analysis and instructional planning including collecting data using *AMC Anywhere* (Modules 1, 2, and 3), printing reports of student progress (Modules 2 and 3), analyzing reports to look at trends in the data over time (Module 3), identifying instructional activities

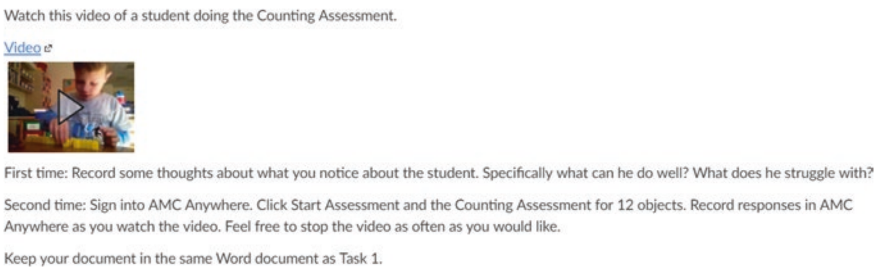

Fig. 3 Screenshot of video-based case from professional development

that meet the needs of specific students (Modules 2 and 3), and making a plan about how to implement those instructional activities (Module 2).

For instance, in Module 2, teachers collected data in the second task using a template designed by project staff to create an instructional plan based on their data. The template included sections for teachers to enter the students they were focused on, their data, a summary of their interpretation of the data, and a list of next instructional steps to meet the needs of their learners. Finally, teachers wrote a reflection of how the implementation of their instructional plan went after 3 weeks of use.

Written Reflections About Students' Performance and Instructional Decisions In each module, teachers reflected in writing about students' performance and data they collected and analyzed. In addition to focusing on student outcomes, the written reflections focused heavily on next steps and the "so what" aspects of teaching. For example, after teachers analyzed data for their entire class, one prompt was, "Based on what you know about your students, identify a small group of students who have the same need and could benefit from the same types of activities."

Reflections on Distinctive Aspects of the Design and Plans for Future Design Work

While the design of online mathematics professional development modules led to gains in primary students' achievement (Polly et al., 2015; Polly et al., 2017) as well as teachers' adoption of specific instructional practices (Polly et al., 2017; Polly, Martin, Wang, Lambert, & Pugalee, 2016), some teachers struggled or were resistant to implementing the formative assessment mathematics practices emphasized in the project. These teachers had less of an impact on their students' achievement (Polly et al., 2015, 2017). These insights suggest necessary changes for our design of future professional learning opportunities for teachers.

Specifically, we feel that based on the data, future designs of online asynchronous professional development activities need more rich ways to support teachers' work in their schools to ensure more of a carryover from the activities into their own classrooms. It was challenging to make sure that teachers felt supported and were likely to apply what they learned from the summer face-to-face workshops and the online asynchronous modules into their classroom on a consistent basis. We know from our project that teachers from the smaller school districts received face-to-face support from a district or school-based leader for each module. In some cases, teachers brought their devices to a common location and completed parts of them with each other to have just-in-time help and support while they were working. From data, the presence of face-to-face support seemed to have increased the likelihood that teachers implemented the formative assessment practices with fidelity. Based on this, in the future, we would think of ways to bring the elements of face-to-face support that led to fidelity into the online professional development experience. For instance, we could provide teachers with the options of online synchronous sessions or video chats with a facilitator.

In terms of the design process, this project was interesting to us and we believe successful since it included the buy-in and input from project leaders who were university faculty in mathematics education, some of which have a background in designing online learning, school-based mathematics leaders, as well as input from the developers of the online formative assessment tool that was the focus of this project. Further, we gathered input regularly, from the initial needs analysis to participants' reflections and responses about the project in order to ensure we were meeting their needs as best we could. At the end of the day, we learned that designing online professional development for multiple districts working with a diverse set of context-specific factors was challenging, and in some cases the fidelity of implementation and impact on teachers' and students' learning varied. Nonetheless, we feel that providing a learner-centered set of opportunities that tried to meet some of their specific needs led to a better designed experience than something that was more generic, only focused on the formative assessment tool and not the needs of teachers or learners.

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Evolutional and Technological Influences in Design: A Longitudinal Examination of the PRIDE Design Case

Robin A. Medley, Charles Nolley, Tony Labriola, Yevette Brown, Mick Polowy, Victoria Lloyd, Cindy S. York, and Lisa C. Yamagata-Lynch

Introduction

This chapter examines a longitudinal view of the design, and re-design, of a foster parent training curriculum, called the PRIDE Digital Curriculum (PDC), over the course of 17 years, with the latest version occurring in 2017. The PDC project was an international and interorganizational collaboration of child welfare agencies, bound by strict state and federal laws (i.e., confidentiality) and sensitive topics (i.e., child abuse, sexual abuse, cultural diversity). The team, led by a university instructional design and media production unit, needed to address cognitive, operative, and affective training. The uniqueness of this design case is that it visually depicts a large-scale training model and how the delivery methods evolved over the 17 years, from face-to-face (F2F) to CD-based to online training. The PDC is an exemplary case for non-profit, interorganizational design efforts. Over 300 people were involved in this multimillion-dollar project to produce 75 hours of interactive training, including training experts, technical staff, staff from multiple state child welfare agencies, foster parents, and actors.

R. A. Medley (✉) · C. Nolley · T. Labriola · Y. Brown · V. Lloyd
Governors State University, University Park, IL, USA
e-mail: cnolley@govst.edu; tlabriola@govst.edu; ybrown@govst.edu; vlloyd@govst.edu

M. Polowy (deceased)

C. S. York
Northern Illinois University, DeKalb, IL, USA
e-mail: cindy.york@niu.edu

L. C. Yamagata-Lynch
University of Tennessee, Knoxville, TN, USA
e-mail: LisaYL@utk.edu

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The PDC design case provides insight into the evolution of the educational technology field and changing role of the instructional designer and developer. The authors of this design case each had different roles that contributed to the project, providing a multidisciplinary perspective on the field (Liu, Horton, Jaejin, Kang, & Rosenblum, 2014). In this chapter, we share what we learned about sustainability and extending the longevity of our design through four overarching themes related to the evolution of our design, collaboration, design rationale, and assessment. We selected these four themes for their role in depicting issues involving sustainability and longevity. Elsewhere, one of the authors (Medley, 2016) shares a broader perspective on the outcomes of the interorganizational collaboration. Some of the features are not detailed in this case to permit us to focus on more salient design features.

Where Our Story Begins: The Time, Place, and Participants

The first four authors of this chapter were part of the multidisciplinary design team of the original version of the PDC. Our expertise evolved from a video production and teaching background to interactive instructional designers over the course of this project. We used our teaching and technical backgrounds to make design decisions. The fifth author was the subject matter expert (SME) from a partnering agency. He was an expert in F2F curriculum development and training for foster parents. The sixth author joined the university staff after the first version was created and was involved in the transition to the LMS. As such, the design decisions were a collection of minds within media development, higher education, and the training industry. The last two authors of this chapter were part of the first author's dissertation advising team. As practicing designers and developers, the authors share their rationale for addressing the complex issues and learning objectives from the PDC.

First, we set the stage for how this case began, since time was quite relevant to the evolution of the PDC and instructional development. Time, place, and context determine what tools are available to instructional designers and developers, expose limitations and contradictions within technology, and reveal paradigm shifts in the instructional design field. As we reflect on our design story, keep in mind that time and space are relevant to understanding the choices that we made during the initial designing and developing phases. So, we are going back in time to when training from a distance was breaking new ground, and the beginning of our journey encountered excitement, challenges, and some resistance to the newer technologies.

The PRIDE Curriculum

Beginning in 1991, several state child welfare agencies, universities, and child advocacy organizations joined forces to develop a model for foster parent training. The steering committee was made up of 65 people with diverse perspectives, such as foster parents, trainers, legal professionals, and youths within the foster care system.

The subject matter expert (SME) was with the training curriculum since the beginning. PRIDE is an acronym for *Parent Resources for Information, Development, and Education* and is a model for recruiting, assessing, preparing, and supporting foster and adoptive parents. The model was conceived out of a consensus design by several organizations. The consensus design meant that the whole committee contributed to the curriculum and everyone's voice was generally in agreement before approving the training.

In 2000, when a $1.3 million *Learning Anytime Anywhere Partnership* (LAAP) grant with in-kind matching was approved, Governors State University partnered with several child welfare agencies on conceptualizing the PRIDE Digital Curriculum (PDC), a digital version of the face-to-face (F2F) training. The rationale for selecting this curriculum, from the university's perspective, was twofold. The PRIDE curriculum was a well-designed curriculum in use throughout multiple countries, and the university had played a central role in the original development. It was our thought, when we entered this project, that the strong curriculum enabled the university to immediately focus on transitioning the training to a distance program.

As we reflect on our early beginnings, we now realize that transitioning from an existing F2F training to digital training was not as easy as we originally thought. The partners wanted to update the content while moving to the digital version; converting the content to visuals opened a can of worms related to issues such as diversity, avoiding stereotypes, the tone of actors, and how they dressed. We detail some of those challenges later. We also learned that setting up an interorganizational partnership requires attention to cultural values, roles, and responsibilities, which we also touch on later. Key elements include long-term commitments, evaluating both the content and the audiences (foster parents and agencies), and the time it takes to maintain long-term partnerships, with enough agencies to create the economies of scale required to fund the ongoing development of this complex enterprise.

Thinking Long-Term During a Rapidly Changing Domain

When new technologies enter the instructional technology domain, it is difficult to predict their growth rate and user acceptance, but we needed to make an educated guess. In our case, we initially designed a standalone product, distributed on CDs. The longevity of the PDC training product was influenced by our early decisions to create the content at the highest quality available and then compress the files to fit the delivery method, rather than creating the content to match the available delivery method.

In this design case, we focus on three versions that depict our developmental trajectory. The first version was developed between 2000 and 2006 on CD. Our reflections on the first version provide the essence of the PDC design rationale when transitioning from F2F to digital media. We transitioned to our first LMS by 2013 (version 2) and the second LMS in 2017 (version 3). Table 1 summarizes the major capabilities and features that changed during the life of the PDC.

Table 1 Feature comparison of different versions

Features	Versions		
	CD – 2006	1st LMS – 2013	2nd LMS – 2017
Creation platform	Macromedia director	SWF files (Flash) in LMS	HTML5 in LMS
Reason for choosing platform	High-quality video and large files limited Internet streaming	Capable of handling large files	Could customize content and data analytics capability
Progress indicator	Index page between lessons	Same as CD	Numbered screens (# out of total #)
Customization for individual agencies/ users	No external content capability	Limited customization to additional information	Broad customization (i.e., assigned roles, data analytics, agency-specific content)
Distribution	Individual user must gain access to physical CD for each session within module (25 disks)	Individual user can access all in-service training from one online location	Individual user can access all pre-service and in-service training from one online location
Community board – communications	Limited capability to send responses by email	Message board available but not monitored	Agency assigns monitor for discussion board. Data analytics capability
Assessments	Stored on individual computer; manually needed to share with trainer	Stored on individual computer; manually needed to share with trainer	Stored in LMS. Agencies can view individual or grouped responses; data analytics capability
Tracking completion	Completion certificate can be saved and printed	Completion certificate can be saved and printed	System tracks completion for individual users; automatically emails certificate and allows printing/saving
Changes/updates	Limited to major revisions and cannot recall all disks in print (already at agency)	Limited – must go through LMS company and have them upload changes	Full control of content. Can make changes to individual parts of training

Available Technologies Influenced Our Media Selection and Early Design Decisions

Over the years, storage capabilities were a major influence on our design decisions. Our design goal was to create interaction and extensive video for affective domain training. Streaming video was not a viable option in the first version. Medley (2016) illustrated, in Fig. 1, the various storage options that were used throughout this PDC design case. In our development stage, we had to share content across locations. For instance, the transcriber's computer only had a floppy drive, and videos were sent on VHS because not all partners had DVD players. But the technology was changing quickly. Our rationale for distributing the training on CD was influenced by both the

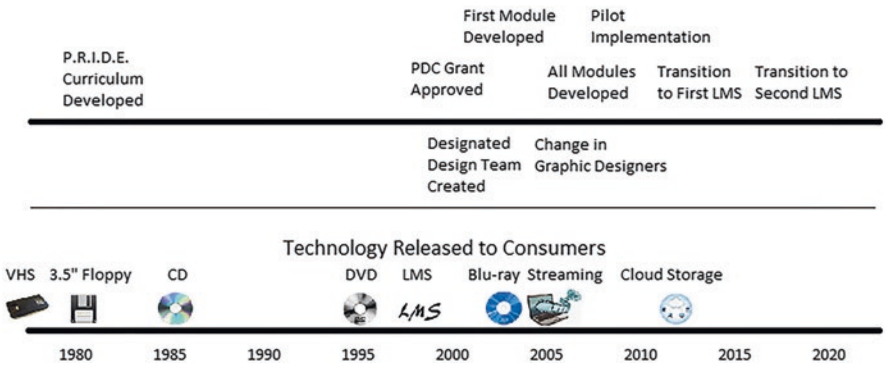


Fig. 1 Changes in technology storage capacity and distribution over the PDC development

technical capability of the available technology and the likelihood that our learner audience would have access to that technology. When we first began the transition to a digital curriculum, we surveyed our potential clients' and learners' technology capabilities. We wanted to create high-quality video, but storage and distribution options were limited during the first two versions. Most of our videos were less than 5 minutes long, which helped keep file sizes small. We decided to create our content as individual objects (e.g., video clips, sound bites, Flash animations, graphics) so that the project could be transferable for future updates and edited to remove outdated content, such as changes in child welfare practices. The latest LMS program offered additional control and functionality through cloud storage. That technological evolution was an explicit design consideration from the beginning.

The technologies in which we stored and shared our data/media files changed over the years. Instead of focusing on the technologies, we focused on the quality (i.e., recorded with professional actors, low compression, on-scene locations, and scripted scenarios). We also focused on saving the media as objects that could be transferable to new technologies, and we learned the key to this strategy was making sure we used consistent names based on the location within the module. When we had to go back to the stored objects during our transition to the LMS, some media objects were not labeled consistently, which caused difficulty and delays in the transition to different formats.

Collaboration Challenges Within the Design and Development of the First Version

There were 9 modules to convert to digital training, separated into 24 sessions parallel to the 24 3-hour F2F training sessions. Design considerations for the visual product were more complex compared to a F2F curriculum. For example, in a class setting, case studies were discussed verbally or read. Creating video vignettes required decisions like choosing gender, ethnicity, age, or the tone of voice – decisions that were not required for printed case studies. Our child welfare partners were wary of visually depicting content, such as sensitive topics, ethnic diversity, stereotypes, attire, how foster parents or caseworkers spoke, how to depict a sexually abused child, and balancing relevant materials for different state child welfare laws and practices. Communication processes were delayed due to debates over the details.

The "Designated" Design Team and Marathon Meetings

The greatest challenge the team encountered in the early phase was time required for design and approval. The later versions did not have as many stakeholders involved because the content was not changed. As mentioned previously, the original F2F curriculum was designed through a consensus design. That method of feedback between stakeholders in 14 states proved too time-consuming. It was hard to keep track of the script versions, as changes came through email from the different child welfare agencies. The multimedia development team wanted all the partners to participate in the design process, but after 1 year, the team had still not completed its first script and risked losing the grant funds. After the first year, the university team requested our partners designate a small group of expert members from the partnering agencies to authorize and design the distance training. We refer to this group as our designated team. We also needed to eliminate the time it took to hash out the details of the script through emails. The designated team met at the university for two to three consecutive days in what we called marathon meetings, during which they would write a near-finished script.

Balancing Language, Culture, and Character Differences

When working with partners from different organizations, we encountered different workplace cultures, values, and language interpretations. While we shared some cultural similarities with our partners, such as all the partnering agencies were non-profit agencies, there were differences in our workplace cultures. Governors State University was a state university and valued education. The child welfare agencies valued volunteerism and ideas that improved the management and development of foster care. Each agency had external rules and requirements, which impacted the dynamics of the group. For example, the university provided the in-kind matching requirements of the grant and thus needed to balance the project within the university and grant policies. The child welfare agencies provided their staff's expertise as volunteers on the project. As such, the commitment, time needed for the project, and value in the finished product differed between partners.

There were many times during the design and script writing process that language interpretation slowed down the process. For example, prior to creating the designated design team, the original designers were together writing the script for one session, when the creative director on the university side used the word “game” to describe an idea for an interactive screen. A child welfare partner was stunned that such serious content would be called a game. The university members decided from that point on to refer to the various activities as “interactions.”

In addition to the interorganizational cultural differences, the university’s internal development team also navigated power dynamics and communication issues that may have been inherited from the team members’ cultural backgrounds. We had a couple team members who were from different countries, and their cultural values, such as gender roles, may have influenced the team dynamics. For instance, one member was conscious of hierarchy and would only collaborate through a top-down authority and not with the team members who were co-equals within the team. Another member was reluctant to share designs until they were finished and perfected, making it difficult for other team members to monitor and assess progress.

We also faced communication barriers and found ways to resolve issues. For example, the designated design team asked a member of the development team if they could create an interaction, such as creating a thermometer on the screen that rises as the learner increases their correct responses. The development team member took an extensive amount of time attempting to create the complex activity. The designers and project manager would have chosen a different activity had they known it would take a week versus a day to create it. Creative staff need time to develop the material, and designers may not know how long specific components will take to create. We discovered that we needed check-in points often with the team members to ensure time was not wasted on the smaller components or details within development. We found that channeling communication between members who work well together helps, and if someone is quiet and keeps to themselves, find someone they open up to and have them share their progress with that person. Maintaining communication and check-in points helped us balance development time within a project timeline.

Documenting a Shared Coding System

As mentioned, time is relevant to the choices made in the design and development. In our case, the original version was created on CDs because they could handle the large amounts of video. But in the early part of 2000, there were not many resources available on how to track each piece of the digital training. The development team’s background was in video production, so they took the coding system used in video and merged it with the original printed training material’s breakdown to help create a system for labeling each screen shot. In video, a standard 1 second timeline consists of 29.97 still images (roughly 30 images per second). Thus, video cameras would record a hidden time, called a timecode, on each still image, which could be seen while editing a video clip. This enables an editor to slice a video within a fraction of a second. The timecode is displayed by hours, minutes, seconds, and frames

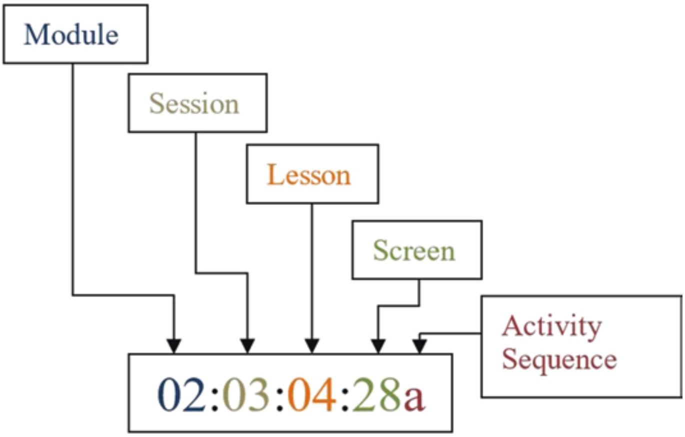


Fig. 2 Screencoding for nonlinear training

(e.g., 00:23:35;15 is 23 minutes and 35 seconds into the video). The struggle with coding the multimedia project was that video is linear whereas multimedia in nonlinear. So, we innovated our own coding system as seen in Fig. 2. We used an alpha system at the end to distinguish sequential animations. Video images were broken down into frames, so we called our nonlinear images as screens, short for screenshot. At the time it was being produced on CDs, so calling it a webpage was not considered. In this chapter, we label our screenshots as "screens" to depict what the end user is seeing on their screen.

Our screencode became an essential communication and documentation feature of the product. Each screencode was a reference point, like an address, to locate that screen within the training. Each session was a separate training, typically lasting about 3 hours. In the first version, each session was produced on a separate CD, but each module was packaged together in the same case. In the LMS versions, learners would click on a module to view and access the available sessions.

One contradiction we encountered with the screencode was that the perspective of the screencode was viewed differently between the stakeholders. The partners and designers understood the sequence of the code, but the animators and computer programmer were confused by the alpha portion of the code and, as a result, thought there were additional files to create. However, once the screencode was explained to them, all stakeholders understood the coding system, and we adopted the term "screen" to refer to all objects. As various versions of the training continued, we found coding the objects within the screens was essential. When we went to our first LMS, each screen was converted to its own unique URL (web address), which then could be called a web page. However, the later LMS was able to embed a sequence of training screens within one URL, thus no longer making it a webpage for each screen. Additionally, as we moved from CD to our first LMS, and then to our later LMS, the screen number changed. As we mention later, moving to the larger screen size enabled us to put more content on the screen, and some screens were combined. Why does this all matter? It is important for longevity to save all screens and objects that went into the screens by a coding system so that we could later reference and locate them.

Samples of Our Navigational Designs and the Rationales Behind Them

The evolution of our roles as instructional designers and our rationale for instructional design decisions coincide with the literature that many practitioners gain their rationale for design decisions based off experience (Ertmer et al., 2008). The primary authors who were influential in our rationale include Gagne (1965), Kirkpatrick (1998), Knowles (1980), Larson and Lockee (2014), and Mager (1997). We also had a multidisciplinary network of individuals to guide us. For instance, the evaluators of the project suggested first describing what the success of the project would look like. So, in the beginning, we gathered all the partners to develop a shared vision of what the training would accomplish. During the marathon meetings, experts were available by phone to answer content-related questions. Our design rationales were linked to our network of experts.

Our designated design team was made up of foster parent training experts (the partners) and creative designers (the university). The university was also the developers, so the creative designers led the rest of the development team to articulate the designs of the designated design team. Subject matter experts (the partners) brought their expertise on training and awareness of the cognitive, affective, or operative objectives in the PRIDE curriculum to the designated design team. It was the creative design team's task to select the most effective method for reaching the learning objectives through a multimedia-rich format and not choosing an activity for the sake of aesthetics (discussed further below). As such, the designated design team was a merging of interorganizational and multidisciplinary members who brought different rationales and perspectives of instructional and creative design to select an appropriate method for reaching the desired outcomes. Table 2 reflects our outcome-based approach to creating multimedia training.

Medley (2016) identified this outcome-based approach to multimedia training based on interviews in her longitudinal study into the PDC development. The SME explained the outcomes and objectives of the existing F2F content and then the creative designers

Table 2 Outcome-based approach to multimedia training (Medley, 2016)

Outcome	Level of competency	Learning objectives	Method of interactive multimedia – examples
Know something	Increase ↓	Knowing (cognitive)	Provide information – graphic list, narration, case study
Develop a skill		Doing (operative)	Illustrates or demonstrates someone using the skill – actors, role-playing, animation
Demonstrate knowledge and skill		Feeling (affective)	Text entry, interaction (i.e., drag & drop)

selected a multimedia method to reach those objectives. The lead SME approached training through three characteristics: (1) training should be based on objectives, (2) trainers should adhere to individual as well as group learning needs, and (3) instructional design of the training should be balanced between active and less active, i.e., when the trainer is more active, the learner is less active and vice versa. This rationale was embedded into the interactive activities in the PDC (Table 3).

The example above illustrates just one screen per desired outcome, but depending on the depth of content, there might be several screens per desired outcome. The knowing (cognitive) and doing (operative) outcomes alternate (i.e., to provide a few case studies on similar topics) before demonstrating knowledge and skills outcomes (affective objective) in a summative assessment. Thus, the desired outcome serves as our purpose for selecting the design elements of the screen. Also, while the cognitive and operative objectives may be less interactive than the affective objectives, they will generally include some interaction (i.e., drag and drop, text entry, multiple-choice questions) within the lesson to provide self-reflective feedback on the learner's understanding of the content.

Next, we share some screens and the rationales behind them. As mentioned, the first version was distributed on CD, and the second and third versions were distributed on an LMS. We did not make many changes when we switched from the first version to the second version, so the examples below only show the second version and third version, unless there was a notable change between the first two versions.

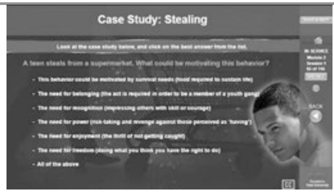
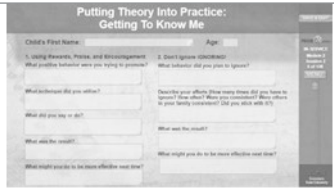
Letting Learners See Their Progress Through Content Pages and Progress Indicators

Within each learning session, there are several smaller lessons (See Fig. 2 for breakdown of modules, sessions, lessons, and screens). The training sessions are broken down into these lessons separated by a *content page* (Fig. 3). Each time the learner completed a lesson, a check mark appeared. The content page served as a progress indicator, letting the learner know how much training they completed. On the LMS versions, we used screen numbers to serve as both a progress indicator for the end user and a reference point within the training. For the designers and developers, those numbers were the identifier we used to store files and reference each screen image when discussing content or changes to content.

Guiding Learners Through the Training

The original F2F curriculum was co-presented by an experienced foster parent and a trainer. The PDC incorporated the co-trainer concept into the digital versions with two actors portraying the foster parent and trainer and with the script based on the original F2F curriculum. The foster parent spoke to the audience from a first-person perspective, while the trainer narrated requirements and best practices. In the first two ver-

Table 3 Example of outcome-based approach applied to multimedia

Outcome/goal	Activity example	Design rationale	Level of competency
The foster parent understands potential reasons for inappropriate behaviors and methods for responding to inappropriate behavior		We introduce a topic through a narration screen and then create a case study to put the topic into context. Learners are less active	Able to understand motivating behaviors for inappropriate behavior and methods for discipline based on situation
The foster parent can handle situations regarding inappropriate behaviors		We provide observations and practice for handling different situations through creative role-playing situations. Learner's activity level increases	The learner develops ability to respond with appropriate discipline
The foster parent selects the best response based on knowledge and skills		We select a series of text entry questions or interactions that identifies the learner's logic or thinking on a topic. Learners are most active	The affective level of competency completes the training of understanding the motive behind the behavior and then selecting appropriate method to respond

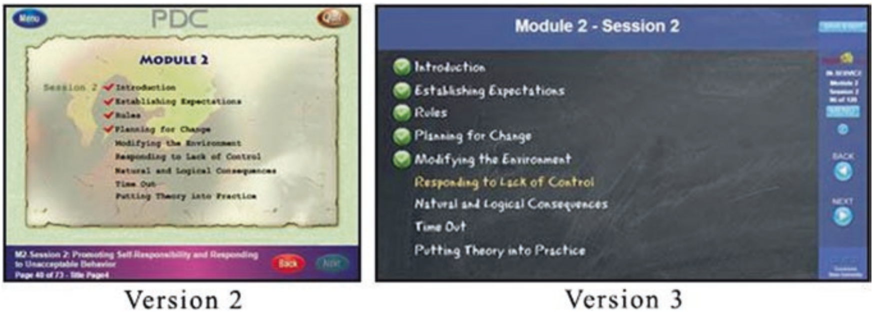


Fig. 3 Example of a content page. Version #2 looked similar to version #1. Version #3 was updated to a more modern look

Fig. 4 Version 2 included side-by-side text and video; with ADA-compliant captions, version 3 did not include the text on the side

sions, the text displayed next to the video to help learners remember content. The learner had the option to turn off sound for the narration. When we transitioned to version #3, all videos were captioned per ADA standards, and we therefore deemed the side-by-side text presentation redundant. Figure 4 compares the versions.

In addition to recording the video narration, actors recorded voice-overs for animations and interactive audio responses, such as “good job!” or “try again,” which kept a consistent narrative voice.

Letting Learners Know the Expectations

The beginning of each training session presented a screen identifying the competencies and objectives to let the learner know what to expect and what they should accomplish within that session. In the first two versions, the competencies and objectives were listed on individual screens because monitor sizes were smaller when we began the design; as monitor sizes grew, and we moved to the second LMS, we were able to get all the content on one screen, which helped reduce the

Fig. 5 Changes over time for our competencies and objectives screens

amount of clicking. Figure 4 displays the competencies and objectives in the different versions. Version 3 eliminated the separate screens. Figure 5 also displays an early version of the competencies and objectives screen to highlight differences in the graphics of these screens. Next, we discuss the rationales and challenges we encountered with the graphics.

How the Look of Our Training Changed over Time

The design coordinator for this project (the third author of this chapter) oversaw and approved every object and style that the creative team developed. However, the individuals on the team, such as the video director, animator, and graphic designer, were given some freedom to express their designs. When interviewed for a longitudinal case study on this project, each of them stated they did not have formal training on learning theories or scholarly influences on their instructional strategies (Medley, 2016). They used their intuition to guide their artistic works by focusing on how their design could be most easily understood within the context of the training.

Changes in Our Graphics

One of the most striking differences between the versions is the graphic design. Elements that influenced the aesthetic appeal of the design were the technical capability of software (e.g., data size, compression, filters, LMS), availability of stock photos, artistic style of the individual designer, and industry norms. Figure 5 demonstrates the changes in the aesthetic look to our graphics. In the first version, we were concerned about compressing a media-rich, 3-hour training onto a 700 MB CD. We selected illustrations instead of photographs because they had smaller file sizes. The first version of the PDC development occurred over the course of 5 years, and we went through several personnel changes as people retired or moved on to new jobs. Additionally, technologies were improving the ability to compress images. There is some discontinuity in visual style over the nine modules as a result of our first graphic designer retiring and a new graphic designer being hired. Their different styles are visible in the top images in Fig. 6. The new designer introduced compressed photographs, which met our limited storage capabilities. Her refinements made the training look more professional; however, we couldn't redo the first modules due to limitations of time and money. Transitioning to version 3 enabled us to update the graphic look once again and bring it into a wide screen (16 × 9) aspect ratio. The content stayed the same, but you can see from the images that we moved away from a child-like look. The newer designs are more common with the professional look of today's training.

Training on a sensitive topic, such as sexual abuse, made it challenging to record video scenarios because we did not want to expose young actors to these topics. The graphic designer instilled the instructional integrity by making the images easily understood. Figure 7 provides an example of how she depicted a sexually abused child to support an affective learning objective. In addition to the sad look on the child's face, the child is viewed from above, creating an inferior position, and clinging to a doll, suggesting a need to be secure.

The Challenges with Creating Videos for the Design Case

We encountered three challenges when capturing scenario videos: talent supply, location, and authenticity. The university is located near Chicago, and we used three talent agencies to help augment our talent pool. We were meticulous in finding diverse talent with specific requirements for age and ethnicity. Over time, it gradually became harder to find fresh faces meeting our diversity criteria. We used professional actors for larger or complex roles but would use department staff, family members, and community theater actors for smaller roles. Many of our videos were scenarios of foster families in a home. Most scenarios were shot on location in borrowed homes using film-style production techniques. We utilized existing locations because it was cost-effective and reduced time needed to set up scenes. To maximize the use of a location, we shot in different rooms and angles. We paid close attention to the details in our videos over the entire 75 hours of training. If we used

Fig. 6 Updating the look and transitioning to less child-like graphics

Fig. 7 Using graphics to depict sensitive topics

an actor as a caseworker in one video, we couldn't use them as a foster parent in another video. We didn't want to create stereotypes by selecting too many actors of one gender or race to represent an abusive birth parent or sexually abused child.

We discovered early on the importance of having a SME on set during recordings to ensure authenticity. For example, caseworkers are never supposed to stand between a birth parent and an exit door, a critical fact when blocking out a scene. In another scene, the caseworker was wearing jeans, which is not allowed. It proved cheaper to fly out our senior SME to attend recordings than to pay talent and crew for re-shoots.

Keeping Score: Our Thoughts on Assessments

Developing foster parent training at a distance initially generated concern about how learners would be assessed and how to document that they – and not someone else – did the training. Training is mandatory for foster parents, but the F2F training required no evaluation beyond attendance. When we first began to design the digital versions, our external evaluator suggested embedding assessments into the training. The interactive media opened opportunities to assess learners at a much deeper level than the F2F training. But creating assessments was just one step in the process. We still needed to consider how the agencies would follow up with foster parents after they completed the training. In the CD version, we programmed some of the assessments to automatically save on the learner's computer. After version 1 was created, we surveyed 477 trainers, staff, and learners about whether they felt the trainer should review the saved files (Medley, 2016). The trainers and staff felt those files should be viewed (82.2% and 77.3%, respectively); however, 94.3% of the learners did not feel their embedded assessments should be shared with the trainer. All the foster parent participants had F2F training, as F2F training is required for the pre-service modules (prior to becoming foster parents). Our training was for foster parents who were already approved. We were not expecting such a discrepancy on that survey question, so we did not provide an open-ended question for the participants to elaborate on their reasoning. However, the SME explained that the foster parents may have felt they should not share their embedded assessments since assessments were not a requirement in the F2F training.

We chose to create the embedded assessments in a way that lets each agency decide how they review the learners. We also provide written guidelines and suggestions for agencies for each version. With version 3, the LMS allowed us to save the assessment questions within the system instead of on the learner's computer. This made it much easier for the agencies to access the files. Each agency can assign roles to the trainers/staff within the LMS, and some roles allow the staff member to pull up the results for the individual learners or aggregate results for the entire agency. That feature allowed the agencies to collect and analyze information from the training that could never have been achieved in the F2F training and provided future opportunities for data analytics. We provide this opportunity to collect the data through the features within our LMS but leave it up to the individual agencies to decide how and if they use these features.

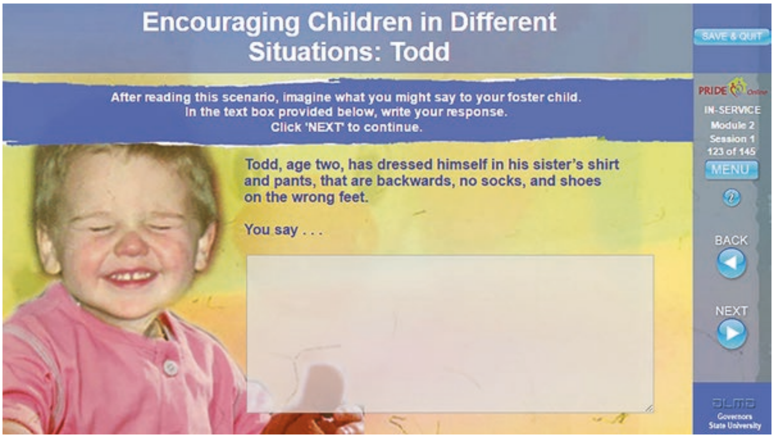


Fig. 8 Short essay, text entry comparison

We created many different types of assessments within the training. Figure 8 shows an assessment that allows the learner to write a brief paragraph by clicking in the text box in the center of the screen. In this example, we choose the short essay assessment because it required the learner to first reflect and then express their thoughts on a case study.

Another example of an assessment we designed used a sliding bar to rank a topic. We used this for self-assessment activities and for saving responses for later review (Fig. 9). The rationale for selecting a sliding bar relates to the principle mentioned earlier; instructional training should be balanced between the trainer being active and the learner being active. This interactivity engages the learner, instead of passively watching videos or reading content. The criterion used to determine if the sliding bar assessment would be stored in the learner's responses or merely used as an interactive feature was determined by the content and whether the results could assist the trainer in evaluating the learner's understanding.

The last assessment illustrates a combination of techniques used for assessment (Fig. 10). At the end of each session, the learner was given a summative assessment on the entire session. These assessments were called *putting theory into practice* and were always saved to share with the trainer at a later time, as determined by each agency.

The Final Take on What We Learned

Over the course of the last 17+ years, as we designed and re-designed the PDC and technology evolved, we learned several lessons. Our design failures were mostly on the early collaborative processes of design. Delays in writing our first script were due to the multiple versions transferred through email and the language interpretations between stakeholders; a deeper analysis of that process was reported

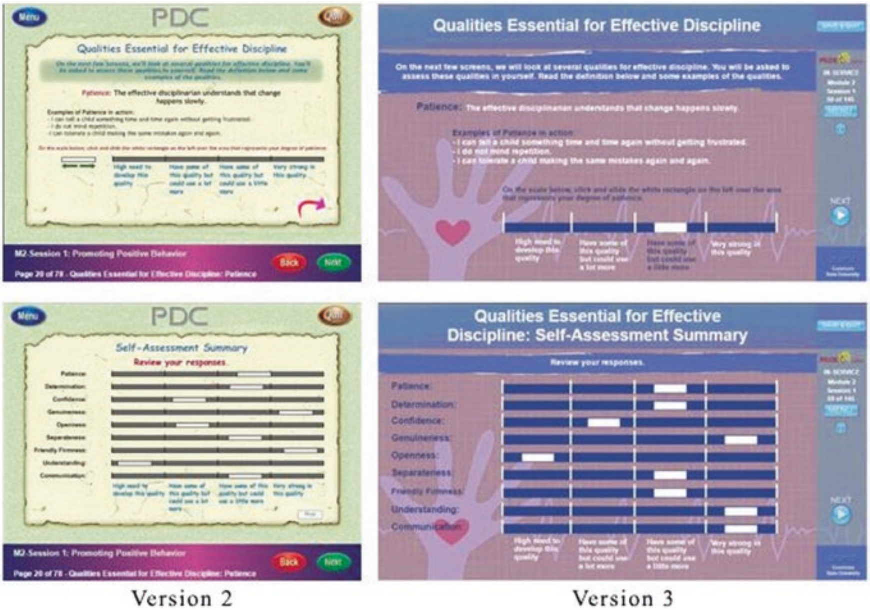


Fig. 9 The top shows a sequence of topics, while the lower image reflects a summary of the combined rankings. In versions 1 and 2, the learner had the option to print this page. In version 3, the learner could access their results anytime within the LMS

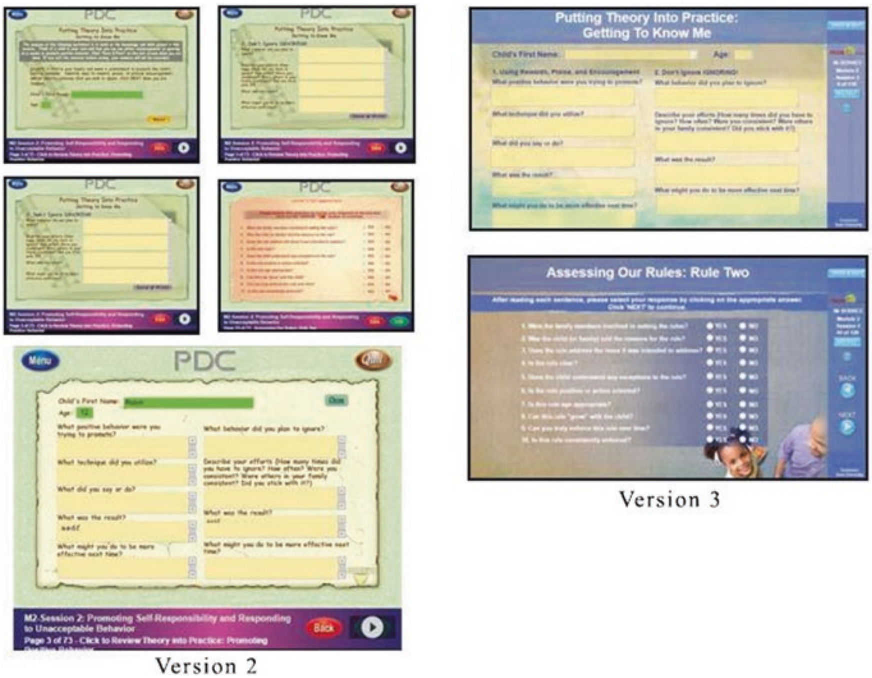


Fig. 10 Summative assessment across versions. Because of the larger screen size and higher resolution for version 3, we condensed two pages into one

elsewhere (Medley, 2016). Selecting representatives with authority to make immediate decisions about the design was essential. Designating a design team from the beginning would have sped our process and is something we would begin with in future projects involving many stakeholders. The challenges in writing the content were great in the beginning, when we had to convert the F2F training from print to digital. It was important to educate print curriculum specialists early on regarding language differences for print (e.g., manuals, F2F curriculum) versus media formats (e.g., videos, graphics, animation). Debating verb usage and word meanings was quite time-consuming, particularly when collaborating with organizations of different cultural language and meanings.

We found it important to balance between encouraging the creativity and ownership of team members and keeping deadlines. The balance point is delicate. Large collaborations in long-term projects involve real people in the process. There will be staff turnover and cultural/personality differences. As our chapter reflects on the design processes and rationale, it is important to recognize the strength in the network of contributors who enrich the training through their own expertise. From SMEs to the university's media expertise and the evaluator who recommend embedding assessments to the graphic designer skillfully selecting the right image, the design rationales and contributions are enriched through collaboration. It was a true network of expertise that contributed to the whole.

Throughout the years, we have been guided by the vision of outcomes that were articulated at the outset of the project. We envisioned developing an aesthetically pleasing, engaging, and instructionally sound product that could continually evolve along with technology and best practices in both training and child welfare. We learned that our early focus on outcomes and continuous adaptations to technologies supported the longevity of the product.

We believe that our product lasted through different distributions methods and technologies because we focused on providing a quality product and service. While this chapter focused on the technological and collaborative affordances and challenges we encountered during the design and re-design of a product, our service to the child welfare agencies could not be overlooked. The technology alone did not drive the longevity. We adapted our skills and product to meet the changing demand and capabilities, but we also continuously evaluated the needs of the agencies and end users and provided technical support during their use of the training.

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Situated Learning Through Situating Learners as Designers

Jonan Phillip Donaldson, Amanda Barany, and Brian K. Smith

Introduction

This chapter describes the redesign process conducted on a 10-week hybrid multimedia development course for students in a teacher preparation program. Though the existing course was created to develop teacher skill in curricular design using various digital tools, our redevelopment emphasized the process of design and how to create designs for learning in which the tools will be put in the hands of learners. The design case described is part of a longer design-based research project focused on the development of courses grounded in the principles of constructionist learning and the design thinking process. This case represents a unique design for learning that is grounded in a theoretical framework which aims to situate learners as designers by connecting constructionist principles, designerly ways of knowing, situated learning, and identity exploration.

Design Goals

This project was a redesign of a 10-week hybrid *Multimedia in Instructional Design* course for students in a teacher preparation program offered through the School of Education at an urban university in the Eastern United States. The course is mandatory for students in both the undergraduate- and master's-level tracks and is intended to help students develop skills in creating and using multimedia and using instructional design models. The existing course originally focused on how to use various tools to create instructional products.

J. P. Donaldson (✉) · A. Barany · B. K. Smith
Drexel University, Philadelphia, PA, USA

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We were invited to teach this course for the summer quarter of the 2015–2016 school year. While the multimedia course is typically offered year-round as an entirely online experience, the summer offering leverages the benefits of both an online class hub (Blackboard) and a weekly in-person meeting, held in the evenings to accommodate students' busy work and teaching schedules. As graduate students and faculty with research and teaching expertise in digital media, design, and collaborative and transformative learning, this course offered a valuable opportunity for us to build on the unique benefits of the hybrid digital and in-person experience in a new course design and implementation. The goal of our redesign was to focus more on the process of design, including not only how those tools might be used to create products but also how to create designs for learning in which the tools will be put in the hands of learners. This paper describes the design process we enacted to create and implement the first iteration of our *Multimedia in Instructional Design* course. We contend that the course design offered richer and more tailored experiences for our group of pre-service teachers who took the class with us in 2016, as design decisions were shaped by the needs of the group and our personal theoretical perspectives and research stances.

Background

As researchers and educators who value deeper learning processes that can meaningfully engage students in self-directed learning as creation and self-transformation, we redesigned the multimedia course to offer experiences that align with these values and research perspectives. More specifically, we leveraged an evolving theoretical framework that synthesized and integrated four distinct lines of theory—three from literature in the learning sciences and one from the literature in the design sciences—to shape our design decisions that we enacted across the learning experience. Given that the research background of designers has a great deal of impact on their design choices (Howard, 2011), we share our individual experiences and roles in the design process below. We then briefly introduce the emerging theoretical framework that informed our assumptions as instructors and course designers.

Designers' Stance

Jonan Donaldson has been an educator for two decades and has participated in extensive instructional design work. In both teaching and instructional design work, he uses constructionist (Papert & Harel, 1991) and situated learning (Lave & Wenger, 1991) approaches. His current research as a PhD candidate investigates conceptualizations of learning and their impact on practices in teaching and learning, design thinking in learning environments, and the relationship between design and learning. He served as the lead researcher in this project and co-teacher of the course.

Amanda Barany has worked and studied in education and educational psychology programs for the last 7 years. Her previous work has explored student interest and motivation, identity exploration, and the effects of implicit bias in higher education, with a growing research emphasis on the affordances of games and digital technologies for learning. Her current research as a PhD candidate investigates patterns of engagement and identity exploration in online communities of practice. She also co-taught this course.

Brian Smith is a professor and Senior Associate Dean of Academic Affairs in the College of Computing and Informatics at Drexel University. He served as associate professor in the MIT Media Laboratory (1997–2002), associate professor of Information Sciences and Technology at Pennsylvania State University (2002–2009), and Dean of Continuing Education at the Rhode Island School of Design (2010–2013). His research interests include the design of computer-based learning environments, human-computer interaction, informal learning, creativity and innovation, and computational thinking and flexibility.

Theoretical Synthesis

The theoretical constructs of constructionist learning, designerly ways of knowing, situated learning, and identity exploration contain features which naturally align, and because they are important perspectives in our work as educators, we leveraged them to synthesize an integrative theoretical framework that supported our design decisions.

Constructionism structures all learning around student construction of artifacts (Papert & Harel, 1991). The construction of meaning informs construction of artifacts, which in turn inform further construction of meaning in mutually reinforcing cycles of iterative development (Kafai, 2006). To facilitate this process, we considered ways to promote focused tinkering (Resnick & Rosenbaum, 2013) and encourage student ownership of artifact construction (Papert, 1999) in our course redesign.

Designerly ways of knowing describes a complex and interdependent set of characteristics enacted by designers (Cross, 2006) including framing (Dorst, 2011; Schön, 1983), wicked problems (Cross, 2006; Rittel & Webber, 1973), abductive reasoning (Dorst, 2011), divergent and convergent thinking (Dorst, 2015; Runco, 2014), rapidly changing goals and constraints (Razzouk & Shute, 2012), prototyping from abstract to concrete (Brown, 2009), constructing prototypes according to designer-constructed meanings (Poulsen & Thøgersen, 2011), contextualized thinking (Suwa, Gero, & Purcell, 2000), reflecting on relevance (Clark & Smith, 2010), and reflection-in-action (Schön, 1995). We extend the traditional definition of a designer to include students engaging in the construction of meaning and classroom artifacts and applied these practices to the redesign of our course.

Situated learning theory emphasizes the collaborative construction of meaning through participation in communities of practices, where newcomers are encouraged to enact valuable forms legitimate peripheral participation that gradually shifts toward more central community activity and expertise over time (Lave & Wenger, 1991). In keeping with this literature, we redesigned our course to encourage authentic participation around a shared practice or topic (digital media use in classroom teaching) (E. Wenger-Trayner & B. Wenger-Trayner, 2015) and in alignment with the specific physical (physical environment, tools, and resources) and social features of this community (Hutchinson et al., 2015; Wenger, 2000).

Identity exploration research reconceptualizes learning as a process of self-transformation over time (Illeris, 2014; Kaplan, Sinai, & Flum, 2014). Learning environments can support this process by encouraging participants to "try on" new roles as they negotiate their internal, historical sense of self in relation their current self a designed context (Erikson, 1959; Markus & Nurius, 1986; Vygotsky, 1978)—in our case the identities of a designer and educator in a collaborative and authentic classroom and design context. We designed our course based on Kaplan and colleagues' (2014) call for environments that facilitate a sense of safety, promote relevance, trigger exploration, and scaffold exploratory actions as a way to encourage identity exploration.

Multiple areas of alignment exist across these theoretical elements, as visualized in Fig. 1. This integrative framework provided the structure for the design case discussed below in which we worked to situate learners as designers and future educators that use digital media tools.

The Design Case

This section will describe the context, the design moves we made, our implementation of the design case (Boling & Smith, 2012), and our reflections on the design.

Course Context

The cross-listed undergraduate- and master's-level course *Multimedia in Instructional Design* is offered each of the four course quarters as a mandatory feature of the teacher preparation program at an urban research university. The course is hosted entirely online and includes readings and written assignments designed to support learners as they "investigate learning theory and its implications for interactive multimedia formats, including the relationship of instructional design principles to selection of media elements (text, video, sound, animation, and graphics) for high-quality design" and "examine human-computer interface principles, navigation features, and visual thinking using a wide range of educational software examples" (Donaldson, 2015).

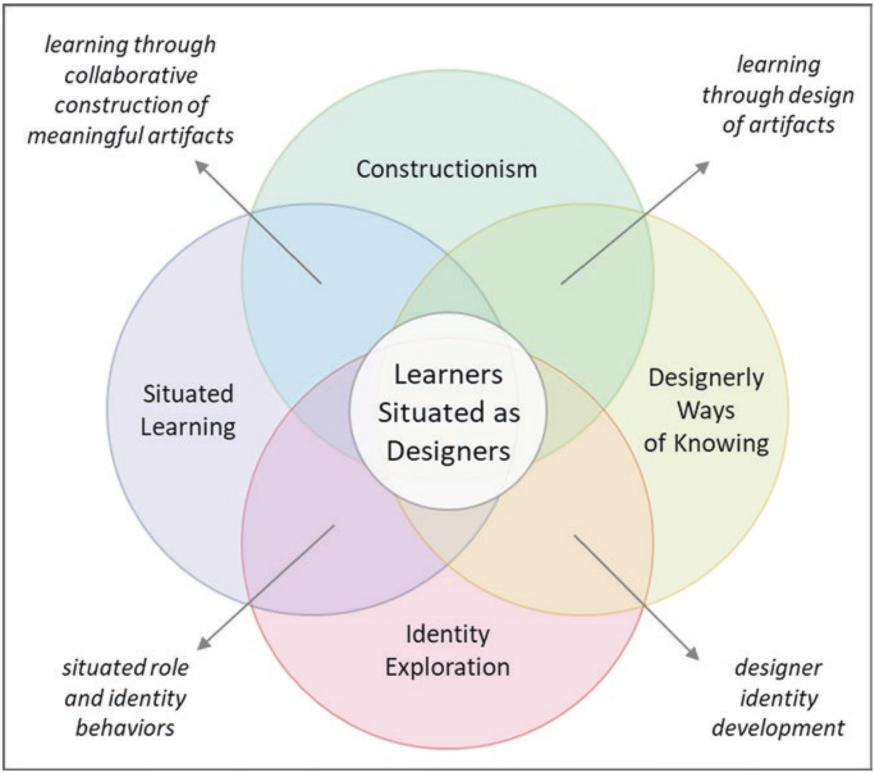

Fig. 1 Theoretical framework integration of constructionism, designerly ways of knowing, situated learning, and identity exploration through which learners are situated as designers and future educators that use digital media tools

Across the 10-week experience, students complete two writing assignments in the early weeks of the course related to the use of digital media tools in education. Using an inquiry-based approach, the learners then explore existing digital media tools (audio, screen capture, animation) and develop their own media elements to share with peers. Discussion board posts every 2 weeks encourage peer-to-peer discussion, and a final group project encourages learners to engage collaboratively at the conclusion of the course. All course elements, including individual submissions and peer interactions, are hosted on the Blackboard Learn course management system.

The initial design of the course offered a valuable and unique structure upon which to base a course redesign that situated learners as designers, given the existence of inquiry assignments that encourage agentic exploration and use of digital tools in their projects. The hybrid-style course, which included the use of Blackboard as well as weekly in-person classes, offers a particularly unique opportunity to design a learning environment more deeply situated in authentic and collaborative designer and educator practices that can be tailored to encourage individual identity exploration and designerly ways of knowing.

The Design

Design decisions were made, rejected, and revised in a fluid and emergent fashion throughout the design process. However, they will be discussed here in terms of three design principles, which in practice were more like discussions with the design situation around design questions. Design is "inherently an emergent, ill-structured problem-solving process" (Svihla & Reeve, 2016, p. 6), and the ill-structured problems in this design project were:

- What features of a designed learning environment can situate learners as designers?
- What designed facilitation practices can situate learners as designers?
- In what ways can constructionist learning, situated learning, designerly ways of knowing, and identity exploration be operationalized in this design situation?

This set of problems were not pre-determined but evolved over the course of the design project. Before we began our own design framing process, the questions were simple and did not include all aspects of the framework described in the previous section. The framework and problems emerged not only in response to design moves but also through negotiated reframing informed by the unique backgrounds of the designers. However, from the beginning the overarching goal of our design was to create a learning environment that encourages future educators to reimagine learning as a design process through their own engagement in the creation of meaning through conversation with the design situation (Smith, 2016).

Design choices—constructionism Early in the design process, we adopted constructionism as our theoretical/philosophical framework to inform course development, so at the earliest design stages the design was structured around learners making things. To that end, we chose to highlight the multimedia projects from the original course and structure the creation of those elements around a design thinking process that could encourage learners to first conceptualize the problem or issue they hoped to address and then creatively and iteratively design their projects as potential solutions. In this way, we encouraged learner agency in the identification of their area of interest, as well as focused tinkering around their designed solutions. We selected a flexible research and design lab room as the site for the in-person class sessions because we wanted an informal space without the physical limitations of many classrooms such as front-facing desks and limited useable wall space.

Ultimately, we found that there are a wide range of possibilities in terms of translating these ideas into practice and therefore chose to integrate aspects of the IDEO (Collins, 2013) and Stanford d.school (Mickahail, 2015) design thinking process models to design our own five-phase model (see Fig. 2). We implemented the five-phase model into the second and third weeks of the course and then referred learners back to the process in subsequent weeks so as to allow for gradually releasing the scaffolding while increasing learner agency as they gained skill enacting this process in their own time.

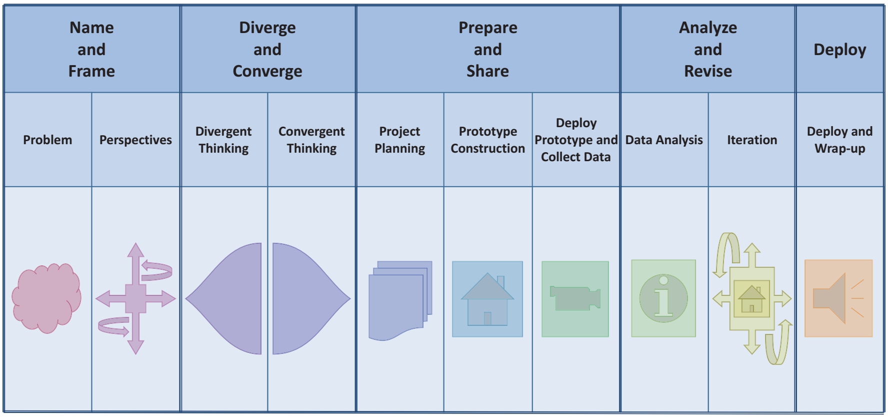

Fig. 2 DTEL process model (DTEL-PM) visualized (Donaldson & Smith, 2017)

The redesigned multimedia projects in weeks 4–8 ultimately consisted of weekly individual multimedia development projects that focused on different multimedia skills (i.e., video editing, music sampling). Each week, we briefly walked students through the functionality and affordances of available multimedia tools, then opened up the room for a period of open exploration and artifact creation while we remained present to provide support.

To further encourage iterative design and focused tinkering around these individual projects, we redesigned the final group project as a collaborative peer effort in which learners could merge and refine their earlier designed elements into a full, cohesive presentation. Figure 3 is a still from a stop-motion video animation created as an individual project, which was later integrated into a group project. The goal of the redesigned group projects was to leverage students' own shifting understandings of learning and knowing to influence similar identity changes in a hypothetical student; thus, we asked students to discuss and reflect on their own identity exploration processes through the course to inform the design of their multimedia tools to support identity exploration and change.

Figure 4 depicts the designed layering of constructionist learning principles (agency, real-world audience, celebrating failure, creating artifacts, and focused tinkering) over the 10 weeks of the course.

Design choices—designerly ways of knowing In our early iterations of course design, we situated learners as designers purely through the use of the design thinking process. Through our discussions in design meetings, we soon agreed that the design would be stronger if we differentiated the design thinking process model from design thinking strategies by adopting Cross's (2006) term "designerly ways of knowing."

We operationalized designerly ways of knowing by embedding opportunities for these strategies into each week of the course (see Fig. 5). For example, during the framing and reframing process, the concept of a wicked problem was introduced

Fig. 3 Example of a stop-motion video participant-designed artifact

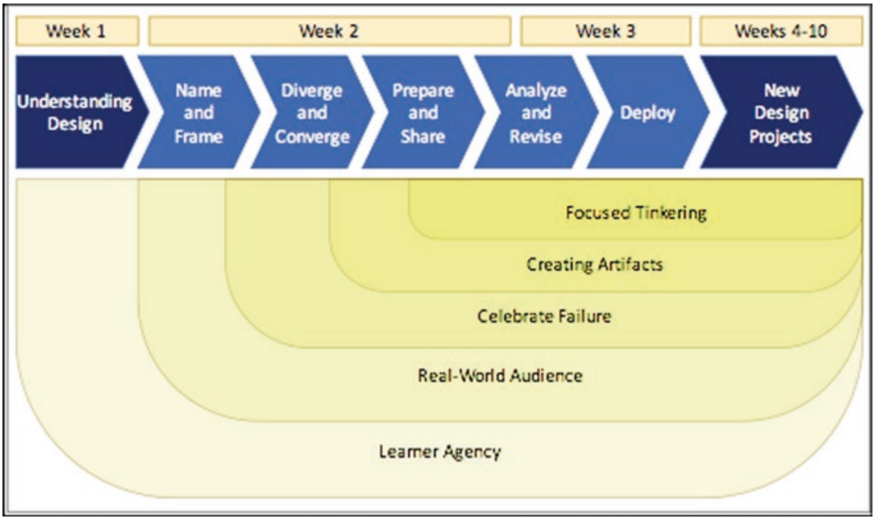

Fig. 4 Constructionist learning principles in the course

using Rittel and Webber's (1973) definition as problems which cannot be defined in the absence of a definition of a solution (the problem and solution definitions co-evolve), have no definitively "right" or even "good" solution, and will inevitably displease some stakeholders. We encouraged students to work in small groups to identify problems they found valuable and to formulate a problem statement around which they could design solutions. Each week, we asked students to spend a few minutes reflecting on their problem statement and encouraged them to shift or mod-

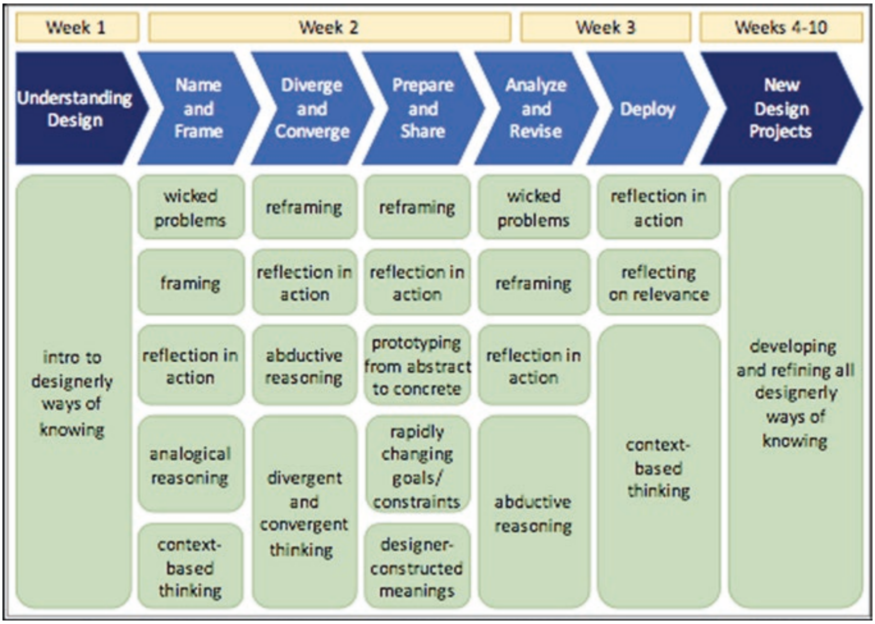

Fig. 5 Designerly ways of knowing in the course design

ify their problem framing to better suit their needs and designs as they evolved across individual and group projects.

Examples of reflection-in-action involved periods of free reflective writing on their design processes, struggles and successes, and shifting understandings of learning and the self. The process of iterative framing and reframing, as well as reflection-in-action, supported learners in the use of abductive reasoning, in which they shifted their understanding of learning and teaching with multimedia tools based on their own course experiences. To further cement these shifts, we encouraged the learners to explicitly reflect on theoretical conceptualizations of designerly ways of knowing and their personal experiences enacting them through weekly class discussions and relevant readings.

Design choices—situated learning Consistent with a situated need for authentic, collaborative learning environments, we selected a digital media design lab that is public for student use at the university as the site for the in-person class meetings. The design of the digital media lab differed from the original classroom reserved for this class, which featured a more hierarchical structure of individual desk chairs all turned toward a podium where the "expert" teacher might transfer knowledge. The new room featured a large, rectangular table around which both learners and the instructors could sit and equitably engage in discussion and collaborative design. We chose this site because it housed a wider variety of digital tools, such as a green screen backdrop and padded sound recording booth. The room was also optimal for use in the redesign because it featured open areas where students could break out into large or small groups to enact the design process and use a variety of tools simultaneously. While the "front" of the room featured a smartboard and projector, we intentionally chose to leverage this feature primarily for the group to share their individual and collective designs, so that they might elicit peer feedback and collectively mediate their learning experiences.

In keeping with their situation in a design lab, we encouraged the group to engage authentically as legitimate peripheral participants in a designer community of practice, enacting all phases of design thinking and utilizing multimedia tools despite limited prior experience. To encourage a sense of safety and promote these kinds of legitimate peripheral participation, we decided to intentionally leave expectations for the weekly individual projects open-ended and graded on completion only to promote a safe environment for students to explore designer identities and support exploration of their triggered interests. During the individual projects, we encouraged students to help each other as often as possible. We discouraged hand-raising in the class and solicited active participation as a vital part of knowledge generation, which positioned learners as valuable contributors of tips for successful tool implementation and the optimal use of digital media to address their wicked problems.

Design choices—identity exploration Our design move of engaging learners in the design thinking process led us to reflect on the implications and affordances of situating learners as designers and aligned with designers' backgrounds and research perspectives. The metaphor of "construction" in which constructivist and constructionist learning are grounded leads to an active/productive conceptualization of learning. The metaphor of "design" could be used in a similar fashion, so we used this metaphor to engage students in conceptualizing learning as the individual and collaborative design of knowledge through the individual and collaborative design of artifacts. This led to our developing awareness that this was not only "learning by doing," or even "learning by making," but also "learning by becoming"—in this case, learning by becoming designers. This perspective aligned with the constructionist principle of designing for optimal learner agency.

Although the designed opportunities for reflection and discussion of the self as a designer provided opportunities for student identity exploration, this concept emerged as a theoretical framework late in the design process. From our previous experiences, we knew that constructionist learning opens up unique opportunities for identity exploration. By going back through the design to make explicit their roles as designers, it was then possible to design reflective activities to trigger identity exploration. Figure 6 depicts our design scheme by which to operationalize Kaplan, Sinai, and Flum's (2014) aspects of identity exploration—trigger exploration, scaffold exploration, promote relevance, and sense of safety.

At each phase of the design thinking process model concluded, we asked students to write reflective posts on their developing perspectives on learning, as well as moments of insight, frustration, and changing feelings (see Fig. 7). Reflection questions such as this related to students' changing knowledge and affect in classroom experiences have been identified as useful design tools for supporting the identity exploration process (Shah, Foster, & Barany, 2017).

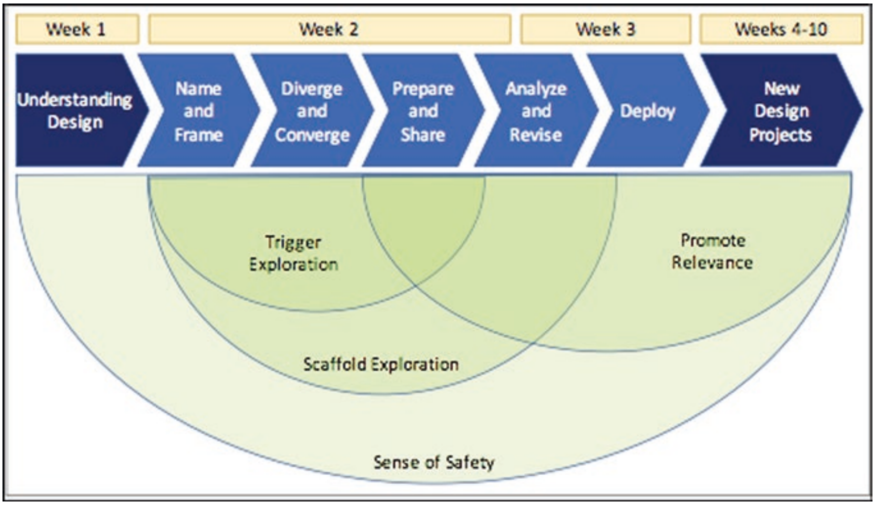

Fig. 6 Identity exploration in the course

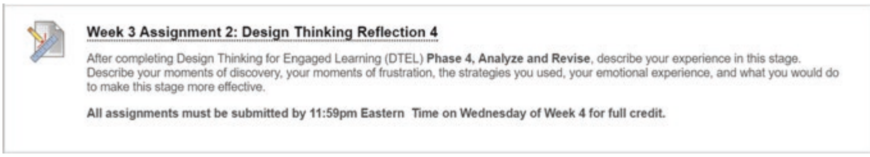

Fig. 7 Example of a reflection prompt

Final Product and Student Response

While our theoretical synthesis served as the basis for initial design changes we enacted (described above), design also shifted to meet the specific needs of students in the course implementation. Nine students attended the redesigned hybrid course in the summer of 2016. They were a nearly even mix of undergraduate and graduate students. There was a fairly even balance between male and female students and participant diversity in terms of race, native language, and socioeconomic background.

During the first week, we asked students to discuss their existing conceptualizations of the word "design" and its role in the life of an educator. We introduced the constructionist nature of the course and the design thinking process we had chosen to implement, and students watched a short video illustrating real-world examples of technology that promotes social connection and change. Ultimately, we learned from week 1 that our students were inspired to use digital tools in their classrooms but had limited knowledge of how to use or implement them. In addition, the majority of the class was unfamiliar with constructionist learning, necessitating that we enact more modeling of the process in early weeks to provide structure and build confidence.

During the second and third weeks, we asked students to form four groups to engage in constructionist learning projects, where they used the design thinking process to develop solutions to a wicked problem that they collectively chose. Based on the needs of our students, we chose to offer more structure to guide their early enactment of design thinking by giving them estimated time limits and brief explanations of how each phase is often enacted by designers. We also regularly participated in the process with the students (i.e., generating possible solutions with them during the idea generation process). After each design thinking stage, we invited students to reflect briefly about that stage (what they liked, disliked, or noticed about the experience), followed by group discussion regarding the purpose and nature of the stage in relation to the larger design thinking process.

During stage one of the design thinking process, we offered each group time to engage in discussion and negotiation, during which they framed the proposed wicked problem, which read "Some of your future students will have conceptualizations of learning as the *acquisition* of knowledge (e.g., memorizing facts). If we believe students will engage in deeper learning if they shift to conceptualizations of learning as the *construction* of knowledge, how might you facilitate that conceptual shift?" After a detailed and situated description of the problem was initially constructed by each group, we guided students through "problematization" of the issue, during which students re-framed it from the perspectives of various potential stakeholders. For example, one group's conceptualization of the problem was reframed from the perspective of a middle-school student in a plant biology lesson who feels unconnected to the course material. We noted that the process of problem framing and perspective-taking necessitated a detailed negotiation process between all nine learners as they grappled with these new processes and ultimately worked to synthesize their different perspectives and areas of interest. We therefore chose to allot twice the planned amount of class time to stage one (almost 2 hours), so that the group had a firm foundation on which to build their designs.

In the second stage, we introduced divergent thinking strategies to encourage students to generate a large number of potential solutions to their wicked problems. Each individual wrote as many ideas as possible on sticky notes, which they placed randomly on their group's wall. After they ran out of ideas, we intentionally encouraged them to come up with many more ideas—no matter how crazy or impractical. We then introduced the convergent thinking process, during which students silently viewed all the ideas on their group's wall and re-arranged the sticky notes into meaningful patterns. Finally, we opened up small group discussions on their various groupings of ideas and invited groups to negotiate a few related ideas into a single, multifaceted idea they could develop into a solution. Ultimately, we noticed that the group was initially hesitant to offer ideas that were too impractical, so we chose to offer up a few of our own (particularly crazy) ideas to set an example for more creative ideation. Figure 8 depicts one such design thinking wall at the end of the divergent and convergent thinking stages. This example group coalesced around creating digital media that connects the growth process of plants to students' development and change as humans.

Fig. 8 Example of a design thinking wall

In the third design thinking stage, we asked students to translate their chosen solution into a plan of action through a project planning activity and then to begin developing prototypes for implementing their solutions (i.e., curriculum). We then engaged the class in discussion on the difference between a prototype and a final design and encouraged groups to prototype in whatever modality they deemed appropriate. In the example group, students merged their specific design interests and skills to develop multiple short digital media pieces that connect botany to student identity. A particularly notable example involved the pairing of a student's original song with a side-by-side video of a growing plant and a student slowly reaching up to the sky (an analogy for personal growth).

The next phase in the design involved groups' deployment of their prototypes to real-world situations to receive feedback. Though we chose to allow students freedom in their choice of deployment method, all groups decided to share their prototype designs via social media; preliminary picture, video, and audio pieces were disseminated to peers online with requests for feedback and development ideas. We noticed that this aspect of the design was difficult to enact on short notice, so we chose to encourage the learners to continue gathering feedback from their sources and to implement them across the weeks.

The fourth phase in our design involved group analysis of feedback collected from their real-world deployment and the process of design iteration based on what they learned. As part of this process, we noticed individuals sharing their creations and asking for feedback on their projects. This inspired us to implement a supportive "art critique" in class, during which students who wanted to could share their work on the smartboard and solicit ideas and feedback from the class. This offered valuable feedback to the designers; the example group discovered that some peers only noticed one half of the side-by-side video due to color and brightness differences and decided to implement video quality adjustments to improve color matching and visibility.

During the final stage of the design thinking process, we encouraged each group to deploy their designs in real-world contexts. The example group integrated their digital media pieces in a real-world biology course, while other groups disseminated their designs in digital formats such as online portfolios, websites, and video platforms.

The course design included two iterations of the design thinking process; in weeks 4 through 6, students developed projects individually, and we provided more explicit scaffolding such as introductions to each phase, descriptions of each activity, and time frames for in-class work. We started the small group design projects in week 4, which continued through the tenth (and final) week. We then chose to pull back scaffolding of the design thinking process at this stage; students had freedom to flexibly implement design phases as we had introduced them. We also encouraged students to integrate or iterate on their individual design projects into their larger group designs (such as the one described above) as they saw fit. Each week, we offered both written reflection and group discussion regarding the relationship between their individual design processes and the larger group design process. We asked students to "publish" their creations in week 10, but encouraged students to choose their own methods of dissemination. We stressed that the final form of dissemination should have real-world impact.

Informed by theory, we chose to frequently and purposefully encourage learner ownership and agency in their own learning process throughout the term. Tinkering was also emphasized explicitly, as was the celebration of failures.

Designer Perceptions and Reflections on the Design Case

Our reflections here are informed by our experience as designers and as facilitators. We include excerpts from students' written reflections to illustrate what we noticed.

We noticed as facilitators that during the first 3 weeks of class, everyone felt disoriented and uncomfortable with the lack of specific directions and detailed expectations. They came into the class with their own set of expectations regarding the roles of the instructors and their roles as students. Initially, students expected us, as instructors and figures of authority, to provide them with information, which they would then be responsible for remembering and using. This suggested that our innovative course design included expectations, patterns of in-class activity, and levels of student agency that were unlike students' existing classroom experiences. We noticed student discomfort lifted toward the end of the design thinking process in the fourth week. Many indicated surprise at the realization that they were actually learning something given the absence of "content" delivery in the course. Their confidence levels rose toward the end of the fourth week and early fifth week, but dropped again during the fifth and sixth weeks in reaction to the removal of the design thinking process structure of earlier weeks. However, toward the end of the course, students demonstrated confidence, learner agency, and excitement as they explored their new-found identities as designers and educators. We believe these patterns of falling and rising discomfort, confidence, and agency were integral to the learning process in this course.

In addition to development of learner agency, we also noted discussion of perceptions of what it means to learn. Many participants discussed their shifting perceptions of the goals and methods of education. There were several variations of the sentiment "In the past I studied for tests and papers, only to promptly forget everything. What I realized recently is that isn't learning, really. I want to be a different kind of teacher than that." Our design intention was that the future educators who participated in this course would approach teaching and curricular design with consideration for these shifted perspectives of learning, as illustrated by the following student example:

> Through this course, we were challenged to experience learning by embracing mistakes. Being encouraged to make mistakes was incredibly enlightening and helped me to better understand the importance of pushing students to take risks, making sure they understand that mistakes are a positive, essential component of learning for understanding

As this course design promoted changes in students' perceptions of learning, and integration of designerly ways of knowing, students discussed their past and present selves as learners; as a whole, students appeared to become aware of the need for an identity shift toward designerly ways of thinking, and many attempted this shift with varying degrees of success. Students reflected on how the process affected them ("I have very rarely been encouraged and comfortable enough to act as uninhibited and silly and creatively") and reflected on the agentic nature of the identity exploration process ("Self-exploration allowed me to craft my own creativity"). On several occasions, students also described how they plan to use elements of this course design in their own classes to enact similar changes:

> This attitude of openness and acceptance seems to be the most critical aspect that I will implement in the classroom environment I hope to create
>
> Just as we were never told that we were right or wrong in the way we approached our designs in class, I want to do the same for my students
>
> At first, the open-ended nature of the assignments was difficult for me to navigate, as the majority of my previous secondary education experiences … were modeled after the transfer-acquisition metaphor. The constructivist and constructionist strategies employed drove me to experience first hand the type of instruction I would like to utilize much of the time in my future classroom

As designers with strong backgrounds in situated learning, we saw this course design as facilitating the development of individual identities as defined in relation to the emerging identities of others, particularly in leveraging the design thinking process to support empathy development. This process of defining the self by considering other community identities became apparent in students' written and spoken reflections. As a result, students regularly reflected on the uniquely situated nature of each learner's experiences and the importance of attending to the situated perspectives of others to understand one's own change and development.

Conclusion

This design case exemplifies a design for learning grounded in a strong theoretical framework reflecting our backgrounds as designers, one which integrates elements of constructionism, designerly ways of knowing, situated learning, and identity exploration. By making design moves which situated learners as designers in a constructionist learning experience that promoted designerly ways of thinking and knowing, learners were pushed to challenge their existing conceptualizations of what it means to be a learner and to reframe their perceptions of self with consideration for existing identities in the broader learning community. This design holds promise as a novel exemplar of curricular experience design to promote shifts among educators and pre-service teachers toward increased learner agency, reframed conceptualizations of learning, and new identities as designers that they can apply to their own future designs for learning.

This design case will be used in our future efforts as designers to produce designs which better support future educators as they develop deeper understandings of learning as a more individualized and situated design process.

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A Cross-Cultural Instructional Design Case Situated in a Global Workplace Learning Context

Jeroen Breman and Lisa A. Giacumo

In this chapter, we discuss the design of training materials for a workplace learning project aiming to build the global supply and logistics capacity of local partners of international nongovernmental organizations (INGOs) in the humanitarian sector. Instead of providing training from a central place, such as at organizations' headquarters or regional hubs, a project team set out to design performance improvement materials, tools, and techniques for local staff of the INGOs in the beneficiary countries to use themselves. The project team consisted of a project coordinator, instructional designer, and subject matter expert trainer, who were managed by one of the INGO consortium member organization's managers.

What does it take to develop a performance improvement solution for distinct target audience groups that are located across the world, in some of the countries where humanitarian organizations operate? We present the context, describe the artifacts and critical design decisions. Also, we discuss the distinctive aspects of the design, development, piloting, and implementation of this performance support and training program. This program includes job aids, operational systems assessment tools, online learning, train-the-trainer, and participant workshops to support the development of knowledge and skills in the field of supply and logistics of local partner organizations' staff.

J. Breman (✉)
Northwest Lineman College, Meridian, ID, USA
e-mail: jeroen@jeroenbreman.com

L. A. Giacumo
Boise State University, Boise, ID, USA

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Context

INGOs operate independently from governments and receive funding from private donations, charitable foundations, and/or church organizations. An INGO is like a nongovernmental organization (NGO), but it operates internationally and often has a presence in multiple countries. According to the World Bank (1989), INGOs are "characterized primarily by humanitarian or cooperative, rather than commercial, objectives," and they "pursue activities to relieve suffering, promote the interests of the poor, protect the environment, provide basic social services, or undertake community development in developing countries" (para 2). Thus, to enhance logistical efficiency, in the past 10 years, international humanitarian aid organizations have begun to change how they deliver aid in crisis situations. Instead of staff from their headquarters or regional offices directly delivering aid, they have begun partnering with local community-based organizations whose staff deliver aid themselves. These local organizations are more adept at facilitating advocacy, policy research, civil society building, etc. They do not necessarily have the talent and capacity to deliver aid during crisis situations. Hence more recently, INGOs have begun to provide training to the staff of these organizations so that they can independently prepare for and effectively respond to crisis situations, as they arise. An advantage of working with local partner organizations is that they have better knowledge of the local markets than aid workers who are flown in from other countries. Building the capacity of local partner organizations in supply and logistics knowledge and skills can improve the efficiency and effectiveness of delivery of humanitarian aid. Capacity building encompasses a very diverse and wide range of activities, processes, knowledge, and skills that organizations undertake to focus on performance improvement by managing organizational culture, relationships, and limited resources allocated across different stakeholders, within and across systems, to effectively meet strategic goals and deliver to a mission. Capacity building may focus on rural economic development, environmental development or protection, schools, and the social sector and at various levels (e.g., community, organization, or individual) (Aref, 2011; Bain, Walker, & Chan, 2011; Barker, 2005; Hinrichs & Richardson, 2015; Wing, 2004).

Historically, members of the supply and logistics department in the humanitarian organization Oxfam Great Britain (Oxfam GB) designed performance improvement solutions and training that headquarters staff delivered to their local partner organization staff in priority countries. As time went on, this delivery model became unsustainable for a variety of reasons. These reasons included high staff turnover rates in INGOs and local partner NGOs, as well as changes in the selection of local partner organizations, and more scrutiny of operational functions from donor agencies such as the European Commission Office for Humanitarian Aid and Civil Protection (ECHO) and the US Agency for International Development (USAID). There was a constant need for retraining, which became impossible to meet. Hence, the Oxfam Great Britain (Oxfam GB) supply and logistics performance improvement team, which consisted of the deputy department head and one of the authors of this chapter who was the department learning and development project manager, came up with a new approach to design performance improvement and training. This new approach shifted the responsibility for implementation from a centralized headquarters to local INGO staff in country who train the local partner organization staff. ECHO showed interest in co-funding a pilot project, if Oxfam GB would collaborate with other international humanitarian actors.

In 2013, ten humanitarian INGOs formed a consortium to develop a capacity building program aimed at the supply and logistics function. The project was called Partner Capacity Enhancement in Logistics (PARCEL) project. Instead of the historic centralized implementation approach, the consortium aimed at decentralizing the training. The goal of this decentralization was to create a more sustainable relationship between the INGO office supply and logistics staff located outside of the UK, near to local partner NGOs, and the local partner organizations staff responsible for supply and logistics activities. The participating organizations were World Vision International, the Save the Children International, Concern Worldwide, Mercy Corps, Tearfund, Oxfam America, Oxfam Australia, Oxfam GB, Oxfam Netherlands, and Oxfam Spain.

The program costs approximately €400,000, and ECHO only allowed 18 months to complete the project. ECHO provided 80% of the funding for this 2-year project and the INGOs 20% or 2% each. None of the ten consortium members would have been able to afford the full cost of the project alone. By working together, the INGOs kept their share of the costs down.

At their headquarters in Oxford, UK, Oxfam GB hosted the project team consisting of one project coordinator, an instructional designer who is also an author of this chapter, and a subject matter expert trainer with experience in humanitarian logistics, under the management of the deputy head of supply and logistics. When this deputy head left the organization, the learning and development project manager of Oxfam GB's supply and logics department, who is also an author of this chapter, managed the project team under the supervision of the head of supply and logistics. Oxfam GB also provided administrative assistance. Additionally, several interns supported the project team, and staff from the consortium agencies sometimes volunteered their time.

Artifact

The PARCEL project team set out to develop training materials for international agencies' staff to adapt and use when building the logistics capacity of their local partner staff. Based on a set of the agreed standards created by a consortium, the team developed a large package of performance improvement and training materials, including:

- An assessment tool to assess local partner organizations' adherence with the standards and identify potential capacity gaps.

- A logistics toolkit with forms and templates for partners to use in implementing the PARCEL standards systematically throughout their organizations.
- Pick-up-and-go training materials to address capacity performance gaps, including a train-the-trainer package and a partner training package.

The project team tested the materials in five countries: Pakistan, Ethiopia, Jordan, Mozambique, and Haiti.

Standards

At the start of the project, the project coordinator and instructional designer, along with the consortium representatives of the supply and logistics function from each of the ten INGOs, came together in a 2-day meeting to agree on the minimum requirements that logistics processes and procedures must meet. Some of these requirements are given by rules and regulations of donor agencies. For example, donors will require that INGOs use a competitive bidding process for purchases over a certain amount. In the meeting, everyone shared their best practices in several areas of logistics. The participants grouped standards into asset management, procurement, warehousing, fleet management, distribution, and cross-cutting issues such as health and safety.

Based on the interests of individual participants and existing best practices in their organizations, the topics were divided up at the end of the meeting to work out details. Several participants volunteered to produce draft standards in one or more of the areas, sometimes collaborating with other participants. Drafts were then shared electronically and refined in several feedback rounds using email, cloud-based file sharing, and phone-conferences. Once agreed upon, the standards formed the basis for all materials that the project team developed.

Performance Support Materials

The performance support materials prevent unnecessary training and support the target audience to build capacity for each of the standards. The performance support materials designed for this project included both an assessment tool and a logistics toolkit. All source files are available on ParcelProject.org in the Resources page links. These performance support materials are designed for use by both the partner NGO staff and their sponsoring INGOs.

The PARCEL Partner Assessment Tool helps partner organizations assess their logistics systems capacity against the PARCEL standards. Specifically, the tool helps identify the resources, internal procedures, and policies to comply with the PARCEL standards and reveals areas for improvement. The assessment focuses on the five areas of the standards mentioned above. The PARCEL Partner Assessment

Tool is for use prior to selection of individual training modules, which may be desired to support partner organizational capacity building goals. Together, a sponsoring INGO and partner NGO staff can assess the strengths and opportunities for organizational capacity building in humanitarian supply and logistics through the systematic analysis of current operational practices.

The logistics toolkit is a collection of forms used in five of the six logistics areas to support the organizational processes and systems required to meet the PARCEL standards. Each area includes a guidance document, which provides explanations on how and when to use the tools. The tools are recommended forms from consortium agencies of the PARCEL project. They have been designed to be as generic as possible and may be modified to suit the needs of the organization. No tools were available for the cross-cutting standard. The logistics toolkit is for use after the implementation of select training modules, based on organizational capacity development goals. NGO staff can select and modify specific form examples for systemic implementation of the PARCEL standards in operational practices, which would potentially be supported through coaching from the INGO.

Training Materials

The training materials are organized for the two different employee groups—NGO partner staff and INGO trainers. The materials for both audiences support instruction and learning needs with facilitator guides, participant manuals, and the ancillary tools mentioned previously. The materials cover all areas of logistics described in the PARCEL logistics standards. The elearning modules can be hosted on an organization's own learning management system. The Articulate Storyline source files and SCORM output files are available on ParcelProject.org in the Resources page links. For those without an LMS, the elearning materials are available on DisasterReady.org.

NGO Partner Staff The partner training program was designed around a realistic scenario to introduce local NGO staff members to the logistics standards and the processes necessary to implement those standards in their own organizations. The training materials for this audience include elearning and face-to-face workshops.

The elearning materials are divided into six 15-minute modules that introduce the standards in a scenario-based format, as shown in Table 1. In scenario-based learning, a series of decision points leads the learner through different actions prescribed by the standards (Clark & Mayer, 2012). Learners make decisions in mini scenarios presented to them, with the logistics standards as guide. For example, in the asset management module, the learner gets the role of the logistician responsible for asset management and needs to decide what to do when a new laptop gets delivered to the office (Fig. 1). The scenarios represent authentic workplace cases where employees would make contextualized decisions aligned to desired logistics systems performance.

Table 1 Scenario-based elearning modules and descriptions

eLearning module	Description
Introduction to standards	This module introduces the PARCEL project, the five logistics areas it covers, and a specific set of common standards and ways of working that apply to all areas of the supply chain
Procurement	Procurement means buying goods and services for your project. In this module you will make decisions about procurement during a typhoon response
Warehousing	Warehousing means storing items for your projects, either for distribution to beneficiaries or for use by your staff members. In this module you will choose a warehouse and then decide how to organize and manage it effectively
Fleet management	The fleet management module looks at managing the vehicles you use to support your programs. In this module you will make decisions about how to manage your fleet effectively to support a multi-site project
Asset management	Asset management is about taking care of your organization's valuable items. In this module you will follow the life cycle of a laptop and make decisions about how best to manage it
Distribution	Distribution is the process of delivering items to beneficiaries during emergency response. In this module you will look at managing distributions within a camp and make decisions about how to do that in the most effective way possible

Note all materials are copyright protected with a creative commons license

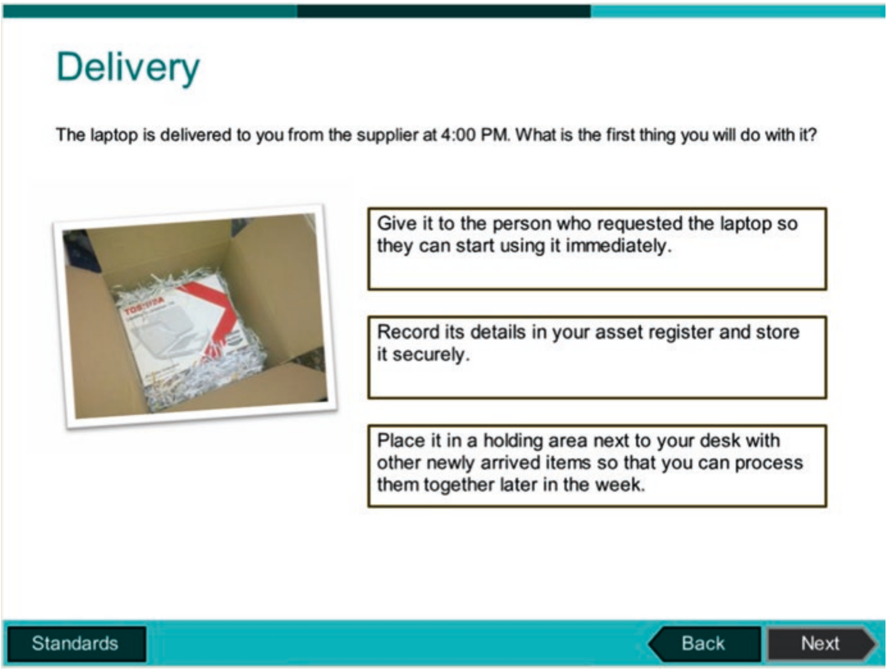

Fig. 1 Example screenshot of elearning module on asset management

The face-to-face workshops materials took the form of what we called pick-up-and-go packages (available on ParcelProject.org in the Resources page links). For each standard, several distinct sessions were planned with an associated package. The packages are such that anyone with some background knowledge of the subject matter and in training should be able to pick up such a package and deliver the session. Each package includes at least facilitator's notes, containing a detailed script of the session, including timings, presentation notes, and descriptions of learning activities. The guide also describes the best setting for the space and materials needed. If applicable the package also includes instructional training materials such as slides, handouts, and descriptions of activities. Examples of these instructional training materials are shown in Fig. 2, 3, 4.

INGO Trainers The INGO train-the-trainer program was designed to prepare INGO staff to do the capacity building in country. The intended sequence of the training materials includes introductory information provided in elearning courses, which preface instructor-led training events. Lastly, follow-on activities are included; they are designed to sustain learning on the job, after the training concludes.

Example slides

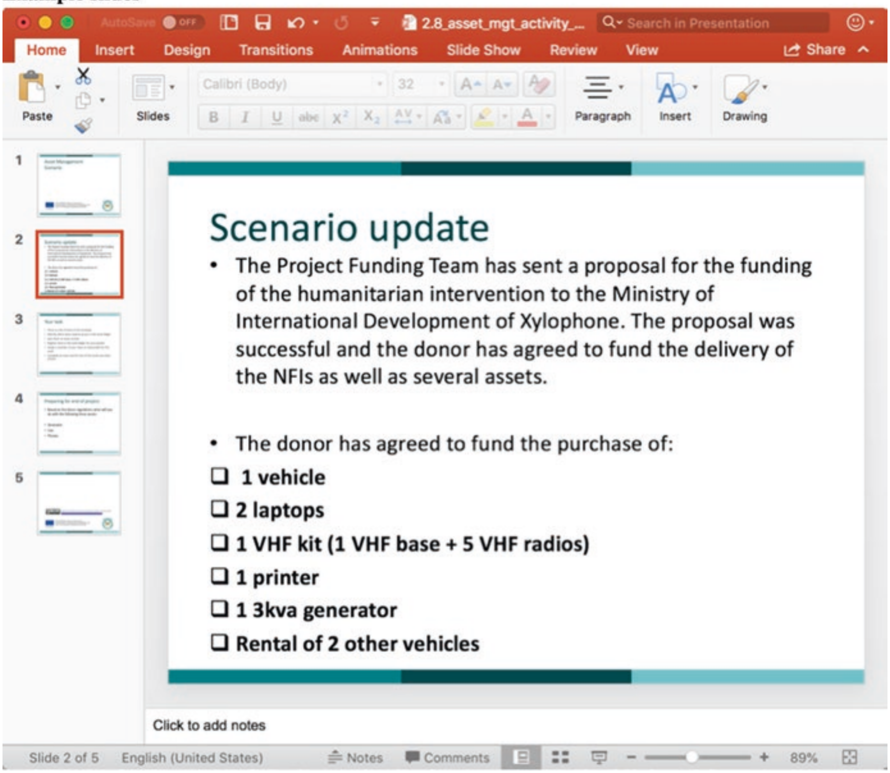

Fig. 2 Examples slides

Example handouts

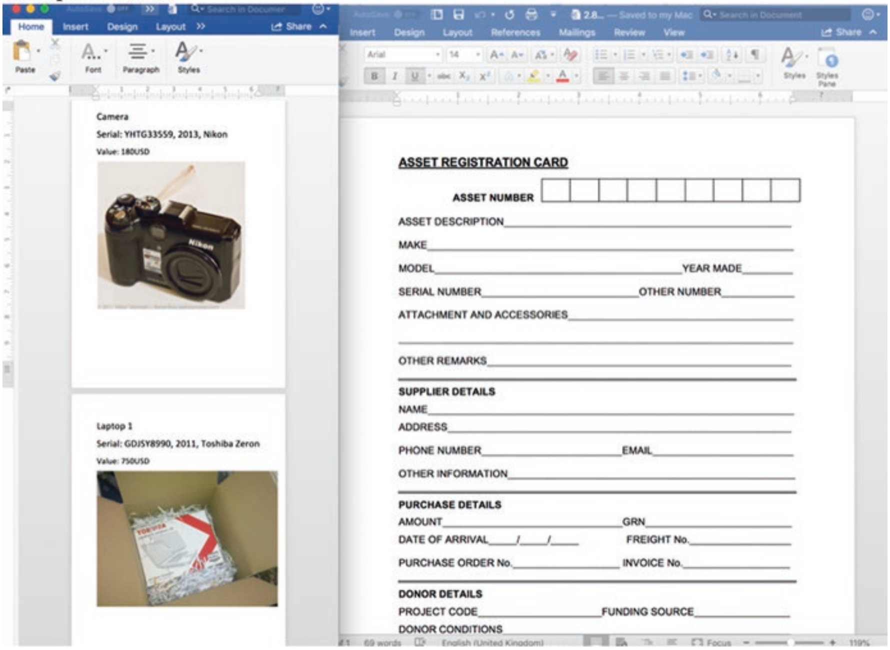

Fig. 3 Examples handouts

The six elearning scenarios previously mentioned are also made available to INGO trainers to support a shared mental model and framework for supply and logistics capacity building among collaborating organizations. We added a seventh scenario-based module for the train-the-trainer materials to introduce the capacity building model. This module is available in the same modalities and systems as the partner elearning materials. It is about sustainable learning—the process of building capacity and applying learning to real-world situations and then reflecting and adjusting one's approach.

During the face-to-face workshop, the INGO trainers learn how to support NGO partner staff learning about how to put the standards into practice in their organizations. During the workshop, they learn to answer common questions that arise about the standards during partner training. The workshop also simulates the partner training environment by providing participants an opportunity to practice training skills by teaching one partner session to other INGO participants.

After participants complete the elearning, at the end of the face-to-face workshop, they develop an action plan to describe what they want and need to properly implement the standards in their organizations. The action plan is a contract between

Example description of activity

Fig. 4 Examples description of activity

the organization and the INGO that they partner with. The INGO supports the implementation of the action plan after the workshop conclusion through continued meetings and group web conferencing events.

Additionally, sustainment activities are provided to facilitate an ongoing community of practice, to support learning and model the desired behavior with training-of-trainer's participants. An example activity is a webinar for participants who use the assessment tool. The instructional designer developed a second example webinar, where the subject matter expert facilitates an interactive webinar session. In this session, participants shared experiences and results of their capacity building efforts with partners and practice coaching skills using Skype.

Critical Design Decisions

Needs Assessment

Although the INGO consortium members involved with the project felt confident in their understanding of the performance improvement needs the project team aimed to address, the instructional designer wanted to survey representative partners. The purpose of the survey was to find out about their experiences of capacity building, their access to technology, and how confident they felt about their organization's logistics processes and systems readiness to respond in a humanitarian crisis. Persistence paid off, as the needs analysis proved to be a key source of information for the instructional design. In this section, we describe the actions taken to assess the performance and learning needs (Breman, Giacumo, & Griffith-Boyes 2019) .

The instructional designer sent a survey to 142 partner organizations in 21 countries (Breman et al., 2019). The 106 responses gave the project team information about the access to technology, willingness to use these technologies for learning activities, and experiences with and preferences for training methods (Breman et al., 2019). The responses debunked some of the misconceptions that the consortium members had about the target audience. For example, they assumed the partners did not have access to technology and would not like to use technology for learning (Breman et al., 2019). The survey showed that organizations had much more access to technology and experience with technology-supported learning than initially thought, which opened the way for a more blended approach (Griffith-Boyes, 2014).

The instructional designer did some research into the use of text messages to deliver micro-learning and/or motivational messages. There are examples where text messaging was implemented in projects in developing nations (see, e.g., Isaacs, 2012). These projects are generally small in scale in a specific country context. Often, they are sponsored by a phone manufacturer and/or local mobile service providers; facilitators send out text messages in the same country. However, when the instructional designer investigated the possibilities to run such projects on an international basis, the service charges were enormous and unaffordable.

In terms of preferences with regard to capacity building options, the respondents asked for a system of performance support. They requested access to experts, support from peer networks, and context-appropriate training tailored to their specific needs. And, they wanted to receive training in a variety of training modalities, including face-to-face and online.

Based on the results from the survey, the instructional designer chose a blended learning curriculum, including a combination of online, face-to-face, and more flexible sustainment activities (Breman et al., 2019). This strategy was chosen because the needs analysis showed that partner staff were willing and able to participate in a variety of training delivery modalities (Breman et al., 2019). The instructional designer determined that the participants' use of elearning prior to workshop attendance would afford everyone with a common framework and language upon which to build new skills. The project coordinator and instructional designer created a systematic communications approach to take participants first through elearning, then face-to-face, and finally sustainment activities, by distributing packaged email scripts, facilitation guides, and communications materials. They created a systemic approach by involving INGOs and partner NGOs in operational systems performance assessments, workshop selections, and two different levels of workshops, which are each built to integrate deliberate feedback loops, tools to support organizational performance, and ongoing learning partnerships.

Materials

The project team set out to develop materials that anyone could use and adapt for any location in the world to support the development of capacity in INGOs logistics coaches and trainers as well as the logistics functions of local partner NGOs. These materials include both performance support and instructional materials. We detail the most critical design decisions made during the process of creating the artifacts previously described in this section.

Designing for a Global Audience—Is that Even Possible? International humanitarian organizations respond to emergencies when they occur in so-called failed states (Oxfam, 2015) or at a scale that overwhelms the local government such that they ask for assistance. Where these crises happen often, international humanitarian organizations work with local partners to develop the capacity to respond in country. Regulations governing humanitarian organizations do require many common performance standards across the globe, and there are also some commonly agreed-upon ethical practices across cultures. In this case, we focused on designing performance support and instructional content that related directly to these agreed-upon performance standards and ethics because many partner NGOs cannot access available funding or lose access due to a lack of human resources and operations capacity. While we succeeded in gaining representation from consortium members in critical program design and development decisions, we fell short on gaining representation from partner NGO staff in the form of reviews to support materials design and development decisions prior to pilot testing.

The instructional designer built the overall curriculum design with the principle of spaced learning in mind (e.g., Thalheimer, 2006). This strategy was chosen because the instructional designer was reading about it and the learning and development project manager had used it previously with some success in the organization. The instructional designer used spaced learning by repeating the same points from the elearning in the face-to-face workshops and sometimes in the sustainment activities, which are each implemented after a break and are interwoven with other related content. In other words, we designed a clear learning pathway from building the foundations, enabling more complex and active learning, and then putting new skills into practice through sustainment activities.

We developed the elearning using the principle of scenario-based learning. We chose this approach because the more successful learning activities from previous projects in the organization linked new concepts with realistic workplace situations. We created these scenarios in dialogue with the consortium members, the subject matter expert trainer, and the instructional designer.

Simulation learning is a form of experiential learning with a high degree of authenticity in a safe learning environment (Breckwoldt, Gruber, & Wittmann, 2014). We chose this strategy because the learning and development project manager had success with it in previous organizational performance improvement projects. Also, the nature of humanitarian emergencies creates high-stress, fast-paced, and sometimes dangerous environments, where novice learner performance is unacceptable. We implemented this strategy in the partner workshop with a realistic emergency scenario, such as a drought or earthquake as a simulation. Learners work through a series of activities related to the PARCEL logistics standards, learning how to apply the standards in such a scenario. The activities simulate the work they would do in a real emergency. By the end of the workshop, participants complete all elements of a logistics plan for the specific scenario.

In this design project, the consortium members' goal was to formalize a support system built on a community of practice framework in which individuals support each other's learning well after the last day of training. This community of practice is thus "organized around professionals who perform similar activities and use their strong social bonds and high levels of intentionality to extend and improve their practices by building a base of shared knowledge" (Smith, Hayes, & Shea, 2017, p. 220). We chose this strategy because of the high staff turnover rate in INGOs and partner NGOs, with the intent to build more connections between new employees and existing employees for the purpose of sharing knowledge. Further, we hoped to move from hierarchal connections between one INGO's staff and its partner NGO staff to connecting different partner NGOs' staff to each other. We did this by putting different partner NGOs in the same workshop with networking activities and through a discussion tool on the project website.

Pilot Testing

The consortium members selected five countries for pilot testing: Pakistan, Ethiopia, Jordan, Mozambique, and Haiti. Experienced trainers delivered the train-the-trainer workshops in Pakistan, Ethiopia, Jordan, and Mozambique. The train-the-trainer participants all delivered one or more sessions in the subsequent partner training workshop, under the guidance of the experienced trainers. In Haiti, the team focused on testing the assessment tool and linking the results to targeted partner training. In this section, we discuss what the project team considered in the pilot test planning, the pilot testing, and what can be learned from the pilot tests.

Representation Between input from the consortium members, the NGO partner staff needs assessment responses, the project team, and the authors' combined experience supporting performance improvement and workplace learning in diverse locations across the globe, we started the project believing we had adequate representation to build an efficient and effective solution for delivery across the globe. In terms of getting diverse representation, the program and materials design, development, and implementation across multiple organizations and geographical cultures were successful. Representatives from each INGO bought in, contributed feedback during review cycles, and implemented assessments and training for their staff. The pilot testing of the partner training materials across multiple organizations and geographical locations resulted in feedback that also contributed to revisions and polished materials for distribution. In short, we are confident that the extent of representation we solicited resulted in materials that are ready for adaptation for any location in the world.

Cross-Cultural Factors Edmundson (2007) describes strategies of cultural adaptation of elearning materials for four levels of complexity. The four levels include (1) simple information, (2) hard skills and core concepts, (3) soft skills and complex knowledge, and (4) attitudes and beliefs. From simple to complex, the suggested adaptations are translation, localization, modularization, and origination, where higher-level strategies also require the underlying lower-level strategies. We found this to be a useful framework to reflect on our experiences of the PARCEL project. The content levels for this project primarily focus on lower-level knowledge and skills. This supports our focus on translation and localization.

Translations Logistics standards and processes were universally applicable, simple knowledge. Thus, we decided translation of the instructional materials would suffice when the target audience did not speak English proficiently enough for workplace performance. Logistics staff from INGOs deemed English to be acceptable for the partner NGO materials delivered in the first two countries, as well as for the train-the-trainer materials for all of the pilot countries. Partner training materials were developed in English and translated to Arabic, Portuguese, and French.

The consortium members overestimated the English language skills of their staff and partner staff in all cases. For example, in Mozambique, six of twelve train-the-trainer participants did not speak English at all. And while the Pakistani trainers did speak English, only a small percentage of the local partners did. In Pakistan, the trainers all volunteered to translate. Thus, the early pilot testing resulted in unexpected time needed to deliver the training, as well as learner frustration, taking attention away from learning. We encumbered unexpected costs in subsequent pilot events when we used professional translators.

When the project team solicited feedback from participants in the workshops, we encountered problems with the quality of the translations in Arabic and Portuguese. The participants in Jordan questioned the quality of the Arabic translation in general. In Portuguese, the problems were related to profession-specific issues. A literal translation does not always reflect the jargon used in a specific field. The project did not have the resources in house, or the time and money, to check the quality of translations in Arabic and Portuguese. All final materials were published in English, as well as partner training materials in French. And even before the project was completed, a volunteer translated the standards, assessment tool, and elearning text into Spanish. After completion of the project, a group of INGOs that work in Spanish-speaking countries funded the translation of the remaining materials.

Localization Designers can adapt materials to local audiences in several ways. In the Parcel project, the team considered imagery. The adapted scenario materials are based on common geographical crises occurring in different locations.

Images Given that the project team developed materials for a global audience, they decided to select imagery from the collections of different INGOs showing a mix of people and places. The team assumed that no one would feel excluded if participants of trainings recognized themselves in part of the pictures. However, one experience in one of the pilot workshops might indicate that this was not the case.

The train-the-trainer workshop includes a section about cultural awareness. Perhaps fueled by this subject, teaching participants to look critically at their training content and materials to make sure it does not conflict with the culture of the target audience, a participant in Pakistan gave disapproving feedback about the use of pictures showing women sitting next to men and images of sub-Saharan African people. While this might be understandable from a cultural perspective, it was surprising to us to get such comments from people who work for organizations that fight gender discrimination and poverty.

As previously noted, when we first prepared the materials for cross-cultural implementation, we decided that the training dealt only with simple knowledge and skills. In post hoc reflection, we realize that we also briefly touched on origination beliefs in the cultural awareness portion of the train-the-trainer instructional materials. Our misconception led to this participant's reaction. We continue struggle with this point. What culture should one adapt materials to in humanitarian and international development project contexts? The sponsoring organization's culture? The local group's culture? This is something we have not found the answer to yet.

Scenarios The partner training materials are scenario-based simulations. Given a realistic scenario of an emergency, groups of participants create a logistics plan for the response. Different regions and countries will be prone to different types of emergencies. So, the training materials are meant to be adapted to include a realistic emergency scenario. The project produced three different scenarios for the five pilot workshops: an earthquake, a drought, and a scenario related to internally displaced people due to flooding. The logistical plan for different scenarios and the challenges around it do not differ a great deal. In the end one needs to procure supplies and get them to beneficiaries in an efficient and cost-effective manner. The final materials that are shared on the project website have placeholders where training organizers can enter a relevant disaster, including locations, dates, and specific challenges related to the disaster. During pilot testing, the adapted and localized scenarios were very well received by workshop participants.

Project Management Projects of this scale and complexity require adequate planning of time and resources, both human and financial. By working together, the INGOs kept their share of the costs down and convinced the institutional donor of the widespread need for the proposed products. But this particular donor also had very strict regulations for the delivery schedule, which put a lot of pressure on the project timelines, with a grant period of 2 years. By the time the proposal was accepted and funding was available, only 16 months were left; this meant we needed to adapt the project plans.

When we first planned the project, we planned to conduct assessments with several partner NGOs to determine training needs and customize workshop content. Yet, the input and review cycles for the standards took longer than expected. However, the pilots were already planned and so we chose to delay completion of the assessment tool in favor of completing the workshop materials. We anticipated delivering a pilot implementation and then making necessary changes to the materials before delivering the next pilot implementation. In the end, we ran out of time to complete major revisions after each pilot and were only able to complete them after every other pilot implementation. We had to skip the full train-the-trainer workshop in the last pilot implementation and instead piloted the assessment tool for the first time, because it was only just completed at the end of the pilot phase and we did not have enough time for implementation.

Conclusion

On December 29, 2014, the project team made all resources available through the project website. The project team delivered on time. There is little information about how and how much the materials are used. The authors and many others who were involved in the project have moved on to different organizations and projects. However, some indications of use exist.

Four years later, statistics from the project website show that the standards document has been downloaded almost 1000 times in English and over 175 times in French, a set of posters of the standards have been downloaded almost 1200 times, and the logistics assessment tool has been downloaded more than 500 times in English and almost 150 times in French. More than 1000 users registered to access the elearning modules on the project site, and about 150 completed all modules. Some of these registered users are from original consortium members, and many are from different agencies, judging from their email addresses. The largest group has private email addresses from providers such as Gmail or Yahoo!.

Given the open access to source materials, we don't know in what other ways the materials are available. For example, the elearning modules are also hosted on disasterready.org where several users have entered reviews. Oxfam GB also hosts them on their own learning management system. Given the open license, anyone could be hosting and sharing materials from the project.

From time to time, when agencies involved in the consortium organize an event around the standards, they reach out to others and see if they want to join. For example, in June 2015, Tearfund and Oxfam co-hosted a train-the-trainer event in London. Next to consortium members, staff from two other agencies joined the workshop. The project website mentions partner training in El Salvador and a train-the-trainer workshop in Bangkok, Thailand, with participants from ten countries representing seven agencies. Finally, a Facebook page exists titled Humanitarian

Logistics Nepal, showing pictures with project materials in them and mentioning logistics training organized by an unknown agency. The page has since been used to share logistics information, training announcements, and vacancies.

The primary design constraints we navigated in this project included the limitations imposed by grant deadlines, a universal design for performance improvement in different organizational workplaces, geographical and cultural settings, and INGO-NGO partnerships. All design projects come with deadline limitations. The unique nature of grant deadlines can be especially challenging because they happen outside of the context of normal intra-organizational operations. Normally, as intra-organizational priorities and needs shift, so do project resources and deadlines, such that a natural balance occurs between the available resources and a project team's abilities to get things done. When working on a grant schedule across multiple separate organizations, shifts in each organization's priorities can disrupt the balance between available resources and the need to meet externally set, rigid deadlines. While we acknowledge that externally set, rigid deadlines can also keep an inter-organization collaboration progress from moving forward, the lack of balance between and fluidity of resources and deadlines means that project teams must be prepared to make more concessions in design work.

We also communicate caution to teams setting out to create a universal design for different organizational, geographical, and cultural settings. While it is possible to create a base of materials for cross-cultural implementation, these materials will most certainly need significant pilot testing along with additional adaptations prior to future implementation in each different setting. We recommend a thorough analysis of the desired learning and performance outcomes with a systematic approach to adaptation for each culture and adequate representation, which matches the target audience's needs with design choices (Asino & Giacumo, 2019).

Lastly, the nature of INGO-NGO partnerships is complex. Unlike performance improvement and training initiatives in most private organizations, sophisticated design work in this context cannot result in performance improvement and training that is prescriptive, directive, and outputs standardized performance operations. While we did develop performance support systems examples and training materials that speak to industry-wide accepted standards, we did not attempt to install specific operations, organizational protocols, or one-size-fits-all implementation strategies in partner NGOs. Instead, we designed for an INGO coaching approach to facilitate organizational partnerships, an operational assessment tool to support partner NGO selection of targeted training, example toolkit resources which can be adapted for specific contexts, and support for local implementations.

As the project unfolded, we periodically looked in the literature for examples of successful projects similar in nature, especially when we ran into pilot implementation adaptation challenges. We didn't find any examples of authentic design cases that would help us decide how to proceed. We hope that this design case helps emerging designers and project managers make informed decisions, avoid what doesn't work, and build upon what does work.

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Reconciliation as Design: A Design Case

Diane P. Janes, Janice Makokis, and Kathryn Campbell

In this paper, the authors describe the case of designing a course in the Indigenous Industry Relations professional certificate, one component in a suite of learning activities that form part of the University of Alberta's response to the calls of the Truth and Reconciliation Commission (TRC) released, in Canada, in 2015. We present this case as a representation of design and teaching as a political act (Turner, 2010)[1].

The Context of the Design

Established on June 2, 2008, the Truth and Reconciliation Commission of Canada (TRC) was created by the parties of the Indian Residential Schools Settlement Agreement. The commission was part of a holistic and comprehensive response to the experiences of Indigenous Peoples attending Indian residential schools, a system implemented in the last half of the nineteenth century. The system has left an undisputed legacy of harm. The Commission, chaired by Justice Murray Sinclair, worked within an Indigenous tradition cross-country to gather stories of survivors, and survivors of survivors, of the Residential School System and concluded with 94

[1] This paper is the collaboration of a non-Indigenous Dean of a University Faculty, a non-Indigenous Instructional Designer who attended the course as a student, and the course co-author, an Indigenous scholar and lawyer. The Instructional Designer was not part of the funding of the project but entered the project later as Instructional Designer and participant observer.

D. P. Janes (✉)
Southern Alberta Institute of Technology, Calgary, AB, Canada
e-mail: diane.janes@sait.ca

J. Makokis · K. Campbell
University of Alberta, Edmonton, AB, Canada

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Calls to Action for "reconciliation." According to the TRC, promoting "reconciliation" requires not only learning about Canada's colonial past and its intergenerational impacts but also creating spaces and places within the academy that bring equity and value to Indigenous knowledge systems and expanding appreciation for the role Indigenous knowledge and traditional ways of learning contribute to social and environmental sustainability.

The Indian residential school system was a network of boarding schools for Indigenous Peoples, funded by the Canadian government's Department of Indian Affairs and administered by Christian churches. The school system was created for the purpose of removing children from the influence of their own culture and assimilating them into the dominant Canadian culture. Characterized now as agents of cultural genocide, residential schools were justified by arguments that they "would assist Aboriginal people in making the leap to civilization" (TRC, 2012, 4).

Survivors of residential schools and their families have been found to suffer from historic trauma that has had a lasting and adverse effect on the transmission of Indigenous culture from one generation to the next. Passed on intergenerationally, historic trauma is the "cumulative stress and grief experienced by Aboriginal communities …translated into a collective experience of cultural disruption and a collective memory of powerlessness and loss" (Reimer, 2010). This trauma is implicated in "persistent negative social and cultural impacts of colonial rule and residential schools, including the prevalence of sexual abuse, alcoholism, drug addiction, lateral violence, mental illness and suicide among Indigenous Peoples" (Reimer, 2010).

Although it is the fastest-growing community in Canada, more than half of the Indigenous population has not finished high school and just 6% have a university degree. The lifespan of Indigenous Peoples living on reserve is many times lower than the average Canadian. Indigenous youth are seven times more likely to be victims of homicide, five times more likely to commit suicide, and twice as likely to die an alcohol-related death. One in three Indigenous teenagers are in custody, the infant mortality rate is double the Canadian average, and Native children are at higher risk of a wide array of serious health problems. Indigenous girls are at greater risk of sexual assault, domestic violence, and teenage pregnancies. Not surprisingly, unemployment among Indigenous Peoples is more than twice the Canadian average. A third of the population is on social assistance, rising to more than 80 percent in some communities (c.f. Barman, Hébert, & McCaskill, 1987; Brody, 1987; McMillan & Yellowhorn, 2004; Pettipas, 1994).[2]

[2] While setting the context of the educational environment, the TRC was completed and its report submitted to the Canadian government by the time this course was designed so the TRC members and staff did not have direct input into the course creation.

The Design Perspective

As we are becoming more globally aware, learners are more successful in environments in which knowledge is organized and made accessible in ways that reflect the worldview of their cultures. Further, evidence is strong that knowledge domains are structured in different ways and that the “skills and competencies” demanded by our societies cannot be universally applied (McGivney & Winthrop, 2016; Spiro, Coulson, Feltovich, & Anderson, 1988; Zhao, Zhang, & Wan, 2015). Learning styles and preferences vary widely, while Western education has privileged verbal learners. Poststructuralists argue that we are simultaneously part of many cultural communities at once. In this view, designers may be part of one cultural community, i.e., the professional instructional design community, at the same time as they are gendered, socialized, and politicized, products of their age, upbringing, and schooling, with core values that implicitly inform their practices. Implicit assumptions, values, and beliefs are represented in choices made for knowledge representation. Justice Murray Sinclair, chair of the TRC, underlines this point when he writes that the Westernization of education was no less than an assault on Aboriginal values, beliefs, and traditional family structures:

> Historically Aboriginal people throughout North America lived in successful and dynamic societies ... (that) had their own languages, history, cultures, spirituality, technologies, and values. The security and survival of these societies depended on passing on this cultural legacy from one generation to the next...through a seamless mixture of teachings, ceremonies, and daily activities...traditional Aboriginal teachings described a coherent, interconnected world... There was no rigid separation of daily secular life and spiritual life... Ceremonial feasts could bring people together for a variety of spiritual, cultural, and economic purposes. At such feasts, people could fulfill spiritual commitments, exchange goods and information, and impart traditional teachings. Elders were the keepers and transmitters of this knowledge... education was woven into everyday activities. In this way, living and learning were integrated. Children learned through storytelling, through example, and by participation in rituals, festivals, and individual coming-of-age ceremonies.... This teaching method was strong enough to assure the survival of identity, history, traditions, and beliefs.... Given that the Aboriginal education system was intertwined so tightly with both spiritual belief and daily life, it is not surprising that Aboriginal people were reluctant to give their children over to others to raise. (TRC, 2012, p. 7–11)

Storytelling, ceremony, spirituality, and ritual – learning processes through which identity is formed – these are now acknowledged as essential attributes of programs for First Nations learners. Ethical program development and/or research with Indigenous communities occurs in ceremony and is presented to community Elders and Knowledge Keepers for their input and guidance. The location of the teaching is land-based and story-based, and “Indigenous and non-Indigenous learners come together in an environment that promotes healthy, respectful discussions of sensitive issues and contributes to relationship building for future networking and advocacy work” (personal correspondence with Fletcher, June 2015).

The Design Space

In 2016, the University of Alberta invited proposals for funding of activities that might address TRC Calls to Action #62 and #63 (below) and the University's commitment to decolonizing the curriculum, specifically:

> TRC Call to Action 62. We call upon the federal, provincial, and territorial governments, in consultation and collaboration with Survivors, Aboriginal Peoples, and educators, to
>
> ii. Provide the necessary funding to post-secondary institutions to educate teachers on how to integrate Indigenous knowledge and teaching methods into classrooms.
>
> TRC Call to Action 63. We call on Canada to maintain an annual commitment to Aboriginal education issues, including:
>
> ii. Sharing information and best practices on teaching curriculum related to residential schools and Aboriginal history.
>
> iii. Building student capacity for intercultural understanding, empathy, and mutual respect.
>
> iv. Identifying teacher-training needs relating to the above.

One-step to reconciliation is learning the history and historical impacts that have negatively affected all treaty people, Indigenous and non-Indigenous. Further to that, reconciliation demands that we privilege knowledge systems that have been silenced for generations.

Accordingly, the Faculty of Extension (FoE) submitted a request to fund a 3-year project titled *We Are All Related*, proposing to pilot and document several approaches to privileging Indigenous knowledge with the intent of improving relations between Indigenous and non-Indigenous people through public education events and undergraduate and noncredit programming. Our team has 11 academic staff representing 4 university units/faculties and Yellowhead Tribal College, 2 support staff, and 2 graduate students – 3 of our team are Indigenous. Our collective activities have directly influenced 68 undergraduate students, 24 Faculty of Extension continuing education students, and hundreds of members of the public (Faculty of Extension, 2017). The project is intended to result in foundational changes to the learning experience of the entire University of Alberta (UofA) community in ways that promote positive engagement and relationships with Indigenous people locally and nationally and globally. Privileging Indigenous knowledge within the formal education systems of Canada is a complex challenge that requires institutional and community support. Out of this bigger initiative, the individual course described here, being one of several created, is a result of this funding submission. While funded by the process, neither the TRC nor the funding agencies, supplied by the University of Alberta, had any overt engagement in the decisions made by the course authors.

The Design Process

Typically, instructional design practice in higher education has reflected a client-consultant relationship in which instructors are paired with instructional designers, each with a specific role in the interaction. The client brings an instructional problem to be resolved and shares content, while the designer provides expert pedagogical advice and support. Usually, the designer's role is not one of active pedagogue nor as learner in the relationship. Nevertheless, decolonizing the curriculum requires challenging the God's-eye practice of Western design practices, encouraging designers, teachers, and learners to "understand how unequal power relations are embodied in, and result from, mainstream design practice and products" (Nieusma, 2004, p. 13). In other words, the balance of design agency is shifting from the all-knowing designer who creates things that are good for passively grateful consumers to a dialogue in which an emerging design democracy turns the designer into conversationalist, facilitator, mentor, pedagogue, and learner.

Designing as an act of reconciliation (inherently a political act that demands acknowledgement and change for past action, going forward) plays through tensions between historical roles and contemporary expectations and is appropriate for the relational design of learning activities that teach and reflect reconciliation (Makokis, Campbell, Steinhauer, & Janes, 2017). In this case, the designer was an active learner and the teacher/clients, who were Elders and Knowledge Keepers, became designers.

The Design

As part of the partnership formed by and within the University of Alberta in response to the call from the Truth and Reconciliation Commission, in late 2016 and early 2017, a Nehiyaw (Cree) Indigenous scholar, with the Faculty of Extension, and a Nehiyaw (Cree) Indigenous knowledge keeper began to work on a course. This course would be one of the first collaborations to try to understand the Nehiyaw (Cree) teachings and knowledge through the lens of the Western academy and the lens of the academic concept of critical thinking (Beckie et al., 2017).

Called *EXARE 4655: Current Issues in Indigenous Relations: Nehiyaw (Cree) Teachings and Critical Thinking*, it was the second course by this team of scholars, who both co-designed and co-taught the course. Held over 2.5 days,[3] it was an intense examination of critical thinking (from a Western perspective) and the connection to Nehiyaw (Cree) teachings as a way to promote and understand Indigenous world knowledge and views. The course comprised three assignments:

1. The precourse assignment – gathering and presenting an Indigenous story (40%)
2. Within the course – reflective journaling (30%)
3. Attendance and participation during the course (30%)

Over the course, Indigenous elders and scholars worked with the participants through the questions and content which included topics such as anti-colonial the-

[3] The Faculty of Extension offers courses in many formats from 2 days to 10 weeks via multiple delivery modalities including blended and online offerings. The courses in this series are designed for working adults and have used the 2–3-day model depending on the content.

ory and critical thinking; how the Nehiyaw (Cree) people came to learn, know, and understand our world; overview of land-based teachings; overview of the Seven Women's Pipe Laws; putting critical thinking into practice; and a study of the child welfare crisis in our community which formed the basis for a group activity to offer authentic solutions to "real-life problems" currently faced by Canadian First Nations (see Appendix for full daily schedule). Discussions and stories enabled the two course authors/scholars to navigate the Western design questions and the Indigenous ways of knowing.

To add to the experience, the scholars agreed to have the Faculty's Instructional Designer (ID) attend the first iteration of the course as a participant observer. It was her goal[4] to take full part in the course as a learner, yet she was also observing the process and experience as an instructional designer. The intention was to examine the design of the course and to see how/what elements could be used in other courses and programs, both Indigenous focused and non-Indigenous focused, offered by the Faculty going forward. She was also fortunate to have had a long, preliminary conversation with one of the instructors, in advance of the course delivery, to understand some of the decisions that underpinned the design and process.

According to the syllabus, this course was designed to introduce students to an Indigenous worldview of learning and understanding critical thinking. Critical thinking would be approached from an anti-colonial framework that challenges the assumptions of conformity, memorization, and obedience with an emphasis on self-awareness through inter-activity facilitated by the instructors. An exploration of Indigenous philosophical teachings through Indigenous knowledge holders (via audio, video, and written text) was used, with an emphasis on Nehiyaw (Cree) teachings (*EXARE 4655*, 2017, p. 2).

Students would learn how Indigenous Peoples developed critical thinking skills using stories and oral traditions that were passed from Elders and Knowledge Keepers to learners. An introduction to concepts such as blood memory, collective narrative memory, and their relation to land/place was also discussed. The course would be co-taught with an Indigenous knowledge keeper and would incorporate traditional teachings and some ceremony and song into the delivery of the course. At the end of the course, students were to have an enhanced awareness and understanding of Indigenous worldviews, Indigenous knowledge, Indigenous philosophy, and the methodology in which critical thinking was developed using stories and oral traditions. A facilitative approach to instruction would be undertaken in order to encourage a collaborative student-instructor approach to learning (*EXARE 4655*, 2017, p. 2).

The core of the course was immersion, immersion into the stories by the instructors and the students. This immersion was identified in the assignments. When entering the classroom the first thing you noticed was the lack of tables and places/

[4] The course was designed by the two Indigenous instructors, in advance of the non-Indigenous Instructional Designer's involvement, although one of the Indigenous instructor/designers and the non-Indigenous instructional designer did discuss the course in advance of its first delivery. During the first iteration of the course the ID was participant/observer.

ways to take notes. Students, instructors, and guests formed a circle with chairs. It is clear from the start that we were there to listen and "hear" the stories and the teachings. Participation in a traditional smudge ceremony and traditional song(s) began the session. Although multiple media were used (video, song/drumming, PowerPoint, Indigenous ceremonial items such as the smudge ceremony) as well as guest Elders who attended the sessions and offered us their insights, the main focus of the course was on listening, talking, and the internalization of the ideas as well as the challenging of understandings among students.

The first assignment, which was done precourse, was very powerful in setting the stage for the conversation about Cree teachings and how it builds critical thinking. Called "Gathering and Presenting an Indigenous Story," it asked even some of the Indigenous students to go outside their "comfort zone". It asked us as learners to participate in the following activities:

> *Before you come to class, you will be responsible for meeting (in person or on the phone) with an elder/knowledge keeper to collect an Indigenous story from them. There is no set length or composition of the story – just go through the process of listening to and collecting a story. The story can be anything related to Indigenous ways of being/life ways. Be sure to approach the Elder/knowledge keeper with appropriate protocol (contact K M, co-instructor for guidance if needed). You may use each other as resources to contact Elders/ Knowledge Keepers and you may also contact K for names (contact information) of Elders/ Knowledge Keepers to contact. You will also need to ask the Elder/knowledge keeper if you can use this story in class to share with other(s). Some examples of stories to inquire about include:*
>
> - *Tell me a wesahkecahk story*[5]
> - *Tell me a grandmothers' story*
> - *Tell me a story about the animals*
> - *Tell me a story of sacred items used in ceremonies (drums, rattles, whistle, pipe(s), etc.)*
>
> *To prepare you for collecting the story, you will need to read the chapters from Neil McLeod's book "Cree Narrative Memory" and Blair Stonechild's book "Seeking Knowledge". Be sure to include elements from these chapters in your write-up to explain how concepts in their work (chapters) guided you in understanding the collection of stories, how stories become knowledge and how knowledge is transmitted to the knowledge seeker.*
>
> *Once you've collected the story, write down the process you used to collect the story and outline your experience in doing this (share any barriers/ challenges/ teaching moments you had in the process). Your write-up shouldn't be longer than 5 pages. If the Elder/knowledge keeper allowed you to record or write down the story, you may write it down so you remember. You will be sharing this story with your colleagues in class and there will be a group exercise conducted in class around the stories that everyone collected. You will receive more information on this exercise during class. (EXARE 4655, 2017, p. 4)*

Originally, the co-designers had considered a genealogy assignment – who are you and where do you come from (to establish both human and land connections – stories of people and the location of place). However, they struggled with how those

[5] Cree Dictionary: Wisahkecahk; Cree culture hero, legendary figure http://www.creedictionary.com/search/index.php?q=w%C3%AEsahk%C3%AAc%C3%A2hk&scope=1&cw r=37023 and A Wisahkecahk Story Video - Joseph Naytowhow. (2015). Retrieved from: http://josephnaytowhow.com/storyteller/a-wisahkecahk-story-video/

questions would tie into the stories that were important to connect to the critical thinking framework. It was important to have the wesahkecahk and grandmother stories and the stories of the animals and the sacred items, as it was with these stories that the Nehiyaw (Cree) began many of their teachings related to the development of thinking and knowledge. Therefore, the search for these stories became the precourse assignment. They also considered how non-Indigenous learners might be shy about approaching an elder. It was agreed that this dissonance is very much the life of many First Nations Peoples every day; and that would also be part of the learning for the settler/ally learner. The Instructional Designer found this dissonance a major learning experience as she engaged with an Elder who was introduced to her by a friend, who is the niece of the Elder.

The quote below is part of the Instructional Designer's journal reflection as a learner in the class as well as via her ID lens. This journaling was an assignment that required us as learners to reflect on each day of the course, and it was required to be sent to the instructors at the end of each day. The reflection gives a sense of what the Instructional Designer experienced during the first night and day of the course, as she engaged with the instructors, the materials, and co-learners as a participant/observer.

> *First let me say that the stories brought to the class by the participants on Sunday evening and into Monday am, was an amazing experience. I was surprised at how much we shared in our fear/difficulty in finding access to an elder. I guess I had made an assumption that folks either working with Indigenous communities or from those communities, would have found this an 'easy' ask. I appreciated all of my classmate's openness and thoughtfulness in relaying the stories of their partner elder.*
>
> *Opening the class with a smudge each day was also an experience. I had been engaged in smudge in the past but did not understand the significance and the cleansing that it provided; clearness of body as well as mind. It was (and is) a great way to start the class.*
>
> *Monday left me with a headache, literally. And I say that with a smile on my face. I was challenged, and it caused me to reflect on a lot (hence the headache). The day was INTENSE. Each component was well structured and I am not surprised we ran out of time – pacing on a course like this, as an instructional designer I can observe, would be difficult. How do you stop someone who is clearly articulating a story (be it from an elder or 'on point' on the discussion) passionately? This opportunity to clearly state how you feel about an issue or topic is one that does not come along often; so taking full advantage is expected. Both of the instructors, were respectful and encouraging even when I knew (as a teacher) that you had more to do and fewer and fewer minutes to do it in.* (Janes, Assignment Reflection, February 6, 2017)

The Process

What was unusual about this design was how the two instructors arrived at their course creation. To arrive at the place where the two were able to begin the course design process, one instructor, even though a Nehiyaw Iskwew (Cree woman), had been primarily educated in the Western systems. She attended, in advance of the design of the course, many ceremonies and listened to elders to ground herself in cultural teachings and values – ways that a Nehiyaw (Cree) society and family would have grown up with before the residential schools history of First Nations Peoples in Canada, as well as before the impact on colonization on those values and traditions. The second instructor, whose parents did not go through the residential school system, was able to learn from his parents many of the traditions, values, and stories that have been passed down through the generations.

For about 9 months before the course was finalized, the two instructors spent hours discussing the Western academic concepts while negotiating and discussing a translation to the Nehiyaw (Cree) ideas and knowledge, going back and forth to find the common threads of the two cultures. They worked to put the Nehiyaw (Cree) traditions and cultural structures alongside a Western educational anti-colonial framework and environment that would become the course. Taking the idea of critical thinking in the academic framework and talking it through, they came to envision the connections to the teachings and stories that make up an Indigenous knowledge framework – how First Nations Peoples developed their intelligence about the world around them and how it could be connected to the Academy.

The instructors came to discover how the questions are asked is as important as the questions that are asked when using using both English and Cree words, ideas and traditions. An example of this is how the Western learnings and traditions can often be barriers to Indigenous knowledge and, as such, needed to be worked through before the learner could "see" the connections between the Western world and the Indigenous world. This discussion with the instructors as to how they arrived at their choices in the course (through those questions and their experiences within the Canadian education system) was extremely valuable to the ID as she began to see the issues they were engaged in through their eyes.

This groundwork was necessary as the instructors had seen in their students, especially Indigenous students, an unspoken, invisible barrier that could be felt in the classroom; they struggled to participate with the material and with the environment in the class. They were often so removed from the culture that was their own that they often did not know how to engage with the Indigenous knowledge and learning. This was borne out by the instructors understanding that the Alberta government (provincial) curriculum was and is geared toward preparing students to enter the workforce. Local employers want someone who is literate and obedient and has the ability to take direction. They felt that this is what Indigenous students were/are exposed to when they attend schools administered by the province. They began to see that an Indigenous education, founded in Indigenous knowledge through ceremony, stories, and land and cultural traditions, would prepare a person who can think on their own. This became their primary reason why the course was developed – to decolonize the social conditioning experienced through the public education system.

Therefore, the instructors asked themselves the question: "What kind of course can I create that breaks that barrier?" In examining the transformative learning that was being undertaken by the instructors, they began to see what was missing...a foundations course for Indigenous students to come to "know" of how to think critically within this academy utilizing Indigenous knowledge as the teaching method.

The intellectual framework to develop critical analysis skills – to fundamentally think Indigenous – to analyze from an Indigenous lens, was necessary. Over the design phase, they began to connect the analysis skills to the storytelling traditions of the elders, who used them to guide the young and teach them the skills necessary for growth and understanding. So began the examination of Nehiyaw (Cree) traditional teaching and how the Cree created those skills.

The depth of the transition and the depth of the immersion, which was created by this process over months, is in the course and in the experiences of the learners. There is very little written or developed around Indigenous critical thinking and how the Nehiyaw (Cree) have developed this knowledge. There are some works on oral traditions written by Nehiyaw (Cree) academics. This told the instructors that the knowledge of these traditions within the Academy was scant at best. This is best shown by the ID's final reflection on the last day of the course:

> *Overall, this course has been quite profound in its ability to make me think and to make me listen, in a way, I have acknowledged, has not happened in a while. It also makes me consider as an educator and instructional designer, how I can be of assistance to Indigenous experts to ensure that non-Indigenous colleagues such as myself consider how to engage and create our content in ways that honors the traditions of Indigenous knowledge.* (Janes, Assignment Reflection, February 7, 2017).

What the Instructional Designer found was so exciting about this course, and the work of the two instructors, was that it was designed to meet the challenges experienced by First Nations in Canada via the residential schools legacy and the effects of colonization over centuries. It was designed to start to reconcile both the Indigenous learner/teacher and the settler/ally learner/teacher, and it is an example for non-Indigenous instructional designers, like her, to assist in making this reconciliation possible in many types of courses in the Academy. This experience allowed her, and encouraged her, to think differently as an instructional designer and to begin to understand the power and place of instructional design in supporting the shift in thinking among our colleagues, learners, and the landscape of an Academy and Government. This road of reconciliation will be long and fraught with conflict and context. It is up to the Instructional Designer, going forward, to be part of the allies needed to start to engage the traditional academy and the Indigenous community.

This design approach, framed by settler/ally relations and the "collective lift" (Fletcher, Hibbert, & Hammer, 2017; Rice & Snyder, 2012), is ethically aligned with Indigenous knowledge creation, a lifelong process, starting and staying grounded in community with Elders and other Knowledge Keepers. Fundamentally, it is a design to move Indigenous Peoples forward to claim their rightful places in their context and in the Canadian context; this course is a step in working on solutions to the challenges that remain to be overcome. Given the context of the First Nations Peoples within the construct of the country of Canada, shifting this learning lens to include Indigenous knowledge creation and understanding is a political act and has the opportunity to make critical change in both futures.

Appendix

Daily Schedule for *EXARE 4655* (2017)

Day/time	Topic
Sunday	
6:00 pm	Welcome Blessing
6:30 pm–7:30 pm	Grounding “Who are you” Circle
7:30 pm–7:45 pm	Break
7:45 pm–9:00 pm	Sharing your Stories[a]
Monday	
8:30 am	Song/Prayer/Smudge
9:00–9:30 am	Debrief of previous evening
9:30–10:00 am	Overview of Anti-Colonial Framework
10:00 am–10:15 pm	Break
10:15 pm–11:00 am	Nehiyaw wisdom, knowledge, and understanding
11:00–noon	Human Development (Parenting, Intervention, and Prevention)
Noon	Lunch
1:00 pm–2:15 pm	Nehiyaw (Cree) Women’s Pipe Teaching(s)
2:15 pm–2:30 pm	Break
2:30 pm–3:30 pm	How We Come to Learn/Know
3:30 pm–3:45 pm	Break
3:45 pm–4:45 pm	Debrief/Questions
4:45 pm–5:00 pm	Preparation for Next Day
Tuesday	
8:30 am	Song/Prayer/Smudge
9:00 am–9:45 am	Opening Circle
9:45 am–10:30 am	Land-based Teachings
10:30 am–10:45 pm	Break
10:45 am–noon	The Child Welfare Problem/Issue(s)
Noon	Lunch
1:00 pm–3:30 pm	GROUP EXERCISE: Working Through a Real Life Problem/Issue
3:30 pm–3:45 pm	Break
3:45 pm–4:45 pm	Final Circle
4:45 pm–5:00 pm	Closing

[a]Depending on timing, pipe ceremony may be held Sunday evening or Monday morning

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Design Case Chapters Afterword: The Challenges and Opportunities of Sharing Design Studies

Joshua Danish

I am a designer, and the core of my work for over 20 years has been the design of educational technologies and activities. I designed primarily educational software first for a home school, then for a "traditional" CD-ROM-based company, and then for a series of Internet startups and finally returned to the academy to explore, document, and teach the design of innovative educational technology and curriculum. Across these experiences, one fact has continued to stand out: good design is really hard. Teaching and learning how to design is even harder. One of the reasons for this is that good design is always adapted to its context of use, and the contexts that we design for are continually changing and increasingly diverse. Our users are also continually changing: knowing, expecting, and being capable of completely different things than past generations.

This challenge, which is also at the heart of what I think makes design so incredibly interesting and rewarding, is exacerbated by the fact that most of the exemplars we have to look at as (emerging) designers are "final products." Often, we only write about the successful products, with the exception of the most exceptional failures of others. However, either way, we get to see the products, not the process that led to those successes and failures. We can learn what finally worked, or didn't, from looking around us, from reading typical research reports about design innovations. But, we rarely get to glimpse inside the process through which designers achieved their final product. We don't get to learn from the smaller incremental trials and errors nor to see the challenging compromises that drive all design efforts. This is why I think the design cases in the current Handbook are so incredibly important for the field because they let us learn from and about the actual lived design experience of our colleagues and to see how those experiences shaped their final products. Our own paths will be different, but we can gain insight into the

J. Danish (✉)
Indiana University, Bloomington, IN, USA
e-mail: jdanish@gmail.com

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kinds of hurdles that they navigated and begin to apply those insights to our own new opportunities. And, importantly, as we work with the next generation of designers, we can show them that they are not alone in struggling, that no design is without struggle, but that all of the great designs we encounter emerged from a continual, iterative process.

In reflecting on the power of presenting design cases, it occurred to me that there are three sets of challenges that need to be overcome for this kind of presentation to come to light and to be of value: (1) the challenge of writing about one's design, (2) the challenge of reviewing design cases, and (3) the challenge of learning from a design case.

The Challenges in Writing a Design Case

First and foremost, designers need to be willing and able to share their design stories. This includes making themselves vulnerable in a way that is not always familiar nor comfortable. After all, we are asking designers to pull back the curtain of their sometimes well-known designs and admit that it wasn't all smooth sailing, that every step did not follow the others perfectly and in quite the clean and clear sequence that our publications often imply. Having done this myself a few times (see, e.g., Danish, Enyedy, Saleh, & Lee, 2016), I can say from experience that it is not always easy to admit to oneself and to the field where you stumbled along the way.

This is also related to what I see as a second key challenge, which is that while our writing about design is often read in a linear and sequential manner, our design processes are not. As Boling and Svihla note (this volume), design experiences are often far more iterative and staggered than the design processes that we teach. How, then, do we recount this process in a linear manner that will make sense to those who were not present to experience those moments of surprise, inspiration, and disappointment? This is an art, and the answer is that the best way to accomplish this is to try and then iteratively refine our accounts as we receive feedback from other designers. Each design case requires a slightly different presentation to highlight the key issues that the designers experiences within their own context, and thus we cannot offer a uniform approach, nor would we want to. However, I believe you'll find that, thanks to careful stewardship and iteration, the present cases capture this process quite well.

Another challenge in presenting a design case is in identifying what to include. The design experience is deeply personal and so often includes many elements that we'd like to share with the reader, many ideas that feel important, or felt important at the time. But, which ones actually matter? As with much of our academic writing, the solution here is to identify a take-away, a story, that the author hopes will inspire their readers. Once this story is identified, it is easier to identify specific aspects of experience as relevant to share. How does one identify a story that matters, though? For me, the answer is that I think of the story I wish someone had told me before I began my design process, the one I wish I had learned previously. Then, I tell that story. No doubt, our authors each have their own process, but the implication is that as readers we should all recognize that they likely struggled with this and that we should aim to read their story as yet another design, one intended to convert their own experience of design so that we can learn from it. It's not easy, and I am deeply appreciative of the authors who have set out to do this.

Finally, I think it is incredibly important to recognize that writing about the design of educational technologies is different from writing about other design genres. Each genre has its own concerns, and my experience is that educational design necessarily includes several others within its umbrella. An educational design needs, after all, to be able to be used, to support work, and to support learning. That is, it might be enough for some designers to focus solely on how effectively users can take up and engage with their tools and how they iteratively supported that outcome. However, a great deal of scholarship highlights for us that even when a design is usable, it might not support the kind of work that real people engage in on the ground. Exploring the design process for supporting this thus introduces an added dimension of complexity. We know engaging in successful work with a learning technology doesn't always mean that learners take away what we'd hope! That is, they might work together brilliantly with our tools and yet not learn what we'd hoped. This adds yet another layer to the design process and thus further complicates the presentation of a design case. In fact, I find we often see interesting contradictions across these layers that are worth sharing. My favorite example of this to share with my students is one where learners' most desired use of a tool is in fact the worst for learning. As an example, consider my design of the BeeSign computer simulation (Danish, 2014). This simulation is intended to help young children (kindergarten through second grade) explore how honeybees collect nectar. To do this, students need to explore the impact upon nectar collection of invisible bee behaviors that occur off-screen, within a virtual hive. Without fail, when I ask learners what they'd like to see changed, they suggest that I should have simply reported that invisible behavior on-screen, making it easy for them to see. I have no doubt that they are right – they'd be able to recognize this much more quickly with some easy iconography. But, the struggle to identify what the hidden bees are doing is at the heart of the learning process! Trying to figure out how this hidden behavior impacts the visible behavior of bees foraging for nectar is the whole point of the exercise. Thus an important aspect of my design process and the one I want to share with my colleagues and students is how I chose to violate student experiences of usability to instead support learnability.

The Challenge of Reviewing Design Cases

Given these challenges in writing a good or great design case, what is the secret to accomplishing it? Simply put, like all design processes, iterative effort combined with thoughtful feedback is crucial. In this case, that means drafting a design case and receiving and then responding to thoughtful reviews. However, reviewing design cases is, not surprisingly, quite different from reviewing traditional research reports due to the alternative goals and intentions. Having reviewed for the present volume, for the wonderful set of design cases in Svihla and Reeve (2016), and in other contexts, I think that we can again learn from the challenges a reviewer faces.

First and foremost, it is often necessary to focus not just on the details that are present but on those that are missing. What about the design process do we need to know more about? Just as it is challenging for the authors to decide what to include in their drafts, it is challenging for reviewers to reflect on what else we might need to know without asking for every possible detail. Here I think the key is to reflect on what story the authors are telling and how we can learn from the process they are sharing. What else will help us gain insight from this design case? Which details matter?

Relatedly, as reviewers, we need to reflect on which details other readers might want and might benefit from. Do we want additional details because we are curious about the history of a well-known design or because they help to tell the story of a design case in a way that others can learn from? We can always ask for more, and as designers we are likely curious to learn more about our peers' experience. But we need to focus on the story they are telling and the ways that we can all benefit from this story. Otherwise, these cease to be design cases and might instead become chaotic design anecdotes. I view this distinction as quite important and as one that I know Boling and Svihla worked closely with the authors to engage with. The included final chapters are design cases that tell a coherent story from which we can learn and benefit. They are not simply stories told for posterity.

Finally, reviewers no doubt struggled with how to respond to these efforts at vulnerability with mindful suggestions for how to improve the story, rather than how to improve the design, or to satisfy one's curiosity. I know I wanted to go back to the origins of the designs I read about and try to help the designers succeed more quickly! I'm reading as a designer, inspired to suggest alternatives, so why not share them? But that's not the point. Rather, I had to constrain myself to helping them craft a successful design case, for a broad readership. It is often an act of convenience to ask chapter authors to review each other's chapters as a service for being included in a volume. In this case, however, I think that asking authors of design cases (here and elsewhere) to comment on emerging design cases is crucial to insuring that the readers know what it means and what it takes to both produce and commune a productive design case. Having done that, Boling and Svihla helped these authors reach their potential in part by helping the reviewers also reach theirs.

The Challenge of Learning from Design Cases

My hope is that by illuminating these challenges, I have helped the readers to appreciate the complexity and value of these design cases that they can now explore. However, as a reader we also face the challenge of reading these cases in order to transform our own practices, of learning from these cases. Boling and Svihla offer some wonderful suggestions for how to engage in this process, depending on your goals of the moment. However, I'd like to again highlight some of the challenges that you will likely face in the hopes that this helps you in taking up this challenge.

The first challenge is likely what to focus on? As you read a case, where should you focus? As noted above, each design is deeply contextual and highly specific, so how can we read with that in mind? I think the answer here is that we ought to focus on the relationship between context, challenges, and solutions. We should think both narrowly about how the context led to those solutions and then expansively about how those solutions might apply in new, future contexts (Engle, Lam, Meyer, & Nix, 2012). That is, we should start thinking about how these ideas might apply and be transformed if we look into new and distant contexts. Ideally, we should also do this in conversation. Read these cases with your team, and discuss them, exploring how you'd solve these same challenges and how you'd take those solutions into the future. These aren't meant, I think, to be purely historical accounts, nor are they intended to apply "directly" to some new problem. Design principles might be applied in such a way, but as noted above, those principles often ignore the complexity of their own application. Rather, design experiences and design processes are intentionally messy, iterative, and responsive and so their value comes from reflecting on how they came to be and on how we might build on that in our future work.

Given my prior suggestion, it might seem as if it is most valuable to read about design cases that have some surface overlap with our own expertise and interests. If you are interested in design of higher education learning environments, you might then focus solely on design cases that take place in such a context. However, I think that would be a mistake! Within their own contexts, each designer has encountered and reported on a truly unique set of experiences and decisions. However, they also endeavor to share how they thought about the kinds of problems that they experienced and that we likely experience in our own design efforts. Sometimes those challenges and solutions are tied to seemingly familiar aspects of the designed context, and sometimes not. So, simply put, I think it is best to read outside of our own experiences and silos in search of new forms of inspiration. And, again, talking about this and how we might adapt is likely to support us in truly benefiting from this broad reading.

Finally, unlike our usual approach to reviewing the literature, a challenge of reading design cases is that they are rarely valuable for solving the specific problems you are engaged with today. Rather, their value comes in how they shape your own ideas about design and designing. That is, we benefit from them best when we incorporate them into a broader sense of ourselves as designers who have experience of many different solutions than when we view them as simply a case of solving a single specific problem. They might, of course, represent that too, but I think we miss a lot if that's all we are looking for. Thus I encourage the reader to reflect on these with the intention not just of helping them with their current design project but with the goal of becoming a better designer overall, one who benefits from the trials and challenges and solutions of their peers, not just from their own immediate experiences.

Design Cases as and for Research

In addition to being a designer, I am also a researcher, as I suspect are the majority of those reading this handbook. An important question that arises is how design cases support us as researchers and not solely in our design role? To me, there are three complementary answers. First, while design cases likely do not "generalize" to all contexts and situations, they do provide valuable guidance to be used as a starting point in our own studies. That is, while we would not want to assume that a single highlighted contextualized design dilemma or resulting design choice will always work, we can nonetheless read it as a starting point to motivate our own designs. Each subsequent design that shows the utility of a design solution in a new case will provide insights into its generalizability, and each contrasting case will help us to understand its limitations and contextualized nature. For this to work, we need to appropriately qualify our claims and also view the design literature as inter-related and ongoing rather than consisting solely of one-off exemplars to be taken as design laws, but I have argued above that this is nonetheless a valuable path. Related to this, I think a second important role here is to think of design cases as the starting point, when combined with other forms of design research for larger programs of research into how we actually design in the field and how we adapt to practical circumstances of design and implementation. No designer I have ever met uses design approaches and theories in a consistent and linear manner, nor do they all use the same approaches in identical ways. Design cases thus become valuable data for understanding all of the diverse ways that design is undertaken and exploring what we as a field can learn from them.

Finally, I think it is valuable to think of design cases as providing added insight into the design principles and results that they describe. Many of the designs described in this section of the handbook have also been described in other forms of scholarship. Necessities of publication outlets and journal audiences require us to share primarily the final products of our designs, often in abbreviated form. Elaborating on the process here helps to shed new light on those other findings, helping us to better understand how they evolved and in many cases not only why they worked (or didn't) but why other approaches were abandoned along the way.

Coda

Great design cases are incredibly challenging to produce, to review, and even to read. But, I think they are absolutely worth it for us as individuals and as a field. Experience is the best educator for great design, and design cases help us to learn from each other's experiences, from each other's processes in new, robust ways. They help us recognize and explore the messy, contextual, iterative process of design for what it is, rather than attempting to continually reduce it to a series of simple guidelines that we might pass along. Those guidelines might help, but we need to know how to fold them into our practices or else they'll likely lead to as many missteps as successes. I wish that I had had access to this kind of design case when I first started studying educational design, and I am thrilled to see this genre growing in prevalence. I can't wait to reread these chapters with my team and my students and to continue to learn together from my colleagues' work, shared so bravely with us all.

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