Research Highlights in Technology and Teacher Education 2018

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FOREWORD

It is a pleasure to present the 2018 edition of the Research Highlights in Technology and Teacher Education, now in its tenth year of publication. The collection of peer-reviewed articles represents the outstanding scholarship and notable work presented during the past year at the annual meeting of the Society for Information Technology and Teacher Education (SITE). SITE is a global community committed to advancing the creation and dissemination of knowledge about information technology in teacher education.

The distinguished research articles included here illustrate how teacher educators, researchers and practitioners are collaboratively addressing the use of technology in teacher education as they explore contemporary, creative and innovative solutions to integrate technology across the world. The Research Highlights book would not be possible without the dedicated leadership of senior book editor and distinguished colleague, Leping Liu.

SITE is extremely grateful to have members who are willing to take on extra work in order to strengthen the organization’s outreach and impact. We would also like to thank the numerous reviewers who took time to review, select, and provide feedback on the chapters. Because of these efforts, the society can engage in a rigorous review process that promotes and maintains the high-quality standards present within our organization.

Enjoy reading this tenth edition of the Research Highlights in Technology and Teacher Education. Remember to share it with your colleagues so others can learn and grow!

David Gibson
Senior Editor

Denise Schmidt-Crawford
SITE President
PREFACE

Research Highlights in Technology and Teacher Education is now in its tenth year of publication. Collections in this book series have continually presented distinguished work by leading educators and researchers in the field. Their research is highlighted and presented as contemporary trends and issues, creative research methods, innovative ideas, theory and practice-based models, and effective use of research tools and approaches in the field of information technology and teacher education. This year, twenty-two chapters are included, organized into six themes: (a) Technological Pedagogical and Content Knowledge (TPACK), (b) Mathematics Education, (c) Practice and Applications, (d) Teachers’ Perceptions and Experiences, (e) K-12 Studies, and (f) Assessment and Evaluation.

TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE (TPACK)

Every year, the theme TPACK (technology, pedagogy, and content knowledge) is a highlight of this collection, and has served as a model of technology integration in teacher education over several years. The model provides a theoretical and practical framework for educators and researchers to explore effective ways to improve technology-based teaching and learning. This year, two chapters are included in this section.

In the first chapter, “If There is TPACK, Is There Technological Pedagogical Reasoning and Action?” Judi Harris and Michael Phillips present a critical literature review in light of the original conceptions of knowledge base for teaching, which includes pedagogical content knowledge (PCK); of technological pedagogical content knowledge (TPCK/TPACK); and of the original model of pedagogical reasoning and action. This literature analysis leads to recommendations for a new direction in future TPCK/TPACK research.

Next, in “Impact of Prior Knowledge, Course Design, and Technology Preparation on Pre-service Teachers’ TPACK Development in a Required Educational Technology Course,” Yi Jin and Denise Schmidt-Crawford report a quantitative study in which they investigated the impact of prior knowledge, course design, and technology integration on pre-service teachers' post-TPACK scores in a required educational technology course. They found all three variables affected pre-service teachers' post-TPACK scores, which is discussed in the context of further directions for research and practical implications in this area.

MATHEMATICS EDUCATION

Mathematics education has garnered more and more attention and been one of the most studied areas in the field of using information technology in teacher education. A significant issue is how higher education prepares school mathematics teachers to educate students with the necessary knowledge and skills for their future jobs. Five chapters are included which explore this theme.

Lindsay Reiten begins this section with a study titled “Teaching WITH (not near) Virtual Manipulatives.” In this study, a task analysis framework with guiding questions are used for mathematics teachers to support their efforts in teaching with rather than near virtual manipulatives (VMs). Findings focus on teachers’ appropriation of two tools to support their efforts to critique and modify VM tasks. Implications for supporting teachers’ integration of technology tools are discussed.

In chapter four: “Challenges in Mathematics Teachers' Introduction of a Digital Textbook: Analyzing Contradictions,” Marie Utterberg, Martin Tallvid, Johan Lundin and Berner Lindström report a qualitative study that explores how the introduction of a digital textbook (DT) affects the activity of teaching mathematics. Four contradictions arose in the activity: first, teachers’ need for coherence and linearity vs. the DT with a wide range of content and nonlinear paths; second, teachers’ need for transparent learning processes vs. the digital textbook as opaque; third, teachers’ beliefs about appropriate pedagogy for learning mathematics vs. the pedagogy embedded in the DT; and fourth, differentiated instruction for all students vs. DT supporting individualization for every student.

Next, Kara Suzuka, Rebecca D. Frank, Erica Crawford and Elizabeth Yakel introduce a study “Video reuse in mathematics teacher education.” This study examines the re-use of existing video records of practice (VRPs)
in preservice mathematics teacher education. Interviews with 34 mathematics teacher educators from 24 different institutions were conducted to find out (a) how mathematics teacher educators make use of existing VRPs to support the professional learning of preservice teachers, (b) the instructional goals teacher educators try to achieve when re-using VRPs, and (c) the types of activities when re-using VRPs.

Chapter six “Video Case Analysis of Students’ Mathematical Thinking: Initial Development Process,” by Laurie Cavey, Tatia Totorica, Michele Carney, Patrick R. Lowenthal & Jason Libberton, describes a design-based research project on using video-based online learning modules as a component of a teacher preparation program to improve candidates’ ability to recognize and make connections between patterns in students' informal and formal reasoning. The initial development process yields a range of student ideas from which they construct modules.

In the last chapter of this section, Jennifer Lovett, Lara K. Dick, Allison W. McCulloch and Milan F. Sherman introduce a study “Preservice Mathematics Teachers’ Professional Noticing of Students’ Mathematical Thinking with Technology.” This study examines the ways preservice secondary mathematics teachers (PSMT) professionally notice middle school students’ mathematical thinking on a technology enhanced mathematical task. The PSMTs recognize that the middle school students’ mathematical understanding are tied to their interactions with the technology. Implications for mathematics teacher education are discussed.

APPLICATIONS

With the rapid development of new technology, every year a variety of technology applications are presented at the conference. Three chapters are included in this section. We hope the experiences the authors shared will be helpful reference for other educators.

In chapter eight “The Digital Learning Framework: What Digital Learning can Look Like in Practice, An Irish Perspective,” Deirdre Butler, Michael Hallissy and John Hurley describe the evolution of a Digital Learning Framework (DLF) from November 2016 to July 2017 that helps Irish schools embed digital technologies more deeply into their classroom practice. The design, development, and initial evaluation of 50 schools in the Irish DLF are introduced.

Next, in chapter nine “Fostering Children's Creative Thinking: A Pioneer Educational Robotics Curriculum,” the authors Nikleia Eteokleous, Efi Nisiforou and Christos Christodoulou present a study that explores the potential of a robotics curriculum for developing creative thinking skills in the context of non-formal education. They examine pre/post changes in the creativity level of thirty-two school students who participated in a non-formal educational robotics intervention. The Torrance Test of Creative Thinking is employed to measure students’ level of creativity and significant differences are found.

Chapter ten “Opportunities and Challenges of Using Technology to Teach for Global Readiness in the Global Read Aloud,” by Jeffrey Carpenter, Sydney Weiss & Julie Justice, introduces the Global Read Aloud (GRA) project that connects classrooms via digital technologies to discuss common texts. They also investigate the pedagogical opportunities and challenges associated with technology use in teaching for global readiness in GRA.

TEACHERS’ PERCEPTIONS AND EXPERIENCES

Using information technology in teacher education is the main theme of SITE. This year, a collection of six chapters exhibit current trends, issues, preservice teachers’ perceptions and experiences, and some widely discussed topics in this scope.

A number of states and organizations have begun to add cross-content technology elements to their educational standards, providing teachers opportunities to use social media communication (SMC) technology in teaching and learning. In chapter eleven, Brett Tozer studies “Teachers’ Perceptions and Intended Use of Social Media Communication Technologies as a Pedagogical Tool in Teacher Lectures.” The study examines the attitudes, subjective norms, perceived behavioral control, and intentions of public secondary teachers’ use of SMC technologies as part of their teacher lectures. Results suggest that teachers’ intentions to use SMC in their lectures
are low; however, their perceptions of the use of SMC as a pedagogical tool are positive. Teachers’ positive perceptions suggest they view the use of SMC technologies in teaching and learning as appropriate for the classroom.

In chapter twelve “We are Just Expected to Know How: Unpacking Pre-service Teachers’ Beliefs about Technology Integration,” David Mulder reports a case study that examines a particular teacher preparation program at a private comprehensive college, and how the pre-service teachers in that program perceive their self-efficacy for technology integration. The results indicate that pre-service teachers generally feel confident in their abilities to teach with technology, but also feel a sense of pressure to be effective in technology integration.

Chapter thirteen “Development in Pre-service Teachers’ Readiness to Use ICT in Education: Longitudinal Perspectives” is authored by Teemu Valtonen, Jari Kukkonen, Erkko Sointu, Susanna Pöntinen, Tom Stehlik, Pia Näykki, Anne Virtanen and Kati Mäkitalo. These eight scholars present a three-year longitudinal study focusing on pre-service teachers’ readiness and willingness to use Information and Communication Technologies (ICT) in education. Data on attitudes, subjective norms, self-efficacy and behavioural intentions related to ICT in education from three Finnish universities are collected and analyzed. Results indicate positive changes in pre-service teachers’ self-efficacy through the three years.

Next, Medha Dalal and Leanna Archambault present a study in chapter fourteen, “International Teachers’ Evolving Relationships with Educational Technology.” The study examines how a technology-related professional development experience influenced three secondary school international teachers from Kenya, India, and Brazil. The narrative inquiry results exhibit participants’ desire and determination to deliver technology-infused instruction.

Chrystalla Mouza, Soumita Basu, Hui Yang and Yi-Cheng, Pan introduce a study in chapter fifteen “New Content for New Times: Pre-Service Teachers’ Exploration of Computer Programming in Educational Technology Coursework.” It investigates the development of computational thinking skills and knowledge in pre-service teachers after they took an educational technology course on the integration of computational thinking in K-8 contexts. Both quantitative and qualitative data are collected and analyzed. Results indicate that the majority of the participants successfully integrated programming into suitable content areas.

This section ends with a mixed-method study titled “Pre-Service Teachers’ Exploration of Professional Role Identities for Teaching with Games,” by Mamta Shah and Aroutis Foster. They report preliminary findings from Games, Science, and Identity Change - a year-long professional development (PD) program undertaken to develop pre-service teachers’ (a) knowledge and skills to facilitate identity exploration through game-based learning (GBL); and (b) professional identities as teachers who adopt GBL as an instructional approach in the future. The Projective Reflection theoretical model and the Game Network Analysis framework are used in the study.

K-12 STUDIES

Researchers also introduce their studies and experiences in the area of K-12 education. K-12 education always provides a practical and fundamental research context where many potential areas could be explored. Three chapters are presented in this section.

In chapter seventeen “Examining a “Five Community Typology” to Support Designing for Community Participation in PK-12 Practice: Does “It” Belong?” Dawn Hathaway’s study examines 27 practicing teachers’ perspectives about the efficacy of a five-community typology to inform their learning and designing. Threaded discussions, synthesis reflections, and design documents are qualitatively analyzed. Findings indicate that the five-community typology enlightens notions about the importance of community participation, brings definition to the concept, and provides a number of affordances to support designing for community participation.

Next, Shaunna Smith, Jim Van Overschelde and Teri Evans-Palmer present a mixed-method study in chapter eighteen “Art Ed Maker PD Experience: Impacts of an Immersive Professional Development for “Making” STEM Connections in K-12 Art Classrooms.” This study examines the impact of an eight-month Art Ed Maker PD experience focused on STEM-infused “maker” activities using New Media Arts. Data include quantitative pre-/post-test and ethnographic techniques including field notes, focus group, interview, observation, and personal communications. Findings suggest that participants have developed technical confidence, understood
multidisciplinary connections between New Media Arts, visual arts, and STEM, and had a willingness to collaborate with STEM teachers to improve student learning.

Chapter nineteen “Teacher Experiences with Professional Development for Technology Integration at a K-12 Independent School: A Multi-Case Study” introduce a qualitative study by Amy McGinn & Liyan Song. This qualitative study explored seven independent-school teachers’ experiences with professional development (PD) for technology integration through the lens of diffusion theory. Findings suggest that participants have varied experiences with PD for technology based on their innovativeness, and have different learning needs. The informative information in this chapter could be a good reference for educators.

ASSESSMENT AND EVALUATION

Assessment and evaluation have always been major topics in our annual collection. Scholarly work focuses primarily on the development of assessment methods and tools, examination of valid and reliable instruments and measurements, and analyses of data to provide insights concerning the quality of technology integration. This year, three chapters are included in this section.

Chapter twenty “Evaluating University Facilitators’ Perceptions of Video as an Observational Tool” by Lindsay Watkins Zurawski, Debra Sprague, Andrew Porter and Kamilah Williams evaluates university facilitators’ (UFs) perceptions of the use of video recordings as a means of teacher observation. Results show that UFs perceive both benefits and challenges regarding the use of video as a tool for teacher observation, but see the most benefit in a combination of the two practices. Implications for the field of teacher education are discussed.

Stephen Adams and Fabian Rojas report a study in chapter twenty-one “High School Teachers’ Self-Assessment of their TPACK after Graduate Coursework: A Mixed Methods Evaluation.” The study used a quantitative method, a survey of TPACK (at the beginning and end of instruction) together with a qualitative method, and a Graphical Analysis of TPACK Instrument (at the end of instruction). The TPACK survey showed statistically significant changes in most subscales, including large effect sizes on scales related to Technological Pedagogical Knowledge and TPACK. The complementary GATI instrument provided self-reflections extending the surveys. A comparison of the two methodologies illuminates strengths and limitations of each.

The study in the last chapter “Transforming Teacher Preparation: Assessing Digital Learners’ Needs for Instruction in Dual Learning Environments,” by Susan Poyo, aims to determine if active engagement with content of an online instruction module would affect the attitudes, knowledge and skills, and instructional centeredness of pre-service teachers towards technology integration in an online learning environment. A mixed-methods concurrent triangulation design is conducted to evaluate the effect of engagement. Upon completion of the intervention, participants made significant gains in all the measured areas.

Finally, we would like to take this opportunity to express our congratulations and our appreciation to the book review board, the book editors, and the authors of all the manuscripts contributed this year. We believe that this collection of papers is a welcome addition to the literature in the field of information technology in teacher education.

September 1, 2018

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If There Is TPACK, Is There
Technological Pedagogical Reasoning and Action?

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Abstract: Substantial evidence from research done with both preservice and inservice teachers demonstrates that the nature of teachers' knowledge is expanded and changed when educational technologies are incorporated effectively into teaching. If teachers infuse use of digital tools and resources in their praxis — that is, if they use them to access and comprehend content and teaching materials, to facilitate students' learning, and/or to reflect upon their teaching and their students' learning — does this use of digital technologies also change the fundamental nature of their educational planning and decision-making? Several researchers have asserted that it does. In this critical literature review, we consider these claims in light of the original conceptions of Shulman's (1987a) knowledge base for teaching, which includes pedagogical content knowledge (PCK); of technological pedagogical content knowledge (TPCK/TPACK); and of Shulman's model of pedagogical reasoning and action. This analysis leads to recommendations for a new direction in future TPCK/TPACK research.

The notion of pedagogical content knowledge (PCK) was modified by multiple authors to become technological pedagogical content knowledge (TPCK or TPACK), spawning much active and dynamic scholarship since 2001. Currently, many researchers see TPCK/TPACK as the knowledge that teachers need to integrate technologies effectively into learning and teaching. Shulman’s PCK, however, was just one element in a much larger conceptualization of a knowledge base for educators, and that full range of knowledge was posited as being used by teachers in recursive processes of pedagogical reasoning and action (PR&A). This begs the question: if there is TPCK/TPACK, which is rooted in PCK, as many studies have suggested, is there also technological pedagogical reasoning and action (TPR&A)? If so, what are its distinguishing characteristics? If not, why would TPCK/TPACK not be mirrored in TPR&A? These questions are addressed in the following critical literature review.

PCK and TPCK/TPACK

Close examination of teachers’ work reveals that teaching is an “outrageously complex activity” (Shulman, 1987b, p. 11), made even more complicated when educational technologies are incorporated (Mishra & Koehler, 2006). A range of theoretical models have been proposed to help unpack the intricate, contextually situated work undertaken by teachers. One powerful idea (Papert, 1980) that has helped researchers articulate the knowledge that is required for effective teaching is pedagogical content knowledge (PCK), and its corollary, technological pedagogical content knowledge (TPCK or TPACK). PCK originated in Shulman’s (1986, 1987a, 1987b) research program that investigated teachers’ knowledge base for teaching. As part of his 1985 American Educational Research Association presidential address, “Lee Shulman tossed off the phrase ‘pedagogical content knowledge’ and sparked a small cottage industry devoted to the scholarly elaboration of the construct” (Nelson, 1992, p. 32). The extensive PCK research conducted in the years immediately following the construct’s introduction has continued. This ongoing inquiry has deepened PCK’s conceptualizations and added much empirical research to Shulman’s initial work, but these efforts have not led to a consensus in descriptions of PCK or the ways in which it is believed to be developed and represented (Park & Oliver, 2008).

While PCK inquiry continues, educational technology researchers have begun to extend the construct to examine the knowledge required for effective integration of digital technologies into teachers’ praxis. Pierson (2001) suggested adding technology knowledge to the conceptualization of teachers’ PCK, noting that the effectiveness of technology
integration may increase with overall pedagogical expertise. Koehler, Mishra and Yahya (2004) similarly added technology knowledge to PCK to form TPCK, positing P-T, or “pedagogical-technology knowledge” and C-T, or “content-technology knowledge” (p. 3) as intersecting aspects. Niess (2005) proposed the term “technology PCK” (p. 510), and Angeli and Valanides (2005) named the construct “ICT-related PCK” (p. 294). While the elements and configurations of these models differed somewhat, and the methods recommended to develop the specialized knowledge that they represented varied, all shared PCK and technology knowledge as their conceptual basis.

In the ensuing years, TPCK/TPACK scholarship has examined how this knowledge is developed, applied, and assessed in diverse settings (e.g., K-12, post-secondary, and informal learning environments) and across multiple content areas. The construct has been utilized in more than 3,200 publications that have appeared in fewer than 17 years (http://activitytypes.wm.edu/TPACKNewsletters/index.html), and this work has impacted the practice of teachers, professional development providers, administrators, and other stakeholders invested in meaningful educational uses of technology (Harris, Phillips, Koehler & Rosenberg, 2017). Despite these efforts, and in a manner similar to PCK scholarship, the TPCK/TPACK research community has yet to reach consensus on definitions of the construct and its components (Cox, 2008; Cox & Graham, 2009; Willermark, 2017). Notwithstanding this disagreement, the rapid diffusion of PCK in the late 1980’s and 1990’s, and of TPCK in the 2000’s, may well be linked to the constructs’ utility as powerful ideas, or "concepts [that] … become tools to think with" (Papert, 1980, p. 132).

**Beyond PCK and TPCK/TPACK**

Yet for all of the attention that PCK and TPCK have been paid during the past 30+ years, two key aspects of Shulman’s pioneering work have received markedly less attention by both research communities: how teachers’ knowledge is used, and what is beyond PCK that also comprises the knowledge base for teaching. Shulman’s research presented another powerful idea that is beyond, but connected to, PCK: pedagogical reasoning and action (PR&A), “within which…teacher knowledge is used” (Shulman, 1987a, p. 5). Building on the work of Green (1971) and Fenstermacher (1978), Shulman’s basis for PR&A is a belief that teachers should not be trained to behave in prescribed ways. Instead, they should be educated to reason soundly about their practice and perform their teaching skillfully. To Shulman, teaching “begins with an act of reason, continues with a process of reasoning, culminates in performances of imparting, eliciting, involving, or enticing, and is then thought about some more until the process can begin again” (p. 13). These interconnected, recursive reasoning and action processes both spring from and add to teachers’ ever-evolving professional knowledge. They include six processes: comprehension (of what is to be taught and the purposes for teaching it); transformation (of what is to be taught, into conceptual models, learning activities, and adaptations to specific learners’ needs and preferences); instruction (the observable acts of teaching); evaluation (of both students’ learning and the teacher’s instruction); reflection (upon teaching/learning processes); and new comprehension, which is built in an ongoing way from reflexive experience of the other five processes. Shulman (1987a) further delineated these six pedagogical reasoning and action processes with specific subprocesses, as explained in “Pedagogical Reasoning and Action with Technology,” below.

It is important to note that Shulman’s (1987a) conceptualization of PR&A draws upon the full range of knowledge domains that are included in his depiction of the knowledge base for teaching. These domains extend beyond PCK, because teachers require “both a process of thinking about what they are doing and an adequate basis of facts, principles, and experiences from which to reason” (p. 12). In addition to PCK, teachers’ PR&A therefore draws on their knowledge of content, general pedagogy, curriculum, learners and their characteristics, educational contexts, and educational ends, purposes and values. A large proportion of teachers’ PR&A depends upon their experiences or “wisdom of practice” (p. 12) relative to all of these components in their knowledge bases.

According to Shulman (1987a), teachers’ knowledge-based PR&A explain both educational decisions and actions, because “[t]eaching is both effective and normative; it is concerned with both means and ends. Processes of reasoning underlie both” (p. 13). Might PR&A also explain teachers’ decisions and actions regarding integration of educational technologies? Probably so. But is there a distinctive technological version of Shulman’s pedagogical reasoning and action (TPR&A), parallel to TPCK/TPACK? Several authors have asserted that there is. Our view is somewhat different.
Does TPCK Imply TPR&A?

The notion of teachers as active decision-makers is not new. Teachers’ decision-making has been investigated since the early 1970’s, when several influential researchers realized that “decision making [is] central to understanding and improving teaching” (Borko, Roberts & Shavelson, 2008, p. 37). Highlighting teachers’ roles as ever-adaptive, creative designers, Mishra, Koehler and Kereluik (2009) state that the TPACK construct:

…emphasizes the role of teachers as decision makers who design their own educational technology environments as needed, in real time, without fear of those environments becoming outdated or obsolete. Using this approach, teachers do not attend to specific tools, but instead focus on approaches to teaching that endure through change in technologies, content, or pedagogies. (p. 52)

Is there something unique about this decision-making process when digital technologies are incorporated into PR&A? Richardson’s (2009) in-depth study of twelve fifth-, sixth-, and seventh-grade teachers’ instructional planning processes for their students’ technology-infused learning in four different curriculum areas showed that the teachers followed Shulman’s model of PR&A, “loosely applied” (p. viii). By contrast, the results from four other studies have been interpreted to assert that technological pedagogical reasoning and action is sufficiently different from Shulman’s original PR&A to warrant an amended model.

One of these views states that since digital tools and resources are incorporated during each and all steps of PR&A taken by technology-using teachers, these processes are fundamentally different from the model that Shulman proposed. Smart, Finger & Sim (2016) assert, for example, “…just as Shulman suggested that the processes of pedagogical reasoning develop PCK, …with the introduction of technology, teachers technologically pedagogically reason to develop their TPACK” (p. 61). In other words, this view argues that teachers’ PR&A processes change significantly when technologies are incorporated into their educational reasoning and decision-making.

Another research team found that seven technology-proficient teachers participating in a multiple case study also used Shulman’s PR&A processes when planning and teaching with digital tools, but suggested including technology selections and technology-related “caution,” or plans for what to do when technologies failed, as additional processes in the PR&A sequence (Feng & Hew, 2005, p. 3177). Based upon the results of data analysis, these researchers, like Smart (2016), combined and renamed several of the reasoning processes in Shulman’s (1987a) PR&A model. Still, like Richardson (2009), they found that participating teachers generally engaged in PR&A while actively using technologies.

Six “digitally able” (p. 236) teachers in Starkey’s (2010) multiple case study also appeared to follow the processes described in Shulman’s model when explaining their pedagogical reasoning and action. Starkey, like Smart, Sim and Finger (2015), noted that “the greatest variation appeared to depend on the resources the teachers chose to use” (p. 240). However, when describing the nature of each of the PR&A processes that she observed, Starkey recognized “a fundamental change since 1987: …students creating knowledge in the digital era through connections in an open and flexible curriculum, rather than the teacher transmitting the ‘truths’ and methodologies of a subject according to a prescribed curriculum” (p. 241). Loveless (2011) observed and described a similar shift, citing the student, rather than the teacher, as central in the connection-making:

Learning experiences [now] can be more fluid, interactive and multimodal. They are more mobile, not because the technologies are necessarily mobile, but because the learner can be placed more centrally, given access to information and opportunities to make meanings in a variety of linked environments. (pp. 305-306)

Starkey ascribed this change to the theory of connectivism, within which “a teacher…would transform existing knowledge as outlined in Shulman’s model, but would also encourage students to go beyond the teacher’s existing knowledge base by making or enabling connections” (p. 240). Starkey, therefore, adapted Shulman’s model “for the digital age” (p. 243) by renaming and redefining Shulman’s knowledge transformation processes to emphasize “enabling connections” (p. 242) in the ongoing customization of students’ learning opportunities. She also recommended fusing teaching, learning, and formative evaluation, rather than conceptualizing them as separate processes.
Niess and Gillow-Wiles (2017) used Starkey’s interpretation of PR&A as part of an in-depth study of master’s-level mathematics teachers’ electronic portfolios. Their study described the teachers’ technological PR&A that was applied at a systems level (p. 78). During several years of mathematics education degree work, participating teachers learned how to select and utilize multiple technologies in concert (as a system), and in content- and pedagogically appropriate ways. The researchers concluded:

> Teachers must develop a pedagogical reasoning process that makes valid and important connections with multiple technologies for the students as they are learning, beginning with comprehension of the subject matter and continuing with new comprehension after reflection on the instruction – a technological pedagogical reasoning process. (p. 79)

Clearly, Niess & Gillow-Wiles’ students engaged in conscious PR&A regarding educational technologies in their professional learning and work. These particular decisions and acts do differ from those that do not incorporate digital tools and resources. They are based in the teachers’ TPCK/TPACK; knowledge that multiple researchers have described as fundamentally different from PCK (e.g., Angeli & Valanides, 2005; Mishra & Koehler, 2006; Niess, 2005). But does having a greatly expanded set of (digital) tools available for learning and teaching change the essential nature of teachers’ comprehension, transformation or connection-enabling, instruction/evaluation or teaching/learning, and/or reflection/new comprehension processes (Shulman, 1987a; Starkey, 2010)?

Starkey later summarized her views on the essential differences between PR&A when it was conceived and shared more than 30 years ago, and what she sees it to be now, by saying:

> In the digital age, teachers will prioritise student learning over teaching. There is a subtle but important difference between teacher decisions which prioritise teaching above learning and those which prioritise learning over teaching. They are two perspectives; both value teaching and learning, but they approach the teaching process from different perspectives. The former is to keep the students engaged through the use of resources and carefully designed lessons, the latter is to monitor student learning through use of formative assessment and base teaching decisions on the learning progress of the students. (2012, p. 92)

Yet Shulman (1987a) seems to acknowledge this particular type of active monitoring and connection-making that Starkey (2010) and Loveless (2011) describe when he suggests that

> …students can literally initiate the process [of PR&A], proceeding by discovering, inventing, or inquiring, to prepare their own representations and transformations. Then it is the role of the teacher to respond actively and creatively to these student initiatives. (p. 14)

Further, Shulman (1987a) suggests that comprehension can focus upon values, or “the characteristics, needs, interests, or propensities of a particular individual or group of learners.” (p. 14) Given these rather flexible parameters offered by Shulman in his original description of PR&A, we question whether the interpretations of Smart, Feng and Hew, Starkey, and Loveless’ research results, as summarized above, depict truly fundamental differences in 21st-century pedagogical reasoning and action beyond the incorporation of new (digital) tools, resources, and communication networks in all aspects of teachers’ decision-making and pedagogical actions. Shulman’s model did not eschew student-centered, formative, constructivist approaches to learning and teaching. It also did not describe types of tools and resources that are used in learning and teaching in any detail. It did imply, however, that teachers hold primary responsibility for planning, facilitating, assessing, and customizing students’ learning. It with this basic assumption that another view of digital age pedagogical reasoning and action disagrees.

**Notions of TPR&A**

Like Smart (2016) and Feng & Hew (2005), Webb and Cox (2004) argued that “knowledge of affordances of ICT and decisions about their use” should be added “to the pedagogical reasoning process when teachers are planning and teaching lessons that incorporate ICT use,” (p. 238) especially during the process of representation. Representation, according to Shulman (1987a), is one of four processes that comprise transformation, which builds upon
comprehension, in teachers’ PR&A: preparation of material to be taught/learned, representation of the material in ways accessible to students, selection of instructional materials and methods, and adaptation of the materials and methods to both general and specific student characteristics. In Shulman’s model, teachers’ transformations form the basis of ongoing pedagogical decisions during planning, teaching, and evaluation. Webb and Cox (2004) remind us that expanding the knowledge base for teaching by adding technology knowledge makes PR&A considerably more complex.

Later, Webb (2011; 2014) extended these notions to assert that learning and teaching in technology-rich environments have begun to change the basic roles that students and teachers play. ICTs’ affordances permit teachers to design learning experiences for students in which “much of the traditional role of the teacher in structuring and scaffolding learning is done by the technology” (p. 4). Therefore, Webb says, learning and teaching are not as clearly differentiated in this digital age as they once were, with learning becoming more self-directed and metacognitive, and teaching and assessment becoming more collaborative. To Webb, this means that students “are undertaking some of the pedagogical reasoning that is traditionally done by teachers” (2011, p. 4).

Webb (2011) acknowledges that this fundamental shift in responsibility for learning and teaching can present significant challenges, especially as students and teachers are becoming accustomed to the expectations of their new roles. She recommends “extensive modelling and interaction…for students to (1) come to understand what is required of them and why it is important; (2) self-assess their current achievements; and (3) increase their involvement in pedagogical reasoning” (p. 11). Webb admits to the deluge of complexities that result from shared responsibilities for PR&A. She notes “major challenges” that this particular type of teacher-student collaboration causes, and the need for finding “ways of enabling learners to share as much as possible of the pedagogical reasoning process to manage their own learning and to engage in interactions…to support the learning of other students” (p. 12).

We wonder, however, whether the fundamental changes in teachers’ and students’ roles that Webb describes are more actual or aspirational at the present time. The presence of networked technologies with affordances that can support highly individualized, comparatively independent, self-monitored, self-assessed learning doesn’t necessarily suggest that most school-based activity has or will shift to this mode soon. With ever-increasing requirements of teachers and schools to ensure students’ measurable, reportable learning that is aligned to externally derived curriculum standards, societal and professional expectations of teachers to be the ones who are ultimately—but not necessarily exclusively—responsible for PR&A may be unstated, but strongly assumed. Moreover, teachers shouldering these decision-making and instructional responsibilities does not obviate the rich possibilities of student choice, self-assessment, peer feedback, or collaborative learning that can be supported by well-informed uses of educational technologies.

Does Knowledge Change Require Process Change?

Our central question, then, can be stated as follows. Do the educational affordances of digital technologies used in learning and teaching require a reconceptualization of the processes of teachers’ PR&A, similar to the ways in which the addition of technology knowledge to PCK fundamentally redefined it as TPCK/TPACK? If so, what is the nature of the essential and necessary differences between PR&A and TPR&A, beyond the pervasive use of digital technologies in the latter?

To answer this question, we first examine how adding technology knowledge to a part of the knowledge base for teaching (PCK) required us to change our understanding of that particular aspect of teachers’ knowing.

PCK with Technology

The TPCK/TPACK construct builds on Shulman’s (1986, 1987a) conception of PCK by integrating technology knowledge into this component of the knowledge base for teaching. TPACK (Thompson & Mishra, 2008) is most commonly represented as a Venn diagram with three overlapping circles: pedagogical knowledge (PK), content knowledge (CK) and technology knowledge (TK) (http://www.tpack.org/). In addition to these core forms of knowledge, this illustration of the TPACK construct also draws attention to combinations that represent specific aspects of teachers’ knowledge, including PCK, technological content knowledge (TCK), technological pedagogical knowledge (TPK) and TPACK, which sits at the nexus of all of the elements in the diagram. Despite the simplicity of
this representation, the addition of technology knowledge (TK) “increases the conceptual complexity [of PCK] by at least an order of magnitude” (Graham, 2011, p. 1955).

When contrasted with PCK, the comparative complexity of the TPACK construct is usually attributed to the introduction of TK. An argument can be made, however, that technologies are not a new aspect of the educational landscape, and that teachers have been required to think about tools such as books and pens for many decades. Bruce and Hogan (1998) have suggested that the ubiquity of such technologies renders them “transparent,” however, “or in other words, they [have] become commonplace and [are] not even regarded as technologies” (Mishra & Koehler, 2006, p. 1023). Graham (2011) extended this idea, suggesting that the knowledge needed to integrate use of transparent technologies in teaching and learning could be considered to be part of Shulman’s original knowledge base for teaching, specifically within “content representation or even curriculum and media” (p. 165).

To support this perspective, Graham (2011) notes that Angeli and Valanides (2009) also stated that Shulman intended for technology to be included as part of his knowledge base for teaching—specifically within curricular knowledge and associated materials—but that he

…did not explicitly [emphasis in original] discuss technology and its relationship to content, pedagogy and learners, and thus PCK in its original form does not specifically explain how teachers use the affordances of technology to transform content and pedagogy for learners. (p. 156)

If the use of transparent technologies can be considered to be part of the knowledge base for teaching, and if PR&A is the process by which teachers use tools (in part) to assist their students’ learning, then the introduction of transparent technologies into a teacher’s repertoire should not require technological pedagogical reasoning and action (TPR&A).

Not all educational technologies are transparent, however. Cox (2008) made a useful distinction between transparent and “emerging” technologies. She defined emerging technologies as new (in individual teachers’ experiences), typically digital, technologies “that are not yet transparent in the context under consideration” (p. 73). According to Cox, emerging technologies can become transparent over time if they are used habitually. The use of emerging, instead of transparent, technologies requires, in Cox’s view, the addition of TK to PCK. This definition of TK that sits outside PCK has two important implications.

First, emerging technologies’ ongoing proliferation has necessitated the introduction of TK to the knowledge base for teaching. This is not simply a matter of adding TK to Shulman’s original list of knowledge domains. In addition, and in a manner similar to the intersection of PK and CK to become PCK, the introduction of TK to PCK adds new overlapping dimensions: TCK, TPK and TPACK. Second, adding TK to the knowledge base for teaching, plus expanding PCK to become TPACK, reveals the temporal, “‘sliding’ nature of TCK, TPK, and TPACK” (Cox, 2008, p. 78). Cox explains this characteristic by suggesting that now-transparent technologies were once emerging technologies, as books were approximately five hundred years ago. Initially, the pedagogical use of books required TPACK in this sense, but now requires PCK, plus the curricular knowledge (and associated materials knowledge) that Shulman listed as part of the total knowledge base for teachers.

Does the use of presently emerging technologies (in Cox’s way of describing them), which requires TPACK (not PCK), in addition to the other parts of the knowledge base for teachers, also require a sliding version of PR&A; that is, TPR&A? To answer this question, we will consider each of the six PR&A processes in Shulman’s model next.

**Pedagogical Reasoning and Action with Technology**

We have argued above that the professional knowledge base needed for teaching changes as educational technologies emerge in the sense that Cox (2008) suggested: specifically by adding TK to the base (Smart, Sim & Finger, 2015) and transforming PCK into TPCK/TPACK. By implication, this suggests that instruction and evaluation that utilize emerging technologies according to their particular educational affordances (Bower, 2008) or “action potentials” (p. 3) also will change. Instruction and evaluation were two of the six primary processes that comprised Shulman’s (1987a) model of PR&A. He described instruction as “active teaching, discovery or inquiry instruction, and the observable forms of classroom teaching” (p. 15) and evaluation as “checking for student understanding” (p. 15) both during and after teaching, plus self-evaluation of teaching performance. Thus, pedagogical action likely changes when
incorporating emerging technologies in accordance with their particular educational affordances. What about pedagogical reasoning?

To answer this question, we will consider the other four primary processes named in Shulman’s PR&A model: comprehension, transformation (involving preparation, representation, selection, and adaptation/tailoring to student characteristics), reflection, and new comprehension.

**Comprehension**

Shulman (1987a) asserted “teaching necessarily begins with a teacher’s understanding [and analysis] of what is to be learned and how it is to be taught” (p. 7). This “comprehension” is the first of the six named PR&A processes. However, Shulman reminds us that

…the rhetoric of the analysis [of what is to be taught] is not meant to suggest that education is reduced to knowledge transmission, the conveying of information from an active teacher to a passive learner, and that this information is viewed as product rather than process. (p. 7)

Instead, Shulman explains that even in the “most student-centered forms of education, where much of the initiative is in the hands of the students, there is little room for teacher ignorance. Indeed…teacher comprehension is even more critical for the inquiry-oriented classroom than for its more didactic alternative” (p. 7). This statement seems to refute Starkey’s (2010) argument that a “fundamental change” has occurred in the teacher comprehension processes that Shulman posited in 1987: that students now create knowledge “through connections in an open and flexible curriculum, rather than the teacher transmitting the ‘truths’ and methodologies of a subject according to a prescribed curriculum” (p. 241). Comprehension in Shulman’s PR&A model does not imply a teacher-centered, didactic, or transmission model of teaching. It does acknowledge, however, that teachers bear the primary responsibility for PR&A, even when it is done in collaboration with students.

**Transformation**

Shulman (1987a) also reminded us that comprehending both content to be taught and its purposes for being learned “does not particularly distinguish a teacher from non-teaching peers. We expect a math major to understand mathematics or a history specialist to comprehend history” (p. 15). Instead, incorporating PCK, he explained:

…the key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students. (p. 15)

Shulman (1987a) said that “comprehended ideas” (p. 16) must be processed by preparing and/or interpreting teaching materials, deciding how to represent the comprehended ideas to students, selecting appropriate teaching methods and models, and adapting/tailoring these representations to students both as a group and as individuals. All of these actions are aspects of transformation within pedagogical reasoning. While the knowledge used by teachers within each of these transformation sub-processes can change when emerging technologies (Cox, 2008) are incorporated, we argue that the processes themselves—that is, the pedagogical reasoning used—does not change fundamentally from what Shulman explained in his PR&A model. With this statement, we acknowledge a disagreement with Webb’s (2010; 2014) assertion that, with the use of emerging technologies, pedagogical reasoning is now shared by teachers and students. While this role change may be observable in some higher education contexts—for example, as described in Fielding’s (2011) sixth and final level of partnership between instructors and students called “intergenerational learning as lived democracy” (p. 53)—the primary responsibility for PR&A in most classrooms still rests with teachers, given professional, organizational, and societal expectations both at the present time and in the foreseeable future. However, as explained in the previous section, this reality does not necessarily relegate students to being passive, disempowered, or less active learners.

**Reflection and New Comprehension**

Shulman (1987a) says that PR&A incorporates professional reflection (review, reconstruction, re-enacting, and critical analysis) continuously, which leads to new professional learning, or “new comprehension” (p. 19) for teachers. Smart, Sim and Finger (2015) suggest that these two processes are “fundamentally the same” (p. 3424). We agree that the processes co-occur and feed each other. However, as an important aspect of pedagogical reasoning, and like the
transformation processes explored above, we suggest that when use of emerging technologies is considered by teachers, the acts of reflection and new comprehension themselves (not the technology-related knowledge used in these thinking processes) are not fundamentally different than when emerging technologies are not incorporated in teachers' pedagogical reasoning.

This, then, suggests a direct answer to our central question. Teachers’ knowledge is used to “provide the grounds for [their] choices and actions” (Shulman, 1987a, p. 13). Although teachers’ knowledge (e.g., TPCK/TPACK), and therefore their pedagogical actions, can change in fundamental ways when emerging technologies are incorporated, their pedagogical reasoning processes—that is, the ways in which they ponder and arrive at pedagogical decisions—typically do not, because it is not necessary that they do so. Why, then, is it believed that PR&A must become TPR&A? To conclude this chapter, we will offer a response.

**Technocentrism and TPR&A**

Finding ways to exploit emerging technologies’ affordances (Bower, 2008) in service of students’ learning can expand learning and teaching possibilities—especially instructional selection, adaptation, and evaluation—in great measure, making many more options (e.g., types of learning activities; students’ choices of expression; opportunities for collaborative learning) available to teachers engaged in PR&A. These options encompass a plethora of ways in which students can interact with what they learn, with each other, and with those outside of the classroom, school, or geographic community, and how that learning can be personalized. Familiarity with these learning and teaching possibilities—constituting TPCK/TPACK that extends far beyond merely knowing the educational affordances of particular digital tools and resources—is essential for teachers to build and use, so that they can address their students’ learning needs and preferences with 21st-century expertise. While this is very important additional knowledge that teachers need, in most cases, it does not require substantially different processes for planning and reflecting upon students’ learning from what Shulman (1987a) described so expansively more than 30 years ago.

When might teachers’ PR&A shift in a way that could be described accurately as TPR&A? Only when teachers’ reasoning and/or action are technocentric. Seymour Papert (1987) coined this term to describe an excessive and shortsighted focus upon digital tools, similar to the ways in which a child at an egocentric stage of development has “difficulty understanding anything independently of the self” (p. 23). If, for example, a teacher was forced to surrender his PR&A to using scripted technology-based curriculum materials (e.g., a comprehensive, tracked learning management system) without customizing them to address his students’ specific learning needs, he would be using technocentric pedagogical reasoning and action, since the decision to use the technology-based materials would have preceded, and provided a focal point for, his pedagogical decision-making and action. Similarly, if another teacher built a lesson around students’ use of a digital tool (e.g., an interactive whiteboard) that had just been acquired in her school—at the urging of the school’s principal, who wanted to be sure that the new technology was being used in classrooms—the teacher’s PR&A could legitimately be described as TPR&A, due to its primary focus upon particular technology use, rather than student learning. Although pedagogical action can change in fundamental ways when emerging technologies are used educationally, non-technocentric processes of pedagogical reasoning typically do not.

**Recommendations for Future Research**

Given the past decade-plus of active research about teachers’ TPCK/TPACK, and the comparative dearth of extant research about teachers’ planning and decision-making with educational technologies (Richardson, 2009), we still have much to discover about how and why teachers’ TPCK/TPACK—as one important part of a comprehensive knowledge base for teachers—is applied and expanded within the processes that comprise teachers’ reasoning, planning, and reflection. What, then, is the nature of teachers’ PR&A when they incorporate emerging educational technologies in their praxis? We invite our colleagues to join us in exploring this important conceptual expansion of TPCK/TPACK-based inquiry.

**References**


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Impact of Prior Knowledge, Course Design, and Technology Preparation on Pre-service Teachers’ TPACK Development in a Required Educational Technology Course

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Abstract: This study investigated the impact of prior knowledge, course design, and technology integration on pre-service teachers' post-TPACK scores in a required educational technology course. Statistical analyses, two-way MANOVA, one-way MANCOVA, and one-way ANCOVA were conducted. All three variables affected pre-service teachers' post-TPACK scores. In particular, pre-service teachers who reported higher pre-TPACK scores had higher post-TPACK scores. The second course design, which integrated content-specific strategies guided by the TPACK framework, was more effective for developing pre-service teachers’ TPACK. Findings provide empirical data on the impact of prior knowledge, course design, and technology integration on pre-service teachers’ TPACK development. Future directions for research and practical implications are discussed.

Keywords: pre-service teachers, TPACK, prior knowledge, course design, technology preparation

Introduction

Most teacher educators would agree that developing pre-service teachers' technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006) is quite challenging. Several researchers in the field have conducted a significant number of studies to measure pre-service teachers’ TPACK development in teacher education programs (e.g., Tondeur, van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich, 2012; Willermark, 2017). Many have reported positive outcomes from the various strategies adopted (Chai, Koh, Tsai, & Tan, 2011; Schmidt et al., 2009). Others reveal pre-service teachers who graduate from teacher education programs report feeling unprepared to integrate technology into their curricula (Gray, Thomas, & Lewis, 2010). This troublesome finding warrants more research efforts invested in understanding how pre-service teachers develop their TPACK (Mishra & Koehler, 2006) and TPACK strategic thinking (Niess, 2011, 2016).

In some teacher preparation programs, a stand-alone educational technology course is the first place where pre-service teachers learn about technology use and integration. Many studies have been conducted in these courses (Willermark, 2017). Findings reveal such courses and their effectiveness in developing pre-service teachers’ TPACK domains (Abbitt, 2011; Graham, Borup, & Smith, 2012; Schmidt et al., 2009). However, some pre-service teachers report they need more preparation besides a stand-alone educational technology course (Foulger, Buss, Wetzel, & Lindsey, 2012; Koh & Divaharan, 2011). The purpose of this study was to investigate whether course design can impact pre-service teachers' post-TPACK scores in relationship to pre-service teachers’ prior knowledge.

Literature Review

As technology becomes more and more readily available in schools, it is the expectation that teachers should be able to integrate it meaningfully into their classroom instruction. Furthermore, this trend of increasing technology use in schools highlights the necessity of equipping pre-service teachers with the knowledge and skills to teach 21st-century students (Jonassen, 2003). Brown and Warschauer (2006) stated that technology integration has a peripheral
role in most teacher preparation programs. They reported that pre-service teachers had insufficient exposure to and modeling with technology integration. These findings have profound implications for both teacher preparation programs and K–12 schools. Teacher educators’ efforts need to be invested in developing pre-service teachers' technological pedagogical content knowledge (TPACK) throughout teacher education programs (Mishra & Koehler, 2006).

Most research studies that investigated pre-service teachers' TPACK development is situated in a stand-alone educational technology course (Willermark, 2017). Although positive outcomes were reported (e.g., Kaya & Dag, 2013; Sahin, 2011), most studies did not specifically address how the content was organized and how the course was designed. The stand-alone educational technology courses are typically one semester long (Koh & Divaharan, 2011; Pamuk, 2011). Therefore, it is difficult to know whether pre-service teachers were taught explicitly about how to align content, pedagogy, and technology in the act of teaching (Angeli & Valanides, 2005; Mishra & Koehler, 2006).

With this context in mind, comparing different course designs of the stand-alone educational technology course becomes necessary, where results might shed light on whether different designs of the course produce different results on pre-service teachers’ TPACK development. The purpose of this study was to compare the impact of various course designs of a stand-alone educational technology course on pre-service teachers' post-TPACK scores by examining pre-service teachers' prior knowledge and technology preparation.

Methodology

Study participants were 1, 246 pre-service teachers enrolled in a required educational technology course in a teacher education program at a large U.S. Midwestern land-grant university. The course was composed of two 50-minute lectures and a weekly 2-hour lab section. Over the nine academic years (2009-2017), the course had two specific designs, but the course content did not change dramatically. The first design, which introduced general educational technology topics, such as digital storytelling, digital citizenship, interactive whiteboard, etc., was used from 2009 – 2013. In 2013, the educational technology course (2013 – 2017) was redesigned around the guidelines of TPACK framework, which then included more content-specific technology preparation using research-based pedagogies and strategies (Mishra & Koehler, 2006; Tondeur et al., 2012). For example, in the science content module, inquiry-based learning pedagogy was introduced. Pre-service teachers followed the 5E model and explored the garden ecosystem using augmented reality and iPad apps. Time is an important factor since technology changes rapidly. In another study, several statistics analyses (descriptive analyses, one-way ANOVA test, and regression analyses) were run to determine whether there was a trend over the years. No trend was found over the nine years.

Quantitative data were collected with a validated TPACK survey (Schmidt et al., 2009) using a pre- and post-survey design. This TPACK survey examines the seven TPACK domains: 1) technology knowledge (TK), 2) content knowledge (CK), 3) pedagogical knowledge (PK), 4) pedagogical content knowledge (PCK), 5) technological content knowledge (TCK), 6) technological pedagogical knowledge (TPK), and 7) technological pedagogical content knowledge (TPACK) (for a full list of definitions, see Schmidt et al., 2009). As a result of matching the pre- and post-survey responses, the researchers collected 1,246 matched responses over a nine-year period. The majority of these pre-service teachers (974, 78.17%) were Elementary Education majors, while 222 (17.82%) majored in Early Childhood Education and a few (50, 4.01%) were enrolled in other related majors. There were more female participants (1,115, 89.49%) than male participants (131, 10.51%). Just over 90% of the pre-service teachers were from 18 to 22 years old (1,139, 91.41%). Fewer were 23–26 years old (76, 6.10%) and even fewer were between 27–32 years old (18, 1.44%). Only 13 participants (1.04%) were 32 years or older. Almost half of the participants were sophomores (591, 47.43%) and the rest were classified as juniors (309, 24.80%), freshmen (267, 21.43%), and seniors (79, 6.34%). Participants also had various amounts of prior experience related to participating in the teaching practicum or field experiences. Less than half of the pre-service teachers (515, 41.33%) had some previous practicum experience, while 58.67% (n = 731) had no prior practicum experience. Nearly 20% of the participants (17.72%) acknowledged being enrolled in a Learning Technology Minor offered by the institution, which provides additional targeted preparation (16 credits of classes) specifically in educational technology. For the data analysis, 1,246 pre-service teachers were placed into four distinct groups based on their prior knowledge (pre-TPACK scores) and course design (see Table 1). In another study analyzing the same dataset, cluster analyses were conducted, and the results revealed two clusters (referred to as cluster 1 and cluster 2) of pre-service teachers based on their prior knowledge (pre-TPACK scores). Course design was used as another grouping factor for these two clusters.
### Demographic characteristics

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<td>Freshman</td>
<td>85 (20.00%)</td>
<td>97 (21.10%)</td>
<td>44 (25.00%)</td>
<td>41 (21.90%)</td>
</tr>
<tr>
<td>Sophomore</td>
<td>207 (48.80%)</td>
<td>192 (33.33%)</td>
<td>89 (50.60%)</td>
<td>103 (55.10%)</td>
</tr>
<tr>
<td>Junior</td>
<td>99 (23.30%)</td>
<td>138 (30.10%)</td>
<td>35 (19.90%)</td>
<td>37 (19.80%)</td>
</tr>
<tr>
<td>Senior</td>
<td>33 (7.80%)</td>
<td>32 (7.00%)</td>
<td>8 (4.50%)</td>
<td>6 (3.20%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Major</th>
<th>Group 1 (n = 424)</th>
<th>Group 2 (n = 459)</th>
<th>Group 3 (n = 176)</th>
<th>Group 4 (n = 187)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECE</td>
<td>85 (20.00%)</td>
<td>93 (20.30%)</td>
<td>17 (9.70%)</td>
<td>27 (14.40%)</td>
</tr>
<tr>
<td>EL ED</td>
<td>316 (74.50%)</td>
<td>352 (76.70%)</td>
<td>152 (86.40%)</td>
<td>154 (82.40%)</td>
</tr>
<tr>
<td>Other</td>
<td>23 (5.40%)</td>
<td>14 (3.10%)</td>
<td>7 (4.00%)</td>
<td>6 (3.20%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Enrolled in the learning technologies minor</th>
<th>Group 1 (n = 424)</th>
<th>Group 2 (n = 459)</th>
<th>Group 3 (n = 176)</th>
<th>Group 4 (n = 187)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>46 (10.80%)</td>
<td>42 (9.20%)</td>
<td>32 (18.20%)</td>
<td>26 (13.90%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Past or current practicum experiences</th>
<th>Group 1 (n = 424)</th>
<th>Group 2 (n = 459)</th>
<th>Group 3 (n = 176)</th>
<th>Group 4 (n = 187)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>138 (32.50%)</td>
<td>166 (36.20%)</td>
<td>100 (56.80%)</td>
<td>99 (52.90%)</td>
</tr>
</tbody>
</table>

**Table 1.** Pre-service Teachers' Demographic Characteristics (n = 1,246)

An essential pre-requisite for the data analysis is to verify the reliability of the survey instrument. Cronbach’s coefficient alphas (α) were computed for all TPACK domains. For the pre-test, the Cronbach’s coefficient alphas (α) ranged from .80 to .92 (i.e., TK: α = .86; CK: α = .80; PK: α = .87; PCK: α = .83; TCK: α = .87; TPK: α = .82; TPACK: α = .92). Similar results were found in the Cronbach’s coefficient alphas (α) of the post-test, which ranged from .86 to .91 (i.e., TK: α = .86; CK: α = .86; PK: α = .91; PCK: α = .86; TCK: α = .87; TPK: α = .88; TPACK: α = .91). According to Nunnaly and Berstein (1994) a Cronbach’s alpha (α) of .70 is considered acceptable for exploratory studies, .80 for basic research, and .90 for applied scenarios (Lance, Butts, & Michels, 2006). Paired-sample t-tests were conducted to assess whether there were statistically significant differences in pre- and post-TPACK scores of all pre-service teachers, as well as those for individual groups. Next, a set of two-way MANOVA tests were used to examine whether there were statistically significant differences in the post-TPACK scores based on pre-TPACK scores and course design (Huberty & Olejnik, 2006). Technology preparation was a time variable that showed pre-service teachers’ change in TPACK over time. Afterward, a one-way MANCOVA test was conducted to determine...
whether there were any statistically significant differences between the adjusted means of the four groups, having controlled for a continuous covariate. Follow-up one-way ANCOVA tests were conducted.

### Results

In sum, pre-service teachers developed knowledge in all seven TPACK domains after taking the required educational technology course no matter what group they were assigned (see Table 2 for a synopsis of the scores and the results from paired-sample t-tests). CK, PK, TK, TCK, and TPACK all had medium effect sizes, while PCK and TPK had small effect sizes. This preliminary analysis showed that prior knowledge and course design had the potential to be key variables for pre-service teachers’ TPACK development.

<table>
<thead>
<tr>
<th>TPACK knowledge domains</th>
<th>Group 1 (n = 424)</th>
<th>Group 2 (n = 459)</th>
<th>Group 3 (n = 176)</th>
<th>Group 4 (n = 187)</th>
<th>Total</th>
<th>Difference between pre- and post-surveys</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (SD)</td>
<td>N (SD)</td>
<td>N (SD)</td>
<td>N (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>42.03 (5.10)</td>
<td>45.59 (4.60)</td>
<td>42.74 (5.44)</td>
<td>46.20 (4.47)</td>
<td>44.07</td>
<td>19.65 1245 &lt; .0005*** .42</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>45.42 (5.36)</td>
<td>47.50 (5.32)</td>
<td>47.14 (4.80)</td>
<td>49.21 (4.89)</td>
<td>47.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>23.75 (2.96)</td>
<td>28.15 (2.88)</td>
<td>23.76 (3.70)</td>
<td>28.34 (2.92)</td>
<td>26.06</td>
<td>21.12 1245 &lt; .0005*** .30</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>27.06 (3.42)</td>
<td>29.25 (3.22)</td>
<td>27.40 (3.15)</td>
<td>29.96 (3.47)</td>
<td>28.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>19.81 (3.73)</td>
<td>21.95 (3.88)</td>
<td>19.66 (3.78)</td>
<td>22.89 (3.24)</td>
<td>21.04</td>
<td>24.94 1245 &lt; .0005*** .28</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>22.75 (3.32)</td>
<td>23.70 (3.62)</td>
<td>23.07 (2.72)</td>
<td>24.99 (2.94)</td>
<td>23.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>12.74 (1.94)</td>
<td>15.72 (1.53)</td>
<td>12.29 (2.02)</td>
<td>15.70 (1.52)</td>
<td>14.22</td>
<td>18.30 1245 &lt; .0005*** .21</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>14.72 (2.29)</td>
<td>16.11 (2.03)</td>
<td>15.14 (1.97)</td>
<td>16.56 (1.96)</td>
<td>15.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>11.36 (2.59)</td>
<td>14.47 (2.24)</td>
<td>11.30 (2.73)</td>
<td>14.90 (2.26)</td>
<td>13.03</td>
<td>35.89 1245 &lt; .0005*** .26</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>15.65 (2.09)</td>
<td>16.56 (2.14)</td>
<td>16.18 (1.71)</td>
<td>17.23 (1.84)</td>
<td>16.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>18.07 (2.31)</td>
<td>20.73 (1.79)</td>
<td>17.39 (2.63)</td>
<td>20.62 (1.85)</td>
<td>19.33</td>
<td>27.27 1245 &lt; .0005*** .23</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>21.07 (2.32)</td>
<td>21.97 (2.20)</td>
<td>20.85 (2.03)</td>
<td>22.13 (2.21)</td>
<td>21.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPACK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>25.24 (3.74)</td>
<td>31.59 (3.07)</td>
<td>24.46 (4.27)</td>
<td>31.49 (2.90)</td>
<td>28.41</td>
<td>32.97 1245 &lt; .0005*** .40</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>31.90 (3.69)</td>
<td>33.81 (3.37)</td>
<td>32.33 (3.31)</td>
<td>34.51 (3.60)</td>
<td>33.06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. * p < .05; ** p < .01; *** p < .001.

Table 2. Pre-service Teachers' mean TPACK scores by Group (n = 1,246)
A correlation analysis was executed to explore the correlations between the TPACK domain subscales. Pearson correlation coefficients were used to test multicollinearity. Correlation analysis of the seven post-TPACK subscales was examined. The subscales correlated with each other, but there was no evidence of multicollinearity, as assessed by Pearson correlations (|r| < .9), thus justified the use of a two-way MANOVA analysis (see Table 3).

### Table 3. Pearson correlations among TPACK subscales

<table>
<thead>
<tr>
<th>Post-TPACK Domains</th>
<th>Course Design 1</th>
<th>Course Design 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Difference</td>
<td>95% CI</td>
</tr>
<tr>
<td>Post-CK</td>
<td>2.08</td>
<td>[.39, 2.77]</td>
</tr>
<tr>
<td>Post-PK</td>
<td>2.19</td>
<td>[.75, 2.62]</td>
</tr>
<tr>
<td>Post-TK</td>
<td>1.95</td>
<td>[.52, 1.39]</td>
</tr>
<tr>
<td>Post-PCK</td>
<td>1.39</td>
<td>[.11, 1.67]</td>
</tr>
<tr>
<td>Post-TCK</td>
<td>.91</td>
<td>[.64, 1.17]</td>
</tr>
<tr>
<td>Post-TPK</td>
<td>.91</td>
<td>[.61, 1.20]</td>
</tr>
<tr>
<td>Post-TPACK</td>
<td>1.92</td>
<td>[.46, 2.37]</td>
</tr>
</tbody>
</table>

Note. * p < .05; ** p < .01; *** p < .001.

### Table 4. Post hoc test results of prior knowledge main effects for post-TPACK domains

There was a statistically significant course design effect on the combined dependent variables, F(1, 1242) = 8.18, p < .0005, Wilks’ Λ = .04. In particular, there were statistically significant main effects of course design on six post-TPACK scores (CK, PK, TK, PCK, TCK, and TPACK). Overall, the second course design (the TPACK framework) was found to be more effective in developing pre-service teachers’ TPACK (see Table 5).

### Table 5. Post hoc test results of course design main effects for post-TPACK domains

<table>
<thead>
<tr>
<th>Post-TPACK Domains</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Difference</td>
<td>95% CI</td>
</tr>
<tr>
<td>Post-CK</td>
<td>1.73</td>
<td>[.81, 2.64]</td>
</tr>
<tr>
<td>Post-PK</td>
<td>.34</td>
<td>[−.24, .91]</td>
</tr>
<tr>
<td>Post-TK</td>
<td>.33</td>
<td>[−.26, .91]</td>
</tr>
<tr>
<td>Post-PCK</td>
<td>.41</td>
<td>[.04, .78]</td>
</tr>
<tr>
<td>Post-TCK</td>
<td>.53</td>
<td>[.17, .88]</td>
</tr>
<tr>
<td>Post-TPK</td>
<td>.22</td>
<td>[−.61, 1.17]</td>
</tr>
<tr>
<td>Post-TPACK</td>
<td>.43</td>
<td>[−.18, 1.04]</td>
</tr>
</tbody>
</table>

Note. * p < .05; ** p < .01; *** p < .001.
One-way MANCOVA tests were conducted. Means and adjusted means were not very dissimilar (see Table 6). TPACK domains all showed a general trend to be higher in Group 4 (higher pre-TPACK scores and content-specific course design). There was a statistically significant difference between the different groups based on the prior knowledge and course design on the combined dependent variables after controlling for a pre-TPACK score, $F(21, 3546.80) = 5.02, p < .0005$, Wilks’ $\Lambda = .92$, partial $\eta^2 = .03$.

<table>
<thead>
<tr>
<th>TPACK knowledge domains</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>45.42</td>
<td>47.50</td>
<td>47.14</td>
<td>47.26</td>
</tr>
<tr>
<td></td>
<td>(3.36)</td>
<td>(5.32)</td>
<td>(4.80)</td>
<td>(4.43)</td>
</tr>
<tr>
<td>PK</td>
<td>27.06</td>
<td>29.25</td>
<td>27.40</td>
<td>28.11</td>
</tr>
<tr>
<td></td>
<td>(3.42)</td>
<td>(3.22)</td>
<td>(3.15)</td>
<td>(3.26)</td>
</tr>
<tr>
<td>TK</td>
<td>22.75</td>
<td>23.70</td>
<td>23.07</td>
<td>23.45</td>
</tr>
<tr>
<td></td>
<td>(3.32)</td>
<td>(3.62)</td>
<td>(2.72)</td>
<td>(2.94)</td>
</tr>
<tr>
<td>PCK</td>
<td>14.72</td>
<td>15.66</td>
<td>15.14</td>
<td>15.48</td>
</tr>
<tr>
<td></td>
<td>(2.29)</td>
<td>(2.03)</td>
<td>(1.97)</td>
<td>(1.96)</td>
</tr>
<tr>
<td>TCK</td>
<td>15.65</td>
<td>16.56</td>
<td>16.18</td>
<td>16.46</td>
</tr>
<tr>
<td></td>
<td>(2.09)</td>
<td>(2.14)</td>
<td>(1.73)</td>
<td>(1.84)</td>
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<td></td>
<td>(2.32)</td>
<td>(2.20)</td>
<td>(2.03)</td>
<td>(2.21)</td>
</tr>
<tr>
<td>TPACK</td>
<td>31.90</td>
<td>33.81</td>
<td>32.33</td>
<td>33.07</td>
</tr>
<tr>
<td></td>
<td>(3.70)</td>
<td>(3.37)</td>
<td>(3.20)</td>
<td>(3.31)</td>
</tr>
</tbody>
</table>

Table 6. Means, adjusted means, standard deviations, and standard errors for the TPACK domains for each group.

Follow up univariate one-way ANCOVAs were performed. A Bonferroni adjustment was made such that statistical significance was accepted at $p < .007$. There were statistically significant differences in adjusted means for CK ($F(3, 1241) = 17.26, p < .0005$, partial $\eta^2 = .04$), PK ($F(3, 1241) = 10.18, p < .0005$, partial $\eta^2 = .02$), TK ($F(3, 1241) = 9.60, p < .0005$, partial $\eta^2 = .02$), PCK ($F(3, 1241) = 13.41, p < .0005$, partial $\eta^2 = .03$), TCK ($F(3, 1241) = 11.99, p < .0005$, partial $\eta^2 = .03$), TPK ($F(3, 1241) = 4.03, p < .007$, partial $\eta^2 = .01$), and TPACK ($F(3, 1241) = 6.13, p < .0005$, partial $\eta^2 = .02$) (see Table 7 for pairwise comparisons).

<table>
<thead>
<tr>
<th>TPACK knowledge domains</th>
<th>Difference in adjusted means (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1 vs. 2</td>
</tr>
<tr>
<td>CK</td>
<td>-1.89</td>
</tr>
<tr>
<td></td>
<td>(-3.06, .73)</td>
</tr>
<tr>
<td>PK</td>
<td>-1.04</td>
</tr>
<tr>
<td></td>
<td>(-1.76, .32)</td>
</tr>
<tr>
<td>TK</td>
<td>-.35</td>
</tr>
<tr>
<td></td>
<td>(-1.09, .39)</td>
</tr>
<tr>
<td>PCK</td>
<td>-.83</td>
</tr>
<tr>
<td></td>
<td>(-1.30, .36)</td>
</tr>
<tr>
<td>TCK</td>
<td>-.44</td>
</tr>
<tr>
<td></td>
<td>(-.90, .01)</td>
</tr>
<tr>
<td>TPK</td>
<td>-.47</td>
</tr>
<tr>
<td></td>
<td>(-.97, .03)</td>
</tr>
<tr>
<td>TPACK</td>
<td>-.72</td>
</tr>
<tr>
<td></td>
<td>(-1.48, .04)</td>
</tr>
</tbody>
</table>

Note. * = statistically significant difference ($p < .007$) based on Bonferroni adjustments; 95% confidence interval (CI) is simultaneous confidence interval based on Bonferroni adjustment.

Table 7. Pairwise contrasts for adjusted means for TPACK domains for each group.
Discussion

Three main conclusions can be drawn from this study. First, the required educational technology course was effective over the nine-year period studied, which helped pre-service teachers develop TPACK (all domains) no matter which cluster (cluster 1 or cluster 2) they were assigned. Second, prior knowledge affected pre-service teachers' post-TPACK scores. Pre-service teachers who had higher prior knowledge scores reported higher post-TPACK scores in all seven knowledge domains. This result confirms the findings in the learning sciences that prior knowledge and experiences greatly affect how learners perceive and organize new information and make connections between ideas (National Research Council, 2000). Pierson (2001) concluded that pre-service teachers had different levels of pedagogical expertise and technology proficiency. Because of these differences, pre-service teachers perceived and approached technology integration differently. Third, pre-service teachers enrolled in the second course design, a design grounded in the TPACK framework, reported higher post-TPACK scores compared to the scores reported by pre-service teachers from the first course design (general topic design). Results from this study demonstrate that a content-specific TPACK course design was more effective in developing pre-service teachers' TPACK. However, there was still a knowledge gap between cluster 1 and cluster 2 pre-service teachers, and the new course design (using TPACK framework) could not adequately close this gap due to the pre-service teachers' different levels of prior knowledge and experience.

These results suggest that the content-specific TPACK course design was more effective compared to a course design that focused broadly on general topics related to technology integration into PK-6 classrooms. These results were an extension of previous research studies reporting that a stand-alone educational technology course solely covering technology literacy and awareness was not sufficient (Allsopp, Alvarez McHatton, & Cranston-Gingras, 2009; Herner-Patnode & Lee, 2009; Park & Ertmer, 2008). Abbitt and Klett (2007) compared pre-service teachers' self-efficacy beliefs in three different course designs. They found that the course design, which covered broad issues of technology integration, was likely to have a more positive impact on pre-service teachers' self-efficacy beliefs than a course where the goal was to develop pre-service teachers' proficiency skills with specific computer technology. This current study found that course design mattered in practice, and an approach that focused more on content-specific technology preparation was more effective in developing pre-service teachers' TPACK.

It is worth investigating why the content-specific course design appears more effective in preparing pre-service teachers’ TPACK. As introduced in the methodology section, the second course design touched on content-specific CK and PK with particular emphasis given to the interplay between CK, PK, and TK. Furthermore, every content-specific module (2-3 weeks of instruction) was developed in such a way to model TPACK lessons in practice, which utilized technology at the modification and redefinition levels in the SAMR model (Puentedura, 2006). Besides this content-specific organization, the instructors also adopted an integrated approach to implementing six research-based strategies into the course (Tondeur et al., 2012). These strategies were presented in the inner circle of the SQD Model, which was created based on a literature review and synthesis of compelling qualitative evidence in preparing pre-service teachers for technology integration. Instructors were: 1) using teacher educators as role models, 2) reflecting on the role of technology in education, 3) learning how to use technology by design, 4) collaborating with peers, 5) scaffolding authentic technology experiences, and 6) providing continuous feedback (Baran, Canbazoglu Bilici, Albayrak Sari, & Tondeur, 2017). Overall, this study provided empirical evidence for the content-specific technology preparation and the usefulness of implementing a holistic approach toward technology integration. Therefore, it is beneficial for teacher educators to consider applying these two approaches within teacher preparation programs.

To utilize the power of content-specific technology preparation, teacher educators should provide content-based instructional modeling and application when working with pre-service teachers (Niess, 2005). There are a few possible suggestions for implementing content-specific technology preparation in practice. First, the TPACK activity types are useful resources to help situate pre-service teachers in thinking about and reflecting on the interplay between CK, PK, and TK (Harris, Grandgenett, & Hofer, 2010). These researchers also suggest that pre-service teachers combine and remix the activity types to design TPACK lessons, projects, and units. Since teachers could use these activity types regardless of their teaching philosophy and approach, there is room to teach content-specific pedagogies and instructional models during the process. In this way, using the TPACK activity types as resources, teacher educators could guide pre-service teachers through the lesson planning process referencing the designing cycles created by Hammond and Manfra (2009), Harris and Hofer (2009), and by Hutchison and Woodward (2014).

Recently, Hofer and Harris (2016) designed a customizable, modularized, TPACK online short course that showcases the utilization of the activity types and the real-life modeling from teachers. This short course could also be remixed into existing content-specific modules in an educational technology course. Several other online materials were developed over the years, which are designed to assist teacher educators better prepare pre-service teachers for
technology integration. For example, Figg created a 10-week gamified online learning module (http://www.handy4class.com/h4c2011/tpack-teacher-quest-2015/), while Zeitz and his students wrote a wiki book (https://en.wikibooks.org/wiki/TPACKing_for_a_Wonderful_Educational_Trip). Doering, Veletsianos, Scharber, and Miller (2009) incorporated TPACK into Geothentic (https://lt.umn.edu/geothentic/), while Angeli and colleagues designed a series of curriculum- and classroom-based design scenarios (Angeli, Valanides, Mavroudi, Christodoulou, & Georgiou, 2015). Sharing these materials and other resources online as open educational resources (OERs) and at major national and international conferences would impact and contribute to instructional approaches used with pre-service teachers to foster TPACK development.

It is encouraging to recognize that content-specific TPACK course design was more effective in developing pre-service teachers’ TPACK than a course design more focused on broad topics of technology integration. However, the content-specific TPACK course design did not close the TPACK gap that existed between the pre-service teachers in the two clusters (i.e., difference in prior knowledge). This suggests that pre-service teachers with a different amount of prior TPACK might need more differentiated instruction and scaffolding during an educational technology course. Two specific emerging pedagogies in higher education, like an adaptive e-learning system or team-based learning (TBL), might address this finding, but more empirical studies should be conducted to investigate such effectiveness.

References


Teaching WITH (not near) Virtual Manipulatives

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Abstract: Although mathematics teachers are expected to use technology to enhance student understanding, many teachers report that they are not prepared to teach with technology. The following study presents a task analysis framework and guiding questions used during a professional development (PD) opportunity for mathematics teachers aimed at supporting their efforts to teach with rather than near virtual manipulatives (VMs). Findings focus on teachers’ appropriation of two tools introduced during the PD to support their efforts to critique and modify VM tasks aimed at meeting their student needs and promoting the development of conceptual understanding. Implications for supporting teachers’ integration of technology tools are discussed.

Introduction

Although mathematics teachers have been using technology tools in the classroom for decades, teachers often report that they are not prepared to use technology in an innovative manner and effectively in their instruction (Albion et al., 2015). I define effectively using technology as teaching with technology (Leatham, 2002) and entails teachers using technology to promote opportunities for students to develop conceptual understanding through reflection and communication (Hiebert et al., 1997), as well as through using and connecting mathematical representations. On the other hand, teaching near technology describes teachers using technology in a manner that does not promote opportunities for students to communicate, reflect, and connect mathematical representations. Which leads me to the question, How can mathematics teachers be supported to teach with as opposed to near technology?

Using technology effectively in teaching mathematics requires a deeper knowledge of mathematics and technology, as well as of the ways in which teaching with technology transforms mathematics instruction (Wilson, 2008). Furthermore, Wilson suggests that teachers need to learn how to distinguish between mundane uses of technology (e.g., teaching near technology) and powerful instructional uses of technology (e.g., teaching with technology). Supporting teachers to teach with technology goes beyond providing access to technology tools. Rather, it includes providing opportunities for teachers to interact with and try out the technology tools integrated within their current curriculum. Additionally, it means providing teachers with resources that support their integration efforts and emerging understanding regarding their knowledge growth in how to teach with technology.

Over the past three decades, virtual manipulatives (VMs) are one technology tool that has gained increased attention by teachers, researchers, and organizations as a tool for potentially increasing student engagement and understanding. Although professional development (PD) is considered an integral component to teacher learning when changes to instructional practices and knowledge are sought (e.g., Driskell et al., 2016), minimal studies exist investigating PD aimed at promoting teachers use of virtual manipulatives (VMs) (Driskell et al.). Therefore, the following study investigated secondary mathematics teachers’ appropriation of tools introduced in a PD aimed at supporting their efforts to teach with VMs.

Virtual Manipulatives

Originally, VMs were online manipulatives modeled after physical objects. Although initially java-based applets, VMs are now found in a variety of platforms (e.g., HTML5, flash, cdf, etc.) and as apps for tablets (e.g., iPad and Android). Due to the increased capabilities and platforms on which VMs now exist, Moyer-Packenham and Bolyard (2016) have revised their original definition (see Moyer, Bolyard, & Spikell, 2002). Specifically, a VM is an “interactive, technology-enabled visual representation of a dynamic mathematical object, including all of the programmable features that allow it to be manipulated, that presents opportunities for constructing mathematical knowledge” (Moyer-Packenham & Bolyard).

VMs can be used to address issues of inequity amongst students and make higher levels of mathematics more accessible to all students (e.g., due to the ability to off-load calculations or drawings to some VMs thus enabling...
students to focus on content). Additionally, the interactive (sometimes “game-like”) environment and potential to receive immediate feedback can promote student exploration and perseverance for students who disengage or get frustrated by paper and pencil investigations (Moyer-Packenham & Westenskow, 2013). Recently, studies suggest that VMs can provide equal access for students to learn content by reducing effects of students’ demographics (e.g., SES and ELL status) as predictors of achievement (Moyer-Packenham et al., 2014) and can be used as a tool for differentiating instruction (e.g., Bouck et al., 2015).

Although VMS are relatively easy to find (e.g., an internet search), VMs or tasks may not meet the needs of the students in the classroom or promote opportunities to develop students’ conceptual understanding. Unfortunately, current studies typically focus on how or why teachers use VMs, and/or the effects of using VMs rather than investigating how teachers critique, modify, or develop tasks based on their students’ needs and learning goals. Additionally, minimal resources exist for supporting teachers in critiquing and modifying tasks to support their efforts to teach with VMs (see Ok, Kim, Kang, & Bryant, 2016 for evaluating instructional apps and Trocki, 2014 for evaluating dynamic geometry tasks).

Some of the virtual manipulative collections used by teachers in the PD included: ExploreLearning’s Gizmos, Flash & Math, NCTM Illuminations, Shodor Interactivate, and PhET Interactive Simulations. Visit http://bit.ly/VirtManips for an annotated list of virtual manipulative collections used during the PD. Visit http://bit.ly/VMActivities for a sorted compilation of virtual manipulative tasks, some of which were used be teachers in the PD.

Task Analysis Framework

Given the lack of resources aimed at supporting teaching with VMs, a task analysis framework was developed (see Table 1) and introduced to teachers in a PD. The framework intended to support teachers as they i) critiqued, modified, or designed VM tasks for use with their students that promoted the development of conceptual understanding and ii) distinguished between mundane uses of technology and powerful instructional uses (Wilson, 2008). A VM task refers to a VM and all accompanying instructional materials (e.g., prompts and directions) whether on screen or in printed form. Drawing from Sinclair (2003), a VM task may include more than one task focused on investigating a particular concept (e.g., through alternative exploration paths), but it may include only one task. Portions of the framework were adapted from frameworks by Trocki (2014) and Sinclair (2003), both of which were designed to support teachers’ development of tasks involving dynamic geometry software.

<table>
<thead>
<tr>
<th>Affordances</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Task is primarily a technology task with no focus on mathematics.</td>
</tr>
<tr>
<td>N/A</td>
<td>Virtual manipulative does not have mathematical fidelity required to respond to the prompts.</td>
</tr>
<tr>
<td>A</td>
<td>Task prompts students to recall a mathematical fact, rule, formula, or definition.</td>
</tr>
<tr>
<td>B</td>
<td>Task prompts students to report information from the virtual manipulative or consider mathematical concepts, processes, or relationships in the current display. The student is not expected to provide an explanation.</td>
</tr>
<tr>
<td>C</td>
<td>Task provides opportunities for students to explain the mathematical concepts, processes, or relationships in the current display.</td>
</tr>
<tr>
<td>D</td>
<td>Task provides opportunities for students to make predictions and then test their predictions using the virtual manipulative.</td>
</tr>
<tr>
<td>E</td>
<td>Task provides opportunities for students to connect multiple representations of a mathematical concept (e.g., graphical, algebraic, and tabular representations of a relation).</td>
</tr>
<tr>
<td>F</td>
<td>Task provides opportunities to check students’ understanding of mathematical concepts, processes, or relationships. Task may provide minimal feedback to the student based on specific errors.</td>
</tr>
<tr>
<td>G</td>
<td>Task provides opportunities for students to go beyond the current display by considering multiple examples to generalize mathematical concepts, processes, or relationships.</td>
</tr>
<tr>
<td>H</td>
<td>Task supports students’ exploration through manipulation of the display that may surprise one exploring the relationships represented or cause one to refine thinking based on themes within the surprise (e.g., addressing a common student misconception).</td>
</tr>
</tbody>
</table>

Table 1. Task Analysis Framework, Trocki (2014) and Sinclair (2003)

The affordances in the framework are separated into three hierarchical groups. When teachers applied or used the framework, they were to apply affordances to the task as a whole. Therefore, a task generally contains multiple affordances. If either of the first two prompts applied (i.e., primarily a technology task or the VM does not have mathematical fidelity), then it was suggested that teachers not use the VM or do the task. Although “lower level” affordances, A and B (i.e., prompting students to recall or report information) are helpful when activating
background/prior knowledge, familiarizing students with the VM, or launching a task. Affordances C through H provide opportunities for students to create explanations, make predictions, connect multiple representations, receive feedback, generalize, and potentially address common student misconceptions. Tasks that have affordances primarily from this third category have greater potential for promoting students’ development of conceptual understanding and are therefore more beneficial for teachers to use in their classroom.

Theoretical Grounding

This study draws from the third strand of activity theory (e.g., Engeström, 1999) to investigate teachers’ instructional practices related to using VMs and tasks, more specifically, their appropriation of tools introduced in a PD aimed at supporting their implementation efforts. Although the unit of analysis is an activity, an activity consists of a subject, object, and actions, all of which form the context of the activity. The subject, in this case the teachers in the PD, is the person or people engaged in the activity. The object (in this study teachers’ use of VM tasks) gives the activity specific direction and is the motivator for the activity. Actions (i.e., teachers’ instructional practices related to implementing VM tasks), are goal-directed processes of the subject as they achieve the object. Due to the dynamic nature of the activity system, overtime actions may become operations (i.e., teachers’ practices may become routinized and subconscious). Other aspects of this activity system (see Figure 1) include the tools/mediating artifacts (e.g., the VMs and tasks, the task analysis framework), rules (e.g., curriculum, instructional style), community (e.g., other teachers in the school), and division of labor (e.g., do teachers work primarily individually or in collaboration with others).

![Figure 1. Structure of an activity system for this PD](image)

Methods

The aim of the study was to design, implement, and investigate a PD aimed at promoting teachers’ effective use of VMs. Teachers’ work, conversations, and reflections during the PD were used to investigate how they appropriated tools related to using VMs as well as how systemic tensions influenced their appropriation of the tools. Interviews of focus teachers provided further insight into teachers’ implementation efforts.

Design of the Professional Development Opportunity

To promote secondary mathematics teachers’ effective use of VMs (i.e., to teach with technology), the design of this PD was based on evidence-based decisions. Research investigating technology focused PD opportunities for in-service teachers (e.g., Bicer & Capraro, 2016; Driskell et al., 2016; Martin et al., 2010; Matzen & Edmunds, 2007;
Mouza, 2009; Walker et al., 2012; Yamagata-Lynch, 2003) and components of effective PD (e.g., Borko, 2004; Guskey, 2002; Penuel, Fishman, Yamaguchi, & Gallagher, 2007; Webster-Wright, 2009) was reviewed. Drawing from similarities across the field, the following core components for effective PD guided the design of this PD (e.g., see Desimone, 2009): content focus (mathematics), active learning (teachers used and then critiqued tasks to be used in their classrooms), coherence (with the district/school goals to use technology to transform teaching and learning), duration (20 hours distributed across the school year), and collective participation to build a learning community among a group of teachers implementing the same curriculum (i.e., teaching pairs from the same schools). Over the course of the PD, teachers used and critiqued various VMs and tasks related to their content area (i.e., how the VM and/or task could be used with their students, what may be gained/lost by the implementation, affordances for student learning, etc.). As the PD progressed, teachers took on the responsibility for finding, designing, and modifying VM tasks to be used in their classrooms, thus strengthening the link between the PD and teachers’ practice (Wilson, 2008). Furthermore, this process supported the expansive cycle of the activity system (Engeström, 1999). Conversations and reflections were facilitated through examples of how VM tasks had been modified and implemented to meet different instructional needs of teachers and students.

Participants

Fourteen teachers from a suburban district in the Midwest participated in the PD. Teachers taught 5th grade through AP Calculus and had 2-20 years of teaching experience (Mean: 12.86 years, Median: 13.5 years). Teachers represented five schools in the district. Ten teachers, three of whom were intervention teachers, taught grades 6-8 in 1-1 schools whereby each student was assigned a Chromebook. The 5th grade teacher had an interactive whiteboard and some tablets available in her classroom. One high school teacher had a classroom set of Chromebooks, the other two high school teachers had access to a class set of Chromebooks and a computer lab. Besides the fifth-grade teacher, all teachers taught only mathematics. Of the 14 teachers in the PD, four teachers volunteered to be focus teachers (meaning there were additional interviews). The focus teachers (i.e., three middle and one high school teacher) had 15-20 years of teaching experience. Although all teachers attended the two PD sessions held during the school day (eight hours), two teachers did not attend any of the six sessions held after school (12 hours).

Data Sources and Analysis

Data collection occurred October through May and consisted of an online background survey, audio- and video-recordings of PD sessions, teacher reflections, and work during the sessions. Semi-structured interviews were conducted with the focus teachers at the beginning of the PD and near the end of the PD. Transcripts (which included screenshots of VMs and teachers’ work) and teacher work were coded using NVivo. Open coding (Saldaña, 2013) provided opportunities for reflection on the subtleties and contents of the data. Some codes rose organically from the data (e.g., how teachers used the tools and tensions described by the teachers,) and others were informed by literature (e.g., teachers’ descriptions of their instructional practice and how they used technology). Using the constant comparative method (Glaser & Strauss, 1967), a second round of analysis occurred whereby coded data within categories were compared, as well as re-readings of transcripts and the writing of memos. Code definitions were refined based on reviewing literature as well as commonalities and themes between data within categories. Memos were used to reflect more deeply on the codes and data, as well as to expound on emerging themes (Glaser & Strauss, 1967; Saldaña, 2013). Focused coding then proceeded, more specifically focused on teachers’ appropriation of the tools and how the PD may have supported teachers’ appropriation. Sorting codes vis-à-vis components of the activity system (e.g., division of labor, community, tools, tensions), looking more thoroughly at the data within a particular code, and linking portions of the data (e.g., teachers’ conversations during the PD along with their work), gave insight into how teachers’ actions were mediated and possibly transformed during the course of the PD. Although the main focus of the data analysis was of the PD data, interviews with the focus teachers were used to corroborate findings of the PD data.

Findings

To support teachers in teaching with VMs and tasks after the conclusion of the PD, sub goals of the PD were to foster teachers’ practices for i) finding VMs and tasks and ii) critiquing and modifying instructional tasks based on their learning goals and the needs of their students. Therefore, teacher reflection documents were used during each
PD session to provide individualized support and support the expansive learning. The first section of the teacher reflection document aimed to support teachers’ efforts in finding VMs and tasks using an annotated VM list and a repository of VMs and tasks. In the second section, teachers responded to guiding questions that encouraged them to think about their learning goal and student needs as they critiqued the VM and began thinking about possible modifications. Finally, the third section encouraged teachers to apply the task analysis framework (Table 1) to the VM that they were exploring. Due to space constraints, the findings presented focus only on teachers’ appropriation of the tools presented in the PD to support them as they critiqued, modified, and developed VM tasks.

Teachers’ appropriation of the following tools is based on Grossman, Smagorinsky, and Valencia’s (1999) *Five Degrees of Appropriation* framework. Drawing from Grossman et al., *appropriation* is defined as the process through which an individual adopts the tools of a particular social environment and through this process may change their practices due to changes in their ways of thinking. The levels or degree of appropriation are dependent on the individual’s active role in the practice and are described as: i) lack of appropriation, ii) appropriation of a label (i.e., an individual learns the name of a tool but not its features), iii) appropriating surface features (i.e., when an individual learns “some or most of the features of a tool, yet does not understand how those features contribute to the conceptual whole” (p. 17)), iv) appropriating conceptual underpinnings (i.e., when an individual understands the theoretical basis that motivates and informs the use of a tool and may be able to use it in novel situations), and v) achieving mastery (when an individual is able to use the tool effectively).

**Critiquing/Modifying Tasks**

Most of the teachers adopted the practice of needing to critique/modify VM tasks rather than implementing tasks as they found them, assuming the tasks would be effective in promoting students’ development of conceptual understanding. Based on teachers’ conversations and work during the PD, all twelve teachers who attended the afterschool PD sessions adopted the practice of critiquing tasks. Additionally, eleven of the twelve teachers demonstrated the need to modify tasks based on his/her learning goal and/or student needs. While interacting with VMs and tasks, teachers consistently talked about their learning goal(s), student needs, and possible modifications of the tasks. Initially, this section discusses teachers’ general change in instructional practice related to intentionally critiquing and modifying VMs tasks prior to implementing them with students. The discussion then focuses on teachers’ appropriation of two tools (i.e., guiding questions and the task analysis framework) aimed at supporting this practice.

During Jake’s final interview in May, he expressed how the PD changed his instructional practices regarding finding and implementing technology based tasks. Jake said,

*I think that the PD helped me kind of think through some things. As opposed to just thinking like, “Ahh well, we’ll try it and see what happens, and then we’ll kind of modify afterwards;” …being a little more thoughtful about how this is going to be used and what type of questions should be asked. Or do I need to modify this … worksheet that goes along with this, so that it’s going to help beforehand as opposed to like, “Oh, well that didn’t go the way I really wanted it to go.” And then you’re doing it after the fact (italicized portions represent change in tone).*

Jake’s reflection highlights how he and 10 other teachers changed their instructional practices related to finding and implementing technology based tasks. Rather than initially implementing the task as is with students and then determining what modifications may need to be done in subsequent iterations of the task, Jake discussed how the PD helped him to think more critically about a task and modify it proactively rather than retroactively.

**Guiding Questions**

To support teachers in adopting the practice of regularly critiquing and modifying tasks, the first tool presented to the teachers was a set of guiding questions. The guiding questions evolved during the course of the PD to better support teachers in critiquing the VM tasks and thinking critically about their proposed modifications. The final set of questions were:

1. What is your learning goal (for your students)?
2. How might your students struggle in this exploration?
3. How might your students benefit from engaging in this exploration?
4. Thinking about your learning goal, what is one modification you would make so that the exploration better fit the needs of your student? Why would this modification help your students engage in the learning goal?
Teachers initially went through VM tasks as though they were a student. Working through the task provided a context for teachers to then critique the task and made them more aware of possible modifications to make so that students’ explorations were focused on the development of conceptual understanding as opposed to trouble shooting unnecessary challenges. For example, teachers thought about how their students might struggle with the task or how they might benefit, the types of questions that were asked, how their students might respond (e.g., whether they would click through the task without making connections), the opportunities for feedback and the type of feedback given, and how they might use the VM task in their classroom.

<table>
<thead>
<tr>
<th>Definition</th>
<th># of data excerpts</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assessment:</strong> Modifications related to using the task as an assessment tool (at least in part).</td>
<td>6</td>
<td>Daron (DecReflecDoc): I would also like to see some assessment questions to see if they understood the point of the applet.</td>
</tr>
<tr>
<td><strong>Curricula:</strong> Modifications related to teachers’ curriculum.</td>
<td>13</td>
<td>Josh (JanReflecDoc): We would eliminate the Lateral Area and put more focus on exploring what surface area is and how it is found (thinking about adding the area of all faces).</td>
</tr>
<tr>
<td><strong>Instruction:</strong> Modifications related to how the task would be implemented.</td>
<td>19</td>
<td>Curt (JanReflecDoc): Walking through a unit rate to help with writing ratios and labeling measures. This will help with labeling a unit when setting up proportions. Having them check in with the teacher after Activity A, #7.</td>
</tr>
<tr>
<td><strong>Instructional Guides:</strong> Modifications related to developing an instructional guide.</td>
<td>33</td>
<td>Jake (NovReflecDoc): Create an activity guide</td>
</tr>
<tr>
<td><strong>Learning Goal:</strong> Modifications related to the learning goal.</td>
<td>51</td>
<td>Curt (talking with Karen in Nov about a modification): Add the question “How do the image and preimage compare when the scale factor is one?”</td>
</tr>
<tr>
<td><strong>Miscellaneous:</strong> Modifications did not fit into one of the other defined categories (e.g., related to technology constraints or non-specific modifications).</td>
<td>8</td>
<td>Josh and Mark (after Obs3): We would make changes based on the constraints (#3), but that can’t be done to our knowledge.</td>
</tr>
<tr>
<td><strong>None:</strong> Teachers said they would not modify the task.</td>
<td>8</td>
<td>Erin (FebReflecDoc): I wouldn’t change it, I think it fits the student’s needs.</td>
</tr>
<tr>
<td><strong>Practical Details:</strong> Modifications related to reformatting an instructional guide (e.g., to reduce space on a page or adding screenshots), clarifying directions, or correcting an error.</td>
<td>15</td>
<td>Mari (talking with Pam in Nov about a modification): Maybe we would just edit and only have two (pause) examples and save trees.</td>
</tr>
<tr>
<td><strong>Student Needs:</strong> Modifications related to student needs.</td>
<td>25</td>
<td>Jake (NovReflecDoc): More basic functions. There were some pretty crazy functions that showed up that I wouldn’t want my students to be getting frustrated with.</td>
</tr>
</tbody>
</table>

Table 2. Categories, Definitions, and Examples of Modifications

Table 2 highlights the different types of modifications that teachers implemented during the PD. Although the number of data excerpts related to each category are included in the table, these numbers are for descriptive purposes only and should be treated with caution. Due to multiple data sources (e.g., teachers’ conversations, individual responses on reflection documents when working in pairs, teacher modified instructional guides) and some modifications fitting into more than one category, the numbers are only included to give readers a descriptive understanding of the relevance of various types of modifications. As displayed in the table, most of the modifications that teachers suggested related to helping students engage in the learning goal, creating an instructional guide, and addressing student needs.

Often, teachers’ modifications spanned more than one category. For example, as an intervention teacher, many of Tracy’s students struggled with reading as well as mathematics (Vukovic, 2012). Therefore, Tracy’s modification for the VM task that she was critiquing in December was to, “read each portion to the kids and have...”
them answer before moving on. Give the kids screenshots of what each portion should look like. Possibly adjust the exploration guide to eliminate some of the language to make it a little more user friendly.” These modifications align with the instruction (i.e., reading each portion to the students), practical details (i.e., adding the screenshots), and student needs (i.e., elimate some of the language to make it more user friendly) categories defined earlier.

Drawing from teachers’ conversations and work, all teachers reached the level of appropriating the surface features of the guiding questions. Teachers were able to use the guiding questions as they critiqued VM tasks and began thinking about potential modifications to the tasks based on their learning goals and/or student needs. The following excerpt from Erin and Mari during the December PD session demonstrate how at least eight of the teachers were able to progress to the level of appropriating the conceptual underpinnings of the guiding questions. These teachers began to think about the types of modifications and whether the modifications were more focused on the students and their engagement with the learning goal or focused on a stylistic modification or a modification related to implementation (i.e., modifications that were more for them as teachers).

Erin: What’s a modification we could make? Changing the initial values to smaller numbers?
Mari: (long pause) Umm, (long pause) I had, in the how could you use this exploration, I said break it up. [Erin: yeah.] And make it less of a time commitment, so that you could integrate it into pre-made lessons more easily. But I guess that’s more of a modification for us. For kids (pause)…
Erin: Well it says, “Think about what’s one modification that you could make so that the exploration would be a better fit.” Would better fit the needs of our students.
Mari: I don’t think…(long pause)
Erin: Oh, umm…
Lindsay: Do you want me to try and explain that? (Then I explain different types of modifications.)

On their reflection document, Erin and Mari decided to change the initial values that students investigated. This modification was based on the needs of their students and how they thought their students might struggle during the task due to having to enter numbers in a different scale.

The guiding questions encouraged teachers to think beyond how they engaged in the VM task and consider other aspects of the activity system that may influence how they used VM tasks in their classrooms. For example, the first guiding question severed to focus teachers’ attention on their learning goal to help teachers connect the tasks that they were exploring with their curriculum and learning goals (related to the rules of the activity system). Other guiding questions served to make them more aware of their extended community (i.e., their students) and to begin thinking about modifications that may better support their students’ development of conceptual understanding. Teachers’ responses on the reflection document did not differ much when they worked individually or in collaboration with other teachers (related to the division of labor). However, when revising instructional guides based on proposed modifications, teachers often split up the work when they had a collaborator.

Task analysis framework

To further support teachers in adopting the practice of regularly critiquing and modifying tasks, the third part of the teacher reflection document encouraged teachers to use the task analysis framework. Initially, it was not known whether teachers would use the framework or find it helpful. Although some teachers (i.e., five) mentioned using the framework to help them determine which task may be more productive to use with their students when comparing two tasks (i.e., based on the number of higher order affordances), teachers primarily used the task analysis framework on their own to modify or develop instructional guides rather than as a tool to critique tasks.

Teachers’ conversations throughout the PD and final interviews highlight how they found the framework helpful in supporting their efforts to modify and critique tasks. For example, during the March PD session, Daron said, I am looking at the framework and seeing what I want to change based on that. I think the framework does help you focus on like, different levels and … to ask questions…to activate that background knowledge and get them thinking about what they already know. And then trying to, push them, push that forward too.

Daron used the framework to critique a task and find out if it asked questions that activated background knowledge but then pushed students forward by asking questions relevant to some of the “higher” affordances (related to the rules aspect of the activity system). Furthermore, according to Tracy, the framework helped them (i.e., the teachers), “look at-CRITIQUE them more critically and look for their VALUE versus just, a fun thing to try” (capital letters used to signify emphasis in Tracy’s speech). Tracy’s reflection demonstrates how she (and others) were able to progress from using a task because it looked cool to using a task because it provided opportunities to promote students’ development of conceptual understanding. During their final interviews, all four focus teachers independently claimed that the framework was one of their big takeaways from the PD.
As the PD progressed, for at least three teachers, their use of the framework became operationalized (i.e., a subconscious action). For example, during Josh’s final interview, he said,

Yeah, the framework thing. I mean, in the beginning, it was like, “Well, yeah, I guess that helps you think about is it worth DOING or not.” And then by the time we did the, you know the last few, we didn’t even, it was already in your HEAD. That, “how-wh-what would I change to make it more worthwhile or is it fine the way that it is.” ‘Cause you kind of already have that down. But initially, it was confusing. I think it helped kind of pick out what was kind of, what was needed.

Josh’s reflection highlights how some teachers found the framework challenging to apply in the beginning of the PD. However, through conversations with others and repeatedly using the framework to critique different tasks, during the course of the PD, it became second nature to apply the framework.

Although the framework was intended to provide a means to analyze tasks, at least two teachers began to use the framework to inform other areas of their instruction, thus moving towards the level of appropriating the conceptual underpinnings of the tool. For example, Kelly found the framework helpful to know how to modify her instruction. During the January session, Kelly said

I think for me, the framework helps ME decide what do I need to supplement my lesson in, that they’re not getting in using the tools. So that they can get ALL the well-rounded understanding of the whole piece. So, “Okay, it’s not in there. So what can I do with them, when I’M with them to make it better.”

During the March PD session, Curt talked about using the framework to help him modify other instructional tasks to better support his students’ needs and their understanding.

**Discussion and Conclusion**

An important aspect of the PD was providing teachers with the time and space to investigate VMs and tasks related to their specific learning goals, as well as to support their collaboration and efforts to modify tasks. Encouraging teachers to fully explore a VM or task, as well as using guiding questions that focused teachers to use their learning goal as a lens to critique tasks (i.e., active learning), helped teachers to focus where their students might struggle in a task and how students might benefit by engaging in the exploration. Additionally, a few teachers began being able to distinguish between modifications that might help students engage in the learning goal versus modifications that were more stylistic (e.g., breaking an exploration into smaller components).

However, investigating only teachers’ appropriation of the tools presented in the PD does not give a complete understanding into how the PD supported their efforts to implement VM tasks. Rather, investigating teachers’ actions (i.e., their instructional processes for implementing VM tasks) in conjunction with their appropriation of the tools and other mediating factors (e.g., curriculum, district initiatives, tools, community, etc.) gave insight regarding teacher’s implementation efforts. Although most of the teachers appropriated at least the surface level features of the tools, the number of VM tasks that they implemented varied and was not related to their degree of appropriation for the various tools. Hence, when investigating how a PD supports teachers’ use of a new technology tool and/or how the PD supported possible transformations in teachers’ instructional practices, it is important to consider how factors outside the PD (e.g., community, including teacher’s students and teaching team members) mediate teachers’ instructional practices and technology use.

It is also important to acknowledge the role that VM tasks themselves had in supporting teachers’ appropriation of the tools. Teachers’ quickly bought into the VMs because VMs allowed them to use their Chromebooks more frequently and effectively in their instruction, which supported the district initiative related to technology use in the classrooms. Because many of the VMs that teachers decided to use initially had accompanying guided questions or instructional guides, teachers were often able to modify existing resources rather than designing instructional guides from the beginning. Additionally, teachers and students were drawn to VMs due to the ease of use and the immediate benefits that they saw related to student engagement and understanding. Therefore, when supporting teachers to teach with a new technology tool, it is important to consider the features of the tool itself and resources that already exist that may support teachers in adding it to their instructional repertoire.

The findings indicate that teachers were able to appropriate tools introduced during the PD to support their efforts to begin teaching with VM tasks. Although specific to this PD, the findings and outcomes of this study can inform future efforts aimed at promoting teachers’ use of technology-based instructional tasks whereby teachers are teaching with as opposed to near technology. For example, with minor modifications, the task analysis framework and guiding questions could be applied to non-VM tasks. Based on my experience working with pre-service secondary
mathematics teachers, the use of the guiding questions and task analysis framework would be helpful in promoting their efforts to teach with as opposed to near technology as well.

References


Challenges in Mathematics Teachers’ Introduction to a Digital Textbook: Analyzing Contradictions

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Abstract: The use of digital textbooks (DTs) in mathematics is increasing. However, the implementation of DTs in schools is complicated. The objective of this paper is to understand how the introduction of a DT affects the activity of teaching mathematics. An intervention was conducted where six mathematics teachers, with students in aged 7-15, used a DT for six weeks. This paper applies cultural-historical activity theory (CHAT) to consider contradictions that arose in the activity. Four contradictions were revealed: first, teachers’ need for coherence and linearity vs. the DT with a wide range of content and nonlinear paths; second, teachers’ need for transparent learning processes vs. the digital textbook as opaque; third, teachers’ beliefs about appropriate pedagogy for learning mathematics vs. the pedagogy embedded in the DT; and fourth, differentiated instruction for all students vs. DT supporting individualization for every student.

Keywords: DT, digital textbook, teachers, mathematics education, cultural-historical activity theory, contradictions

Introduction

One of the key resources in mathematics classrooms—the textbook—is now being impacted by the digitalization of education. The printed textbook has been one of the most important organizing factors in establishing the subject and how it should be taught (Pepin, Gueudet, Yerushalmy, Trouche, & Chazan, 2016b; Usiskin, 2013), but many teachers are now beginning to use digital textbooks (DTs) to complement or replace the printed textbook (Pepin, Choppin, Ruthven, & Sinclair, 2017a; Yerushalmy, 2016). The main motives for using DTs are that these will enable teachers to more effectively plan, conduct, and assess activities for students. It is argued that DTs facilitate differentiated instruction and adapted difficulty levels, and provide students with automated feedback and teachers with assessment reports. These opportunities for a nonlinear structure with a wide range of content and interactivity make it possible for teachers to create varied learning environments for their students.

Although ambitious visions and plans for technology-enabled learning have been around for decades, technologies have not transformed schools to the expected extent (e.g., Cuban, 2013; Kozma, 2003). Previous research on the implementation of technology in organizations in general has shown that this is an ongoing and complex process that depends on the technology itself, the users, the environment, and the subtle interactions between these components (Orlikowski, 1992), and the implementation of technology in schools could be considered even more complicated. At best, technology has proven to supplement the conventional curriculum and traditional classroom activities, such as instruction, fact-finding, essay-writing, and evaluation practices (Cuban, 2013; Player-Koro, 2013; Selwyn, 2016). The barriers affecting technology integration in mathematics education have been well documented over time; those often mentioned include the availability of resources, professional development, time to become familiar with new resources, and teachers’ views of how learning relates to technology affordances (Bingimlas, 2007; Hew & Brush, 2007; Utterberg, Lundin, & Lindström, 2017).

The use of digital technologies seems to have been particularly challenging in the case of mathematics. Digital technology is less common in mathematics classrooms than might be expected, given the growing development of digital tools for mathematical learning. In addition, there is evidence that the uptake of innovative technologies featuring new learning methods that support students’ conceptual understanding of mathematics has had little impact on teachers’ practices (Blackley & Walker, 2015; Bretscher, 2014; Lew, 2016). One possible explanation is that what a developer understands as possibilities—for example, individualized and flexible learning activities for students—
may create expectations that teachers find difficult to live up to. Introducing a complex and often non-transparent technology into the classroom changes the conditions for teaching and is eventually likely to challenge teachers’ usual ways of teaching (Remillard, 2016). Rather than merely understanding DTs as the possibility to use a new tool, they must be understood in a wider perspective as something that changes the role of teachers and their teaching conditions.

The introduction of digital technologies for teaching and learning is typically more challenging and less rewarding than envisioned (Selwyn, 2014). Within mathematics education, the use of printed textbooks has been well explored (Pepin & Haggarty, 2001; Usiskin, 2013), but studies offering deeper insights into teachers’ use of DTs in mathematics are lacking (Pepin et al., 2017a; Remillard, 2016). From the analytical perspective of the present study, new teaching tools will affect classroom practices, and any such change can be expected to drive contradictions within the activity system (Engeström, 2014). When a new technology is introduced, any contradictions that arise must be handled to ensure successful implementation. Laferrière, Hamel, and Searson (2013) established that this is a continuing process, because as contradictions are resolved, they are replaced by others or reappear. In our analysis, cultural-historical activity theory (CHAT; Engeström, 2014) is used to understand contradictions that arise when DTs are implemented in mathematics.

To investigate how the introduction of DTs might give rise to contradictions in mathematics classroom practices and ultimately transform these practices, the research team designed an intervention at one school for students aged 7–15, in which the teachers were asked to use a DT over a six-week period. The use of the DT was studied through interviews and observations. The objective of this paper is to clarify how the introduction of a DT affects the activity of teaching mathematics. The paper addresses the following research question: What contradictions occur while introducing a DT in mathematics classes?

**Theoretical Framework**

In activity theory, the foundational unit of analysis is the activity. Engeström (2014) describes activity in terms of a triangular relationship that originates in Vygotsky’s concepts of subject, tool, and object. The *subject* of the activity system refers to an individual or group whose point of view is adopted. *Tools* are artefacts that mediate human actions and are used by the subjects when directed toward an *object* as the problem space that motivates the subject to participate in an activity. Engeström adds three more components; *rules* are regulations and conventions that are explicit or implicit within the *community* of participants in the activity sharing the same object, and the *division of labor* is a social organization that determines how hierarchies and roles are structured. From a cultural-historical perspective, the analysis centers on a subject situated in historically aggregated activities (Cole & Engeström, 2011). Cultures are aggregated over history and become visible through the tools used to mediate an activity. The subject will find that, in responding to a given motive, some of his or her main existing motives or goals may lead away from or come to contradict that given motive (Engeström, 2014). However, contradictions are not interchangeable with conflicts or problems; in the words of Engeström (2011b, p. 609), “Contradictions are historically accumulating structural tensions within and between activity systems.” Furthermore, when contradictions become conscious, they constitute the major cause for change and development (Roth & Lee, 2007). This means that conflicts should not be denied, as they are foundational for transformation. In the context of our study, the motive is the subject’s (teacher’s) reason for participating in the activity (i.e., to use a DT). An activity is accomplished through concrete actions directed toward goals to carry out the activity. Teachers take action by changing their way of working to adapt to goals leading to the motive. Operations respond to goals, and teachers manage operations according to conditions in their practices. As activity systems are transformed over time, they must be understood in terms of their history—that is, difficulties and possibilities need to be understood within their local history alongside the objects and tools that shaped the activity (Engeström, 2014). For this reason, mathematics education must be analyzed in terms of its history, encompassing curricula and local norms for teaching, and learning and tools serving mathematical purposes.

**Digital Textbooks (DTs)**

A DT can be defined as “an evolving structured set of digital resources, dedicated to teaching, initially designed by different authors, but open for redesign by teachers, both individually and collectively” (Pepin et al., 2016b, p. 644). Pepin et al. (2016b) identified three types of DT. The first of these, the *integrative* DT, is an add-on model, where a digital version of a printed textbook is connected to new learning objects (i.e., multimedia, learning management system, evaluation tools, and data search). Second, the *evolving or “living”* DT is developed
continuously by a community, based on ideas from practicing members (for example, teachers) and other users. Third, the interactive DT is oriented toward mathematical objects and activities that can be chosen in any order and are based on activities. The DT used in the present study can be defined as the interactive type. Pepin, Gueudet, and Trouche (2017b) proposed that mathematics teachers’ interactions with DTs when preparing lessons can be viewed as design. Digital resources require teachers to have the necessary competencies to understand how to use those resources to exploit opportunities for transformation that will develop their practices. This design process is characterized as design capacity. Changing the educational environment by introducing an action-based DT reveals challenges when a teacher’s practice changes from teacher-centered instruction to spontaneous mathematical activities performed by students (Lew, 2016). Anthony and Clark (2011) investigated middle school mathematics teachers who were integrating laptops in the classroom. The authors stressed three contradictions: the teachers’ determination of the role the laptops would serve in the classroom, meeting rules misaligned with the use of laptops, and change competence with using laptops despite the lack of professional development. Those contradictions are not just rooted in the classroom, but originated in institutional settings. Tay and Lim (2016), who also examined computers in the classroom, similarly found that a crucial contradiction exists between using a computer and teachers’ competencies in doing so, both in terms of the technical and pedagogical skills appropriate for computer integration. A DT in mathematics (called Séسامath) was developed by a community of teachers and IT professionals. Gueduet, Pepin, Sabra, and Trouche (2016) investigated the process, and contradictions occurred between beliefs in the community about how mathematics content should be structured and designing a DT consisting of a toolkit. A framework for research-based teaching and technology integration (Thomas & Edson, 2017) can be used to evaluate DTs in making choices that facilitate systems integration. As stressed by Pepin, Gueudet, and Trouche (2016a): “Whilst e-textbooks have the potential to fundamentally change mathematics teachers’ work, the revolution depends on didactical (and human) perceptions of the design” (p. 12), which makes teachers’ beliefs and their experiences crucial for integration.

Method

The four authors collectively planned the study and analyzed the empirical data. The data collection was conducted by the first and second author. Observations and discussions with study participants made it possible to gain an informal relationship in their natural environment (Cohen, Manion & Morrison, 2013). During the research process, data were collected through workshops, interviews, focus group discussions, and observations of classroom practices. The study was initiated in March 2017, when teachers were introduced to a newly released DT at a marketing event organized by the publisher. The marketing event was followed up with school-based workshops, both before and during the introduction, allowing teachers to become familiar with the digital textbook and to receive technical and pedagogical support. A representative from the publisher conducted workshops and made suggestions for lesson plans. The authors helped to arrange the workshops, but then stayed in the background taking field notes during the activities.

Two 90-minutes group interviews were conducted with the participating teachers. The first interview preceded the classroom observations, and the second was shortly thereafter. The interviews, led by the two authors and using open-ended questions, were conducted in one of the teachers’ classrooms at the participating school. The first interview focused on teachers’ expectations and concerns, for example: What makes you interested in trying to use a DT in mathematics? What do you think is interesting about it? What do you generally think of digital tools in mathematics education? The final interview concerned teachers’ experiences and opinions, for example: What challenges/opportunities did you recognize? Were your expectations fulfilled? In what ways? Will you continue to use this material? Why/why not? The group interviews were audio-recorded and transcribed verbatim.

Between interviews, 13 one-hour observations of classroom practices was conducted. On two occasions, both authors conducted observations together in the same classroom. Following each observation, field notes were discussed, identifying aspects of teaching practices that were considered relevant in relation to the research question; these were given particular attention during the next observation. This approach was repeated throughout the study, making the analysis an iterative process. Observations were then related to teachers’ reasoning in the focus group interviews. As two of the authors attended two workshops, two focus group discussions, and two classroom observations together, they were able to discuss and compare their interpretations. The data were coded, grouped into categories and CHAT framework was used to analyze contradictions between different aspects of the activity system. Activity system analysis has the possibility to assist researchers making use of complex data from real world settings in a controlled and meaningful way (Yamagata-Lynch, 2010). The results were summarized in written form and communicated to the participating teachers for respondent validation (Cohen, Manion & Morrison, 2013).
Results and Analysis

During the introduction of the DT, contradictions arose. The contradictions identified were related to features in the DT that affected its usefulness and features that conflicted with teachers’ shared norms concerning how mathematics should be taught and learned.

Teachers’ need for coherence and linearity vs. the DT with a wide range of content and nonlinear paths.

The research team identified a contradiction between teachers perceiving the DT as messy and nonlinear, and teachers’ required effort to create students’ learning paths when using the DT. During a workshop, the teachers discussed the difficulty of using the DT.

*The publisher’s representative demonstrates the DT. Teachers point out that the teaching material is messy and non-sequential; topics and sub-areas do not follow a common thread. The publisher’s representative explains that it is the teacher who chooses what the students should do, that there are activities for the whole class and tasks that are individualized (Field note from workshop).*

For Swedish teachers, printed textbooks are often a significant resource in their classrooms (Johansson, 2006). Compared to a printed textbook’s structure, the range of different tasks and activities in a DT can be combined in various ways, both within and between grades. This potential to plan the teaching instruction and support students’ various learning trajectories is often advocated (Pepin et al., 2017a), but this also requires the teacher to adopt a more active approach, which can be time consuming and a challenge for teachers who would like to use tools that provide support and facilitate their work (Yerushalmy, 2016). DTs require that “teachers collect, organize, and design learners’ path through a compilation of tools” (Remillard, 2016, s. 200). The *navigation space* (Pepin et al., 2017a), which refers to students’ different and non-linear trajectories through mathematical contents with a DT, may disrupt lesson structures and the sequence of activities. This complexity makes it difficult to foresee every student’s actions and a consequence could be, according to a teacher, that it is more difficult to give the students clear and consistent instructions, particularly for students in the lower grades.

*These young children have very short endurance; hence, I must be very well prepared for the time I have their full attention. And you must also know exactly what to say, otherwise, it becomes only so-so. Therefore, the teacher must be able to know in advance what she is going to present. Such a new digital resource like this just messes it up. I must know the structure, what the children will do, and how they will do it down to the smallest detail. . . . You must be one step ahead when the children are going to do an activity and give them instructions (Teacher with students in Grade 1).*

The teachers also said it is difficult to get an overview of the DT and what it contains, because you must go to many pages, and navigating through these requires many clicks. The teachers compared the DT with a printed textbook in which it is easier to browse through and see the different topics, tasks, and how they differ from each other.

*But that (the DT) is more difficult to overview. Because if I look in a book, and the students should do tasks on two pages, or if I have some other instructional material we will use, I can somehow scan the content quite fast. Oh, here are such tasks where the equal signs are not placed at the end in the expression but they are open statements. But here (in the DT), I must click on every task to know the level of difficulty, what the students will face, in order to know what I must go through prior to the tasks they should do (Teacher with students in Grade 3).*

Our findings are in line with Gueudet, Pepin, and Sabra (2016), who investigated when mathematics teachers designed a DT. They found structural tensions between teachers’ shared beliefs from experiences of teaching mathematics and possibilities to create a DT based on “toolkits” and bricks. Teachers’ beliefs about mathematics as a subject with progression, in which the order matters, affected the final design. This shows that historically shared norms for teaching and learning mathematics are relevant and impact the use of digital resources. With a DT, teachers must use a range of tools to create students’ individual pathways on a mathematical topic, which requires good curriculum knowledge (Remillard, 2016).
Teachers need for transparent learning processes vs. the DT as opaque

There was also a contradiction in the division of labor. The contradiction occurred between the teachers’ role and features of the DT. In striving to achieve good teaching and learning, contradictions arose between teachers’ responsibilities (i.e., having knowledge about their students’ learning processes and knowing how to best teach the students) and the DT providing instructions, tasks, and adaptivity. As one teacher with students in Grade 2 expressed it: “I feel that mathematics education cannot be controlled by a computer.” When the students used the DT, the teachers said that they lacked information about their students’ mathematical actions. The teachers realized that they often asked the students what they were doing. Furthermore, they did not get sufficient information; that is qualitative information about the mathematical strategies the students had used and which tasks they would be doing next.

*It is more difficult for me to see what they have done. I have less overview as I walk around when students use the digital textbook. It is much more difficult to see what the students are doing in the moment. I just see the current task. It is more difficult for me to get an overview. This overall view in the classroom, information about what everyone is working on, is difficult to grasp from one current task. With the digital textbook, it is much more difficult, because I just see one task, the current task they are working on.* (Teacher with students in Grades 7–9).

The teachers stressed that they are not used to that feeling, the loss of transparency. “It feels like we teachers are control freaks” (Teacher with students in Grades 7–9). The need for information and the feeling of control is well stated by Remiliardi (2016), who highlights that: “still, teachers are critical guardians of the learning process” (s. 197). Another example of when teachers experience a lack of transparency is when the DT only indicates the answer and whether the student’s answer is correct or incorrect. Consequently, teachers felt excluded from their students’ task-solving processes. Therefore, it makes it difficult for teachers to assess whether the students lack an understanding of the concepts, have misunderstood the task as described, or have simply made a mistake. Access to students’ strategies is considered crucial to provide sufficient support (Small, 2017). A teacher with students in Grades 7–9 explained the importance of being informed about students’ strategies. Her explanations to students are dependent on the strategies they have used. Hence, she must know what the students have done as well as their descriptions of their understanding. She compares the different strategies with the type of tasks the students have completed. In a DT, there may be an imbalance between the tasks and the teacher’s feedback. Tasks aimed at understanding concepts and mathematical ideas require a high degree of interpretation, but feedback provided automatically by a DT requires a low degree of interpretation. There is a gain in terms of teachers’ time since they need not correct tasks, but a loss in terms of teachers gaining information about tasks with complex reasoning (Yerushalmy, Nagari-Haddif, & Olsher, 2017).

Adaptivity built into the DT evoked feelings of a lack of transparency when using it. The teachers said it became demanding for them to support each student’s learning, as the control of adaptivity was delegated from the teacher to the DT. When control of students’ learning process is delegated from the teacher to the system, teachers’ competence in how to support their students may be challenged. The teachers considered it problematic that they could not see in advance which tasks the students would be assigned. An example of the DT as opaque is shown from a workshop:

*A discussion ensues about adaptive features. Teachers want to know in advance what tasks each student should do, but this is not possible because an algorithm makes that selection based on the student’s earlier results. The teachers react strongly, because how will they know that the adaptive function provided a suitable task that is based on what the student really needs to practice? The publisher says they can get that information when the students have solved the task but not before.* (Field note from workshop).

Selections of relevant tasks that support students’ mathematical development are important, but the teachers felt that this was handed over to an algorithm. Our result is supported by Choppin and Borys (2017), underlining that the “teacher’s role in adaptive or personalized settings becomes more prescribed and limited, trumping teachers’ decision making” (pp. 668).

Teachers’ beliefs about appropriate pedagogy for learning mathematics vs. the pedagogy embedded in the DT.
The teachers’ shared beliefs about teaching practices that they considered appropriate for learning mathematics were challenged by the DT. The teachers’ beliefs about pedagogy came into conflict with the pedagogy embedded in the DT—a conflict of motives. The teachers talked about the importance of providing the students with opportunities for a deep mathematical understanding, which to them means that instruction should be varied and allow for different ways to learn.

*I also think . . . what you as a teacher present, you present it in various ways. If I should learn a mathematical concept, there are many different ways to learn that. Then, the teacher has to present it in a variety of ways. With the digital textbook, it does not directly become as many ways. I miss that. There are different ways to crack the code, different ways to learn* (Teacher with students in Grade 3).

The term presentation space is described by Pepin et al. (2017a) as the variety of tools (for example, video clips and animations) available in the DT to present a topic to the students before they start to work with mathematical tasks. The teachers expressed the presentation space as limited and not fulfilling their needs. From the teachers’ points of view, it is important that students learn mathematics in a variety of ways, using different forms of representation to proceed from a concrete to an abstract understanding. One teacher explicitly stressed the concrete, representational, abstract (CRA) model (Witzel, Mercer, & Miller, 2003), which means linear sequenced instructions that go from concrete to abstract mathematics. The model is documented in the literature as beneficial for students’ development of mathematical skills (Mancl, Miller, & Kennedy, 2012). In the quote below, with the teacher clearly expressing a “No,” a conflict of motive is implicated (Engeström & Sannino, 2011):

*I really like to work with physical objects as often as possible. . . . Will I be able to do that with this device? No. Learning should go from bodily experience to the brain. You’ll lose that with the digital textbook. . . . For me, you should really understand what you are doing when working with physical material. When you consolidate the knowledge, then you can use the device, that is the computer* (Teacher with students in Grade 3).

The quote shows a conflict of motive between the teacher’s need to use manipulatives and the mathematical representations used in the DT. In the DT, the students were assigned a kind of mathematics task that the teachers had not seen before. The teachers said that this kind of task makes it difficult for students as they only consist of abstract symbols, and they are assigned early in their learning process. The tasks were preceded by an instructional video clip, but the teachers were uncertain whether the students had understood the mathematics that they were supposed to learn. The students struggled to understand the task rather than the mathematics. A teacher with students in Grade 3 explained that the students are used to seeing it linearly, that you write 8 + 3 = __ or __ = 3 + 8. The teachers stressed the importance of students understanding the meaning of the equal sign, which makes it an important foundation in teaching instructions.

*When they did the tasks with addition and subtraction, that circle, it was too difficult, a completely different way, this chain, how that worked. Because they are used to writing linearly, and that the equal sign can have various positions and that they should pay attention to that. There was no equal sign. It was an arrow and a plus or a minus sign. Several did not really understand; they did not really take to it. How they should think, how they should do. So they failed just because of that* (Teacher with students in Grade 1).

The teachers in this intervention stressed instructions for conceptual understanding. This may be questioned. In a study, Boesen et al. (2014) investigated mathematics teaching practices in 76 Swedish schools, and procedural competency proved to be the dominant activity. However, since then, a professional development reform aimed at improving mathematics teachers’ instructions has been implemented in which 76% of mathematics teachers in Sweden participated (Swedish National Agency for Education, 2016). This professional development might explain teachers’ awareness of students’ various mathematics competencies. The participating teachers expressed a belief that the DT did not contribute to the development of students’ understanding of concepts, indicating contradictions between teachers’ shared norms within their teaching culture and opportunities afforded by the DT. By focusing on procedural knowledge rather than conceptual understanding, the learning approaches built into the DT did not align with the teachers’ views.
Differentiated instruction for all students vs. DT supporting individualization for every student

Although mathematics teachers maintain that students with various levels of mathematical knowledge need different educational resources, it is usually challenging for teachers to adapt instructional materials to each student’s needs (Small, 2017). One idea regarding DTs is that they can solve this issue and provide personalized support to each student (Lokar, 2015). Using the DT for this aim evoked a contradiction between teachers’ beliefs about how to meet the diverse needs of their students and how this is embedded in the new tool. Concerning this contradiction, it is relevant to make a distinction between individualization and differentiation. Individualization can be defined as: “methods in which students proceed individually through materials, largely on their own, checking answers against predetermined responses” (Confrey, 2016, s. 9). In this case, with the DT, this can be done through automatic adaptivity based on students’ prior performances, and teachers assigning activities and tasks individually to each student. Differentiation can be defined as: “methods of instruction within a class designed to meet the diverse needs of learners” (Confrey, 2016, s. 8). This may mean creating mathematics activities that allow all students to participate on their own terms while simultaneously being included in the learning context.

The DT’s aim of individualizing tasks for every student could mean that students would progress at different rates, leaving the class increasingly scattered in the process. The teachers said they want to keep students gathered around a learning object. However, with the DT, the teachers said it is difficult to anticipate this common object when students are working on various levels and maybe even with different topics. A consequence of this was highlighted during our observations. The teachers struggled to help all students who raised their hands for help. One teacher (with students in Grade 3) expressed this as: “I must have very good running shoes if I am supposed to catch every student’s individual thoughts.”

Individualized instruction with the DT also affects common threads and discussions in the classroom, which would be relevant to all students regardless of their knowledge level. The teachers emphasized the importance of mathematical discussions in the classroom for deeper learning. “I have had students who have succeeded very well in mathematics for many years. Thus, I think about what my strengths are; lots of mathematical discussions” (Teacher with students in Grade 2). With the DT, the teacher assigns different tasks according to each student’s needs, making collaborative mathematics activities difficult. When students work around common tasks through differentiated instruction, the teachers said they can more easily identify students who need additional help and organize a collaborative activity at just that moment, which will give them instant feedback.

The teachers’ experiences with the DT show a contradiction between their shared norms on how mathematics should be taught to adapt to students’ different needs and how the DT assists with that work. The contradiction reveals the teachers’ value of organizing mathematics activities that allow for collaboration. However, it is challenging to create workspaces with a DT that facilitate each student’s needs while simultaneously enabling collective mathematics activities (Choppin & Borys, 2017; Pepin et al., 2017a).

Discussion – teachers’ practices and teachers’ competencies in transition

Using a DT is not a straightforward process; to benefit from its wide range of functions, teachers are required to create different learning trajectories for their students. Mathematics is often argued as having a logical structure with many possible and beneficial pathways for students to learn at every grade level; however, constructing all the different ways successfully requires particular and adequate competencies (Usiskin, 2016). The teachers compared the DT with the printed textbooks, which they said supported them in their work. Teachers often rely on printed textbooks to facilitate and structure their work, which makes them important (Pepin et al., 2016b; Usiskin, 2013). In creating printed textbooks, the authors make an effort to present content and tasks in a clear and sequential manner to facilitate teachers’ lesson planning for their students’ learning paths. Now, this competence and the workload it entails to create plans for students’ learning is handed over to the teacher using a DT. The teachers themselves now have to navigate through a wide range of content and activities, which may be presented without a clear progression. Another challenge is that teachers perceive the DT as opaque compared to printed textbooks, changing how they gain information about their students’ learning and their possibilities to influence the students’ learning processes. The teachers have to rely on the authority of the DT, which corrects students’ tasks and assigns tasks adaptively based on the students’ achievements. This creates an imbalance in the division of labor. The teachers felt that the DT took over important work tasks when deciding which tasks students should do, while at the same time, they are left with the responsibility
of their students’ progress. The DT requires teachers to have certain competencies as well as time to plan and conduct instructions for every student’s needs and learning paths, but at the same time, the DT takes over some of the teachers’ competencies with its adaptivity and task assignments.

Cultural conditions impact actions, and the teachers made efforts to solve contradictions by learning to use the DT through workshops and apply it in their practices for students’ learning. In the beginning, the teachers seemed convinced that the DT should be comprehensive and fully aligned with the curriculum; however, they later experienced that the focus was on rules and methods rather than the students’ conceptual understanding. They discussed the use of other resources for conceptual learning and using the DT as a complement for procedural knowledge. Additionally, the teachers skills in how to interact with the DT were limited. Although they got support and participated in workshops, they lacked the knowledge to be able to use various embedded functions. They only used a limited number of features within the DT, which they tried to apply together with their commonly used teaching methods. However, they experimented with some new methods made available by the digital tool. For example, the teachers considered the DT suitable for homework. The teachers stressed that if you give students homework, you must give some kind of response to make it meaningful. However, correcting homework is time consuming, and as students would get an immediate response from the DT, teachers could save time. The teachers also said that the DT’s adaptivity was advantageous for high-ability math students, to whom it may be difficult to provide meaningful progression in their learning activities.

The competence to use digital curriculum resources, in this case a DT, is defined by Pepin et al. (2017) as pedagogical design capacity and consists of three main features. The first is using digital resources in a way that is consistent with the goal and the content of students’ intended learning. The second is to possess skills in how to use digital resources in a powerful and at the same time flexible way. The last is the ability to reflect on actions for continuous learning. In this intervention, it appeared that the complexity of the DT and the competencies needed to use it in a functional manner created contradictions. This is in line with Pepin et al. (2017a), who argued that mathematics teachers often find it difficult to integrate a DT in their classrooms. Yerushalmy (2016) suggested that digital resources will probably be used to improve and enhance teaching together with other commonly used teaching materials, rather than replace them. Teachers often use different teaching materials, which they collect from multiple resources and adapt them to support their teaching. The teachers are re-sourcing (Pepin, Gueudet, & Trouche, 2013) materials for their instructional needs, which includes “both using conventional resources in new ways and drawing on new sources” (Ruthven, 2016, p. 75). Teachers have always re-sourced their materials, but the increasing number of digital resources, which afford different opportunities and have embedded limitations according to teachers’ needs and preferences, call for teachers to choose which ones to use and to learn how to use them. Digital resources available from publishers or freely available on the internet require teachers to navigate in an emergent digital landscape.

The implementation of digital technologies in education is demanding (Cuban, 2013), and mathematics teachers need to perceive their benefits in order to accept the change (Utterberg & Lundin, 2017). Digital resources must provide satisfactory opportunities to meet teachers’ needs, giving them a motive to develop their competencies. Contradictions should not necessarily be understood as problematic but can be a “driving force of transformation” (Engeström, 2011a, s. 89) and are consequently important to investigate. Solutions to resolve contradictions and effectively integrate digital technology may originate from local knowledge based on everyday experiences. Tinkering and serendipity, bricolage, can result in new ideas created by end users (Ciborra, 2009). This requires experimentation and high skills about how to interact with digital resources in meaningful ways. Our findings reveal contradictions that occurred when mathematics teachers introduced a DT. Knowledge about those contradictions and how they can be solved deserve further attention, and additional research is needed about how teachers can take advantage of digital resources and integrate them with other teaching materials.

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Selwyn, N. (2016). Education and technology: Key issues and debates (2nd ed.). UK: Bloomsbury Academics.


Abstract: This study examines the re-use of existing video records of practice (VRPs) in preservice mathematics teacher education. VRPs have become an important resource for studying and improving teaching. They are also increasingly available through a variety of online repositories, published alongside professional publications, and shared by organizations and groups. However, efforts to create, share, and re-use VRPs lack foundational knowledge about how they are reused. Through interviews with 34 mathematics teacher educators from 24 different institutions, this study looks at current practice and asks: How do mathematics teacher educators make use of existing VRPs to support the professional learning of preservice teachers? What instructional goals do teacher educators try to achieve when re-using VRPs? In what types of activities do they re-use VRPs? It also discusses what these findings mean for preservice teacher educators who re-use VRPs, as well as for those who produce and disseminate VRPs for re-use.

Introduction

Videos of teaching and learning practices – such as those that capture classroom lessons or document students’ thinking-in-action during interviews and small group activities – have come to play a significant role in the study and improvement of education. These types of video records of practice (VRPs) have long been of interest to educational researchers as well as to preservice and inservice teacher educators (e.g. Biberstine, 1971; Burleigh & Peterson, 1967) for their potential to help individuals and the field of education better understand the complexities of teaching and learning. More recently, VRPs have also been part of bold visions to transform teacher education – such as in Lee Shulman’s 1985 presidential address to the American Educational Research Association (Shulman, 1986) – as well as efforts to re-imagine professional learning more generally. For example, in their 1999 description of a new practice-based theory of professional education, Ball and Cohen argue, “professional development could be improved by seeking ways to ground its ‘curriculum’ in the tasks, questions, and problems of practice” and they suggest that one way to do this would be to

… Collect concrete records and artifacts of teaching and learning that teachers could use as the curriculum for professional inquiries – for example, students’ work, curriculum materials, videotapes of classroom teaching, teacher notes, and student assessments. These could be drawn from teachers’ own ongoing work or be specifically collected from others’ practice, and catalogued and made available to be shared and accessed. These sites of practice would then be used to develop usable knowledge of content, students’ learning, and teaching. (p. 20).

Over the intervening twenty years since Ball and Cohen shared this vision for professional education, there has been considerable work along these lines. For example, there are now a greater number and variety of VRPs available to use as potential “sites of practice” and there are diverse efforts underway in teacher education re-using VRPs to
“develop usable knowledge of content, students’ learning, and teaching” (Ball & Cohen, 1999, p.20). However, this work has proceeded with limited knowledge about the range of ways VRPs are used to support teacher learning.

For teacher educators, this has meant few opportunities to learn about different ways VRP are re-used to promote and support teacher learning or to benefit from the broader range of efforts being pursued. Or, put differently, it has made it difficult for the field of teacher education to build a shared professional knowledge base concerning the re-use of VRPs.

For those who produce VRPs as educational resources, this lack of research has meant that such development work often proceeds with only best guesses and limited perspectives on what teacher educators are doing (or hoping to do) with VRPs. As a result, VRPs are often produced with very little attention to re-use and are developed for highly constrained purposes that limit their educational potential.

This study addresses the question, how do preservice mathematics teacher educators make use of existing VRPs to support the professional learning of preservice teachers? We examine the instructional goals teacher educators try to achieve when re-using VRPs – particularly with preservice teachers – as well as the types of learning activities in which they re-used VRPs. We then discuss what these findings mean for preservice teacher educators who re-use VRPs as well as for those who produce VRPs that can be re-used in teacher education.

**Background**

“Records of practice” are classroom recordings and artifacts that capture detailed facets of teaching and learning that allow people to directly look at and study practice (Bass et al., 2002, p. 79). Interest in records of practice – particularly video records of practice (VRPs) – has steadily grown over the years and VRPs are currently being used in many diverse efforts to improve teaching (Bacevich, 2010; Brophy, 2004; Brouwer, 2011; Gaudin & Chalies, 2015; Janik, Seidel, & Najvar, 2009; Rook & McDonald, 2012; Sherin & Sherin, 2007; Villegas-Reimers, 2003). For example, videos have come to play an important role in preservice teacher education for helping novices learn professional skills and practices (e.g. Boerst, Sleep, Ball, & Bass, 2011; Sherin & van Es, 2005) and for assessing novices’ growth (e.g. Pecheone & Wei, 2011; The American Association of Colleges for Teacher Education, n.d.). Similarly, there has been increased use of VRPs within the profession of teaching itself. For example, they are used in the evaluation and measurement of teaching quality in schools (e.g. Bill & Melinda Gates Foundation, 2013; Ho & Kane, 2013), as part of teacher professional development (e.g. Borko, Jacobs, Eiteljorg, & Pittman, 2008; Santagata, 2009; Seago, Jacobs, & Driscoll, 2010; van Es & Sherin, 2010), and as a critical tool teachers use to represent their professional growth and accomplishment and allow others to assess their achievements (e.g. Lustick & Sykes, 2006).

Along with this growing interest in VRPs there are an increasing number of initiatives to create broadly and easily accessible digital video collections for educational practitioners and researchers to re-use in their work. A few examples of repositories of VRPs that have been designed to grow over time, housing new collections and potentially accommodating a growing user base include –

- **Accomplished Teaching, Learning, and Schools (ATLAS)** case library (http://www.nbpts.org/atlas) – A collection of cases developed by the National Board for Professional Teaching Standards containing video submissions by teachers as part of the National Board’s certification process;
- **Everyday Mathematics Virtual Learning Community (VLC)** (http://vlc.cemseprojects.org/) – An online space for teachers to share, communicate, and reflect on practice, including a resource library containing several hundred VRPs (Virtual Learning Community, 2018); and the
- **Teaching & Learning Exploratory (TLE)** (https://tle.soe.umich.edu) – A repository containing collections of full-length classroom videos from research efforts like the Measures of Effective Teaching Extension (METX) project as well as collections of curated clips such as the TeachingWorks High Leverage Practices Exemplars collection.

Others have also developed smaller, self-contained, online collections such as TIMSS Videos (http://www.timssvideo.com), a set of VRPs collected in seven countries, associated with the Trends in International Mathematics and Science Study (TIMSS) study; or the Teaching the Core Archive (http://achievethecore.org/teachingthecore), a collection of lesson videos to support K-12 teachers’ efforts to address the Common Core State Standards. In addition, it has become increasingly common for small sets of VRPs to accompany publications for education professionals, such as Math Solutions Publications’ Number Talk videos (http://mathsolutions.com/what-we-offer/number-talks-videos) or the National Council of Teachers of Mathematics’
Secondarily, this study sheds light on the re-use of educational VRPs, focusing on the perspectives and experiences of individuals who have used these types of resources to support teacher learning – particularly in the context of mathematics preservice teacher education, where VRPs have played an important role. Mathematics teacher educators have leveraged VRPs in numerous and varied efforts to help preservice teachers come to a different understanding of mathematics than what they experienced as students and prepare them to teach mathematics in ways they may have not encountered before. Teacher educators have used VRPs to provide glimpses of new possibilities for mathematics teaching and learning, build vision and inspire, problematize assumptions and taken-for-granted values, immerse preservice teachers in different classroom environments and cultures, study a diversity of student ideas and ways of thinking, and practice working within different instructional situations — just to name a few (e.g. Brophy, 2004; Brunvand, 2010; Calandra & Rich, 2014).

### Methods

This qualitative study consists of 34 in-depth, semi-structured interviews with individuals who have re-used video records of practice from online digital repositories or other accessible sources in their work as teacher educators – particularly those who have focused, at least in part, on mathematics teaching. The data is part of a larger data set (44 interviews) on the re-use of VRPs in the field of education, however, interviews that did not address VRP re-use in preservice teacher education contexts with some focus on mathematics teaching and learning were not included in this analysis.

Interview participants were recruited through a combination of convenience and snowball sampling techniques. The research team worked with repository and research partners to identify video re-users, we asked interview participants to recommend others, and we identified potential participants through disciplinary publications and conferences. The team continued to pursue potential interview leads until we had achieved data saturation among participants’ responses regarding their re-use of video records of practice. All interviews were audio recorded and transcribed. Transcripts were then initially analyzed with a set of codes that were developed based on themes from the literature. The codes were further refined based on themes that arose from earlier surveys, during the interviews, and during the initial coding and analysis process — this included topics such as instructional goals for data re-use, learning activities in which VRPs were integrated, and teaching context. Using the code set we developed, two coders worked independently to code the same transcript in order to assess interrater reliability. We repeated this process until we reached an acceptable level of interrater reliability for our two groups of interviewees: those whose re-use focused primarily on teaching, and those focused on research. Using Scott’s Pi, a statistic measuring interrater reliability for coding textual data (Holsti, 1969), we achieved a score of 0.732 for interviews that used a version of the protocol primarily focused on re-users’ teaching efforts and 0.712 for a version that focused primarily on the re-users’ research efforts. More details about the interviews, including the full interview protocol and the analytic code set used by the team, have been published elsewhere (Yakel, Suzuka, & Frank, 2018).

This study further analyzed 34 of the interviews (i.e. those involving VRP re-use in preservice teacher education, focusing on mathematics teaching and learning). This included 27 university faculty members, one postdoctoral fellow, three graduate students, two school-based education professionals, and one administrator. These individuals came from 24 different institutions located in 13 different U.S. states as well as three other countries. This study entailed a secondary analysis of the interviews – a fine-grained examination focusing on interviewees’ discussion of:

- **video records of practice (VRPs):** i.e. videos that captured classroom interactions or documented students’ thinking and learning during an interview or other one-on-one/small group interaction. This excluded discussion of other types of videos that might be considered “educational” such as “how to” videos, demonstrations, documentaries, stories or dramatizations;
- **instances of re-use:** i.e. those uses that involved existing VRPs that had been produced by someone else (i.e. not the re-user) and/or had been produced for completely different purposes. This primarily excluded the very common use of video in teacher education that focuses on video of preservice teachers’ own teaching practice for feedback, coaching, assessment, etc.;
• **Instructional goals and learning activities:** i.e. looking closely at what teacher educators were doing and/or hoping to achieve in their work with preservice teachers when re-using VRPs.

The secondary analysis was carried out by a single team member who examined interview data to identify emerging themes concerning how teacher educators were re-using the VRPs – particularly, the ways in which they were trying to use the VRPs, the types of learning experiences and outcomes they hoped to achieve, and the ways in which they went about creating these opportunities for preservice teachers.

**Findings**

Interview participants re-used VRPs in diverse ways (and often, in more than one way) in their work with preservice teachers (i.e. their “learners”). These efforts to leverage VRPs and integrate them into educational experiences for beginning teachers fell into three main categories:

- **Illustrations:** VRPs were used as illustrations, shown to help learners understand or see specific things more clearly.
- **Data:** VRPs were used as “raw” data that captured rich instances of teaching and/or learning for learners to study through close – and often structured – questioning and analysis.
- **Scenarios or simulations:** VRPs were used as practice-based scenarios or simulations to engage learners in doing – “practicing” – certain professional activities and skills.

These three types of VRP re-use were described by interview participants as part of many different learning activities, supporting a variety of instructional purposes. These uses, activities, and purposes are briefly described below.

**VRPs as Illustrations**

The most common way interviewees leveraged VRPs in their work with preservice teachers was to use them as illustrations that offered learners an opportunity to see or understand something about teaching and/or learning captured in the videos. Typically, these videos were carefully selected by instructors/facilitators to intentionally show, convey, or evoke something as part of the learning experience – i.e. to “illustrate” something for learners. For example, one instructor described an interview video she re-uses that provides a “powerful example of letting the (math) student take responsibility for figuring things out” (Interviewee 20, February 18, 2016). Rather than just telling her preservice teachers about the importance of letting math students take responsibility for figuring things out, she offers a powerful instance of this, captured on video, to convey this message as well as to confront a common belief that simply providing clear procedures to follow is an efficient and effective approach to teaching mathematics. Additionally, for students who primarily learned mathematics through drill and practice with set procedures, this VRP presents a counterexample – a new possibility – to consider and with which to grapple. Another instructor described a classroom video he re-uses in his preservice math methods class that he shows to “give them a sense of what a reformed standards-based curriculum looks like enacted in an inquiry-type way.” (Interviewee 15, January 21, 2016). This is done, in part, to help preservice teachers consider new possibilities for mathematics teaching and learning. He notes, “So, most of our students... The future elementary teachers have experienced math classrooms that are very traditional.” He uses this VRP to expose them to something quite different: “What does it look like to have an inquiry-based curriculum enacted in real classrooms, with all the chaos and everything that ensues from that?” and to have them begin to consider, “What can they learn about children's thinking by having these open-ended type discussions that the teacher is facilitating?” He also uses this VRP in his class to start developing a shared understanding of the teacher’s role and actions: “We're interested in demonstrating and having our students start to look for what teacher moves happen.”

Interviewees used illustrations toward different instructional purposes, involving different types of video exemplars and examples. These are categorized and summarized in the table below (Tab. 1).
Table 1: Instructional purposes when using VRPs as Illustrations

<table>
<thead>
<tr>
<th>Instructional purposes</th>
<th>Type of VRP used/sought</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop shared understanding of and/or language around a specific idea, concept, or practice</td>
<td>Exemplars that show typical/clear instances or particularly interesting examples that might seem counterintuitive, complex, or borderline</td>
</tr>
<tr>
<td>Inspire or expand imagination</td>
<td>Outstanding exemplars of what is possible, intended to stimulate the imagination and spark new aspirations</td>
</tr>
<tr>
<td>Convey a specific message or point</td>
<td>Examples that show or could be used to voice a persuasive argument or compelling case</td>
</tr>
<tr>
<td>Consider and grapple with new possibilities for experiencing, knowing, teaching, learning, doing mathematics, thinking about school and society, etc.</td>
<td>Examples that offer a glimpse of human experience different from one’s own – i.e. offering an image of another person’s experience or of educational experiences that the viewer may not have encountered or seriously considered before</td>
</tr>
<tr>
<td>Offer a model for imitation</td>
<td>Exemplars that display teaching practices, approaches, or other actions/activities that can be emulated or used in one’s own teaching</td>
</tr>
</tbody>
</table>

These video illustrations were primarily shown by the instructor during class sessions as part of a presentation or larger activity for helping preservice teachers understand or see something more clearly. The activities included a variety of whole group, small group, and individual writing/thinking tasks – such as working through the mathematics that was (or will be) seen in the video, making/sharing initial observations and impressions from viewing the video, and considering focal questions about the video posed by the instructor.

VRPs as Data for Analysis

Interviewees also re-used existing VRPs as classroom data for preservice teachers to study and analyze. This served two main purposes for these interview participants: to create an opportunity for learners to (a) closely examine an instance of practice, analyzing some of the details or complexities of practice and/or (b) learn to use particular analytic lenses or frameworks for examining practice. For example, one instructor described her use of VRPs with StudioCode, a video analysis software, in a preservice teacher education course:

They’re coding the video for particular high leverage instances of student thinking and then… using an analytic framework to make sense of those instances or to unpack their thinking about those instances and then propose a follow-up move to those instances (Interviewee 25, March 16, 2016).

This type of careful analytic work can take place both within and outside of class time. For example, in the activity described above, the instructor had preservice teachers independently analyze the same video outside of class and send their analysis to her as a StudioCode “timeline.” She then compiled these analyses for an in-class discussion. She explained, “I can put them all together and when we come together they can very quickly see where their coding lines up or doesn’t line up with other people and we can have a discussion around those and unpack those” (Interviewee 25, March 16, 2016).

In this example of re-use, preservice teachers worked directly with the VRPs themselves, taking the time to view instances of student thinking in detail as well as examining multiple perspectives of these instances.

Interviewees who discussed this type of re-use typically described efforts to engage preservice teachers in closely examining the videos to uncover details, processes, relationships, interactions, etc. that could be seen within the footage. And, like the example above, this work often involved having learners spend time working directly with the video (rather than simply viewing a video shown by the instructor) to carry out analyses and consider new or multiple perspectives. These analyses focused on teaching practices as well as student thinking, learning, and problem solving. A few interviewees also described activities where preservice teachers focused on comparing and contrasting practices or approaches by looking across videos of different teachers/students. For example, a teacher educator discussed how, in her course:

We are looking for what's similar across a few different teachers teaching... or what's different. Or they're looking at children's thinking to think about the range of ways that kids might think about something, so the activity is to look at several clips and compare and contrast how kids are thinking about a similar idea (Interviewee 14, January 15, 2016).
In some cases, these activities involved using and testing particular theories or analytic frameworks. In other cases, learners were asked to put forth their own theories and claims, backed by evidence found in the footage. Either way, the videos used in these activities needed to allow preservice teachers to see and examine details of teaching and/or learning practices – making it possible for learners to view practice in multiple and varied ways.

VRPs as Scenarios or Simulations

Finally, interview participants described how they used VRPs to set up instructional scenarios in which to place their preservice teachers or to create simulations of typical/important situations for preservice teachers to work through as if they were the teacher. This type of re-use served the purpose of engaging learners in doing certain professional activities and practicing various teaching skills. Rather than viewing the video as an illustration or studying it as a data sample (as discussed above), this use of video involved having learners do some facet of teaching within a scenario or simulation created with the VRP. For example, one teacher educator described her use of VRPs to develop “professional vision” with its associated skills:

We're really focusing on professional vision and this idea that it's a cultivated skill that teachers have to be able to take in everything that's happening in the really chaotic classroom environment and decide what's important to focus on and how to interpret it and respond to it using your own teaching philosophy and using the theory that you subscribe to, to support why you're making decisions that you're making (Interviewee 41, May 25, 2016).

She explained that preservice teachers were given pre-selected video clips on which they practiced deciding “what’s important to focus on,” interpreting it, and forming their response to it – working alongside peers and with the support and guidance of an instructor.

Teacher educators also used VRPs to create simulations that resemble what might be found in schools and school districts. Sometimes these re-creations were designed to go beyond simply providing opportunities to practice to include other goals for professional preparation. For example, one instructor described how he uses VRPs with his secondary math and science teachers to simulate Professional Learning Communities (PLCs) that are becoming common in schools:

Working with pre-service teachers, we're not just training them on the content, but we're trying to train them to be professionals and really fit in, be a good colleague… We really try to set our classes up almost like the way that districts set up Professional Learning Communities. And so, we might just pick a video or two to watch and have a targeted discussion, identify a student leader or two to kind of guide the discussion, give the follow-up questions and those kinds of things and that's typically what more schools are starting to do with video-based PLCs… Again, kind of setting it similar to the context of what a PLC might look like in a district (Interviewee 19, February 19, 2016).

In both this example and the one before it, VRPs were leveraged to create educational contexts in which preservice teachers began to engage in certain facets of teachers’ work. In the first example, VRPs were used to engage learners in the observational, interpretive, descriptive, and decision-making work entailed in employing “professional vision” as a teacher. In the second example, preservice teachers practiced leading and participating in professional discussions of teaching practice captured on video. This included the diagnostic and analytic work of examining teaching practice but also finding productive ways to discuss teaching with colleagues – to encourage and enhance one’s own and others’ professional learning.

Discussion

One thing to note from these findings are the diverse ways VRPs are re-used to study and improve mathematics teaching in preservice teacher education, going beyond common notions of simply using video to demonstrate how to do something or to offer exemplars for emulation. While VRPs were most commonly used by teacher educators as illustrations, what was being illustrated and how they were being used as illustrations varied greatly among those we interviewed. Additionally, “illustration” was only one of several types of re-use. This array of possibilities is promising for teacher educators who are interested in using VRPs or who are already using them to support teacher learning: It offers expanded options for how VRPs might be leveraged toward various instructional goals and in a range of learning activities. However, at the same time, this array of possibilities presents challenges for knowing what teacher educators are looking for as they search for suitable VRPs and what makes a VRP “good” for a particular use.
This leads our second major finding: Despite the many ways VRPs are re-used, three basic types surfaced among our interviewees. In teacher educators’ hands, VRPs are used as one of three types of instructional materials, each with special functions and features: illustrations, data, and scenarios/simulations. When VRPs are used as illustrations, they serve as examples or exemplars to help learners to see (or come to see) certain things. In these cases, VRPs are selected by instructors to match what they would like preservice teachers to see or experience. These selections often comprise short, carefully crafted video segments that focus in on what is most essential for the illustration. VRPs are also used as data for preservice teachers to examine and analyze. Here, teacher educators look for rich, unedited videos that offer opportunities for learners to study some facet of teaching and/or learning – possibly from different angles and perspectives or across multiple instances. Finally, when VRPs are used as scenarios and simulations, they serve to create realistic situations in which preservice teachers perform particular practices and skills. For this type of work, teacher educators search for videos that make it possible for preservice teachers to hear and/or see what a teacher might hear/see in particular situations.

This typology offers a glimpse into the ways in which teacher educators integrate VRPs into their work with preservice teachers. It offers those who produce VRPs – as well as those who provide access to VRPs and support their re-use – insights into what matters for teacher educators when looking to use VRPs as an instructional resource.

Conclusion

This study examined VRP re-use in mathematics preservice teacher education through the eyes of re-users. This perspective and these initial findings offer several possibilities for those who create, provide, and work with VRPs in teacher education:

- **VRP Re-users**: For teacher educators who re-use VRPs, these findings offer new perspectives on and possibilities for leveraging VRPs for preservice teacher education. Additionally, these findings may also result in more VRPs and better access to them for re-use in teacher education.
- **VRP Producers**: For those who produce VRPs as a facet of their work and see them as a valuable resource for other education professionals, these findings offer diverse images of how VRPs are leveraged in mathematics teacher education. Understanding the ways in which the VRPs could be leveraged offers new possibilities for developing VRPs as educational resources. Rather than producing VRPs for single, focused purposes, VRPs might be developed in ways to facilitate re-use in many types of activities, supporting a range of instructional goals.

A deeper and clearer understanding of teacher educators’ instructional purposes, the types of VRPs used in and sought for these purposes, and the ways in which learners are asked to work with VRPs can offer re-users and producers important insights into re-use and expand their own sense of the possibilities for VRP use, development, and support.

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Video Case Analysis of Students’ Mathematical Thinking: 
Initial Development Process

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Abstract: Video shows promise for supporting mathematics teacher candidates’ understanding of student thinking. As a result, we began a design-based research project on using video-based online learning modules as a component of a teacher preparation program to improve candidates’ ability to recognize and make connections between patterns in students’ informal and formal reasoning. In this paper, we describe the initial development process of the video case analysis of student thinking (VCAST) modules and then share the results associated with developing our first two modules on functional reasoning. This design-based research project is informed by literature on student thinking and involves a purposeful selection of authentic examples of student reasoning. The results indicate that our process led to an adequate range of student ideas from which to build the modules. Moving forward, the research team is continuing this work by investigating additional cycles of development, improvement, and implementation of these online modules.

Introduction

Instruction which progressively builds upon students’ ideas increases the accessibility of mathematical ideas to a broader range of students and results in a more equitable practice (Boaler, 2004). Further, when teachers build upon students’ thinking to develop their understanding of mathematics (e.g. Carpenter, Franke, Jacobs, Fennema, & Empson, 1998), students’ conceptual understanding of mathematics is improved while procedural fluency is maintained (e.g., Fennema et al., 1996). While there are advantages to developing this type of knowledge in teacher candidates through field-based work, there are limitations associated with doing so through field-based work alone (Ko, Milewski., & Herbst, 2017). It was these limitations that motivated us to begin developing a series of video-based online learning modules to improve secondary mathematics teacher candidates’ ability to attend to students’ reasoning. The work we report on here is part of a 4-year design-based research project aimed at iteratively improving upon the design and use of a series of video-based online modules focused on functions and modeling ideas (Lesh, Kelly, & Yoon, 2008). In this chapter, we describe the first two phases of the design-based research approach we used to develop two video-based online modules that feature video case analysis of student thinking (VCAST).

The VCAST project aims to use authentic cases of secondary student functional reasoning to support candidates’ knowledge of the range of informal ideas students have that form the basis for building more formal
mathematical ideas. Because of this, our module development process involves conducting one-on-one interviews with secondary students as they complete mathematical tasks and then curating the resulting videos and student artifacts for module content. The guiding research questions that drove our initial development process are:

1. What does the literature reveal about student reasoning in functions?
2. To what extent does the evidence of students’ functional reasoning represent a range of student reasoning?

Theoretical Perspective

In this section, we briefly describe the four areas of work closely aligned to our project: (1) specialized knowledge of mathematics for teaching, (2) functional reasoning, (3) video and teacher education, and (4) design-based research.

Specialized Knowledge of Mathematics for Teaching

To advance student understanding, teachers must pay careful attention to students’ mathematical ideas and respond to students in ways that enable them to build upon their ideas (Ball, Thames, & Phelps, 2008). Learning to attend and respond in this way requires a specialized knowledge of how mathematical ideas are related, how to represent ideas in meaningful ways, and common patterns in students’ reasoning (Ball, Thames, & Phelps, 2008). Without this type of knowledge, teachers’ attention to students’ ideas can result in teachers doing the work for students (if the student erred) or congratulating the student (if the student used a correct strategy), rather than pressing the student to reformulate or extend their ideas (Henningsen, & Stein, 1997).

Functional Reasoning

A function in mathematics is defined as “a correspondence between two nonempty sets that assigns to every element of the first set (the domain) exactly one element in the second set (the codomain)” (Vinner & Dreyfus, 1989, p. 357). Function is a unifying concept in K-12 mathematics that applies to the study of algebra, geometry, probability, and statistics. However, many secondary students leave high school with impoverished reasoning abilities with functions, equating functions with a single rule or equation and experiencing difficulty in generalizing functional relationships between quantities (Carlson, 1998; Thompson, 1994).

Understanding a concept in mathematics is achieved when one is able to use, identify, apply, generalize and create extensions of that concept (Sierpinska, 1992). For the concept of function, understanding is evidenced by the ability to work with functions in a variety of ways, including:

1. using function notation,
2. recognizing a function as a dynamic process that maps each element from a set of inputs to a single element in the set of outputs,
3. building and working with functions as mathematical models of relationships between quantities,
4. interpreting and making connections between multiple representations of functions,
5. coordinating changes in quantities that covary,
6. manipulating functions as abstract objects, and
7. identifying and using structural generalizations for families of functions.

The modules we are developing are designed to address items (1) through (5).

Video and Teacher Education

Over the years, teacher education programs have placed a greater emphasis on field experiences for prospective teachers (Zeichner, 1981). One of the benefits is the opportunity for prospective teachers to see what teaching and learning look like in real classrooms (Wilson, Floden, & Ferrini-Mundy, 2001). As beneficial as field experiences can be, the variance in their quality makes it difficult to concentrate on specific “teachable moments.” As a result, teacher educators have explored different ways to use video in teacher education to help slow down and capture these teachable moments (e.g., Sherin & van Es, 2005). In addition, videos of teachable moments can help prospective teachers not only “see” important events but also pause, reflect, and even rewatch.
them (Coffey, 2014). Our use of video to prepare teachers has been influenced by the work of multiple researchers (e.g., Philipp et al., 2007; Santagata, 2014; Star & Strickland, 2008).

**Design-based Research**

Informed by other uses of video (Walkoe, 2015; Sherin & van Es, 2005) and research on technology-enhanced learning environments (c.f. Wang & Hannafin, 2005) we recognize that technology is not a panacea; it is the pedagogy and instructional design that make a difference in learning outcomes (Blomberg, Sherin, Renkl, Glogger-Frey, & Seidel, 2014). Following Reeves (2006), we have set out to design, develop, and improve the use of our modules—and in turn candidate learning—through a design-based research approach that involves (1) analysis of the problem, (2) module design, (3) iterative cycles of module testing and refinement, and (4) reflection to produce design principles. Design research methodology (Collins, Joseph, & Bielaczyc, 2004; Reeves, Herrington, & Oliver, 2005) is particularly applicable for curriculum development as it provides “an avenue for studying learning within the complexity of interacting educational systems” (Zawojewski, Chamberlin, Hjalmanson, & Lewis, 2008, p. 220) and has been effectively used in mathematics education to investigate student learning (c.f. Lobato, 2008) and teachers’ development of practice (c.f. Zawojewski et al., 2008).

**Video Case Analysis of Student Thinking (VCAST) Modules**

Each online module incorporates short video clips of secondary students working on a mathematical task and a series of questions focused on the students’ mathematical reasoning while solving the task. The overarching learning goal with each module is for candidates to recognize and make connections between secondary students’ informal and formal reasoning about key ideas of functions and modeling. The two completed modules discussed in this chapter feature students working with figural patterns (Module I) and graphs of discrete data (Module II).

The modules are designed to be used in various formats. While we are specifically interested in using them in face-to-face or hybrid undergraduate courses with the intent that candidates complete each module before engaging in a face-to-face follow-up session, they could also be used in fully online courses. Currently, the modules are embedded in an upper-division mathematics course. The general structure of each module engages candidates in a cycle of different design elements. First, candidates solve the mathematical task and provide a written explanation of their work. Next, candidates either examine written student work or watch short video clips of students working on the task. Then, based on the evidence provided, candidates are asked to formulate hypotheses about the secondary students’ reasoning. Once these hypotheses are made, additional student evidence is provided, either written work or subsequent video clips. Candidates then have the opportunity to revise their initial hypotheses about the students’ reasoning. Finally, candidates are prompted to reflect on what they have learned.

After completion of the module, and prior to the follow-up session, candidates read a research-based article associated with tasks related to the one featured in the module. During follow-up sessions, candidates work in small groups on identifying/describing student approaches, making inferences about student understanding, and relating the elicited student ideas to features of the module task. The follow-up sessions also involve opportunities to examine additional student work, usually in written form so that by the conclusion of the follow-up session, candidates are in a position to engage in a whole group discussion about connections between the assigned reading and a broad collection of examples of student reasoning.

**Module I: The Hexagon Task**

Figural pattern tasks such as the hexagon task in Figure 1 can be used to elicit students’ ideas about building functions that model a situation. Figural patterns allow students to make algebraic generalizations in a variety of ways, potentially leading to the meaningful use of variables and expressions with the quantities involved. In particular, near generalization tasks can be solved by step-by-step drawing or counting (e.g., “What is the perimeter of the 5th figure in the hexagon task below?”), whereas far generalization tasks require determining a pattern that can be quickly applied to a larger number, such as the hexagon task in Figure 1 (Stacey, 1989).
Module II: The Bus Stop Task

Graphing tasks such as the bus stop task in Figure 2 can be used to elicit evidence of students’ covariational reasoning. As noted in various research studies focused on the development of functional reasoning (Confrey & Smith, 1995; Oehrtman, Carlson & Thompson, 2008; Saldanha & Thompson, 1998), students’ ability to coordinate the relationship between successive values in two sequences and then to couple two quantities into a singular object that can be represented graphically is both developmental and nontrivial. In this task, students are asked to coordinate the static quantities of height and age for a group of seven individuals represented pictorially and then to represent this coordination in a Cartesian graph.

Figure 2. The Bus Stop Task (Taken directly from the book, *The Language of Functions and Graphs*, published by the Shell Centre for Mathematical Education, 1988)

Methods for Initial Development

The initial development process for the VCAST modules described here involved two phases (See Table 1). In the first phase, we consulted the research literature on student reasoning for a key idea related to functions and modeling (i.e., Module I: figural patterns; Module II: covariational reasoning), and then selected a task that could be used with secondary students to elicit a range of thinking for the identified key idea. An important driving question in this part of the first phase is, “What does research evidence reveal about how student thinking progresses?” Researchers next conducted one-on-one interviews with secondary students, analyzed the student work (evidenced by video & student artifacts) in relation to the literature on student thinking, and developed codes relevant to a hypothesized progression of learning. Following Reeves (2006), our intent in this first phase was to clarify the learning problem for teacher candidates. In our case, that meant clarifying what is known about student reasoning for a particular key idea in mathematics (e.g. figural pattern tasks) and to what extent we were able to capture samples of students’ functional reasoning along a broad progression of learning. The problem was then articulated around how best to engage teacher candidates in developing understanding of the student thinking captured.

In the second phase, three researchers selected a range of representative samples to potentially use for video cases, independently developed a proposed module structure, and then worked together to blend selected
elements from the proposed module structures. Module learning goals were drafted at the beginning of the process and then revised.

<table>
<thead>
<tr>
<th>Phase 1: Analysis of the Problem</th>
<th>Phase 2: Module Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review related literature on students functional reasoning and related teacher learning</td>
<td>Create a table to display the codes for reasoning elicited by each student</td>
</tr>
<tr>
<td>Select a functional reasoning task that has potential to elicit a range of student thinking</td>
<td>Select potential video cases that represent the full range of student reasoning</td>
</tr>
<tr>
<td>Capture student thinking during one-on-one interviews and analyze data in relation to the literature</td>
<td>Independently develop three possible module structures for consideration.</td>
</tr>
<tr>
<td>Develop potential progression of student learning and identify opportunities for candidate learning</td>
<td>Blend desired elements from drafted module structures and revise learning goals for candidates</td>
</tr>
</tbody>
</table>

Table 1. Initial Development Process Phases

We then interviewed 30 participants: 14 students from a midsized, urban high school and 16 students from a midsized, rural middle school. Both schools were located in the western United States. Students ranged in age from 12 to 18 years and all were familiar with the mathematical topics addressed during the interviews. Data collection occurred at the schools and consisted of video-recorded, individual student interviews as they worked on three to four mathematical tasks. Students spent about five to ten minutes of the 30-minute interview working on either the bus stop task (middle school) or the hexagon task (high school). As students worked through each task, a researcher asked students to document their work on paper and to explain their thinking aloud. The researcher also asked questions to support student progress.

Qualitative analysis of student work involved creating a set of codes for categories of reasoning that were independently applied by at least two researchers. Discrepancies in coding were negotiated among all of the researchers until agreement was reached. Depending on the task, the list of codes for a task was either clearly informed by the literature on student thinking (e.g. Rivera, 2010) or developed through a grounded theory approach (Strauss & Corbin, 1994) of creating and revising codes based on categories of reasoning anticipated by the researchers.

Results and Discussion

The Hexagon Task Results

Approaches to figural pattern tasks can be described in relation to four interrelated categories that depend on the representations students choose for the elements in the sequence (Sequence Elements) and their symbolic generalizations (Symbolic Generalization) (See Figure 3 and Figure 4). With respect to the hexagon task, students may approach the problem by generating a numerical sequence that corresponds to the perimeter of the figure for the first several figures and then base their reasoning on patterns they notice in the numerical sequence. When doing so, they are using a numerical representation of the sequence elements. They may then generalize patterns either by stating a recursive pattern that describes how the values change from one element to the next (Numerical & Recursive), or a functional pattern that describes how to generate a sequence element based on the sequence position (Numerical & Functional). When students observe patterns related to the geometric features of the figures, they are using a figural representation of the sequence elements. These patterns may focus on how the hexagon figures change from one figure to the next (Figural & Recursive), or how the perimeter can be determined based on either the number of hexagons or the figure number (Figural & Functional).

The high school students interviewed used a variety of approaches when solving the hexagon task. Figure 4 illustrates the range of approaches students demonstrated. When solving the hexagon task, some students reasoned through the task using one of the four approaches (Students A, C, F, K) or some combination (Students B, D, E, G, H, I, J, L). For example, one student noticed the number of hexagons increases by two for each figure and then used that information to determine an explicit functional relationship for the perimeter in terms of the number of hexagons (Student B). Other students started by observing the increase in perimeter for each figure
and then used that information to generate an explicit function for the perimeter of each figure (Students H, I, J, L). And other students started by trying to write a function for the perimeter based on the number of hexagons (observing how the hexagons in each figure contribute to the perimeter) and then used a numerical approach to determine the number of hexagons in each figure (Students D, E, G). What is important is that there are identifiable patterns in how the students reasoned about the task that can be built upon in instruction.

Figure 3. Figural Pattern Approaches

Figure 4. High School Student Approaches

As we conducted our analyses, we developed a list of potential opportunities for candidate learning: (1) deciphering students’ cryptic notations; (2) recognizing what is correct in a slightly flawed strategy, (3) recognizing ideas related to an efficient strategy, and (4) making connections between different strategies. We also wanted the module to introduce candidates to a range of ways to approach the hexagon task, but not necessarily all possibilities. We suspected that candidates would be familiar with a numerical approach and less familiar with figural approaches.

The list of potential opportunities for learning, together with the analyses of students’ approaches, led to the articulation of learning goals for the module. Specifically, Module I is designed to support candidates’ ability to:

- Listen and attend to students’ mathematics as they make generalizations about a sequence of geometric figures
- Articulate students’ mathematics about figural and numerical generalizations for a given sequence and how those generalizations are reflected in students’ work
- Recognize correct reasoning expressed via informal language and vocabulary that describes figural and numerical generalizations
- Describe connections between candidates’ mathematical approaches and students’ approaches

These learning goals were articulated and revised in the at the end of the second phase of our process for developing module content.

We selected the work of Student A (Figural & Functional) and Student J (Numerical & Recursive and Numerical & Functional) from which to build case studies for Module I. Because we anticipated candidates would be less familiar with Student A’s approach, we put Student J’s case study before Student A’s in the module. Recall, candidates work through the same task at the beginning of the module. Thus, starting with student work that is potentially more familiar should facilitate candidates’ progress through the first part of the module. We
structured each case study in a similar way, starting with the candidates making a hypothesis about the student’s approach to the hexagon task based on either a short video clip of the student sharing their thinking (Student J) or based upon an image of the student’s work (Student A). Each case study was designed to then present additional information about the student’s reasoning and prompt candidates to revise their hypotheses. The case studies conclude with a prompt for candidates to compare their own approach to the hexagon task to the student’s approach.

The Bus Stop Task Results

Student approaches to the bus stop task can be categorized by the evidence they produced related to four key conceptual understandings: (1) ordering quantities without assigned values, (2) utilizing graphical conventions as they relate to the assigned meaning of horizontal locations in the Cartesian plane, (3) utilizing graphical conventions as they relate to the assigned meaning of vertical locations in the plane, and (4) connecting the coordination of paired covarying quantity values to their representations in the plane.

As anticipated, our interviews of middle school students revealed a range of thinking about the bus stop task. Table 2 provides a summary of our analysis of the collected video and written student data. One student was unable to detach the meaning of a point’s location on the plane from its numerical label and vacillated between having the label represent height or age. Other students (n = 4) attended solely to height and ordered the people represented in the task accordingly. When they encountered two individuals with the same height, they either used age or their position in the picture to “break the tie.” In contrast, those who exhibited nascent covariational reasoning (n = 19) appeared to understand that a single point in the plane carried information about paired quantities. They illustrated this understanding by attending to both height and age as they matched individuals to graphed points. Those who were able to maintain a stable assignment of quantity to graphical coordinate (n = 7) were successful with the task, though 2 of these 7 corrected their thinking following an interviewer’s clarifying question about their approach. Others, for whom the quantity to coordinate assignment was less stable (n = 12), were successful with the task until they encountered individuals or points with a shared quantity value. A trend that emerged from our analysis indicates that assigning quantities typically represented vertically (such as height) to a horizontal coordinate in a graphical representation is challenging for middle school students.

<table>
<thead>
<tr>
<th>Conceptual Understanding</th>
<th>Brief Description as it Relates to the Bus Stop Task</th>
<th>Coding Options and Percentage Receiving Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>A single point can represent the values of two different quantities.</td>
<td>Student understands that each point in the Cartesian plane supplies both age and height information.</td>
<td>Not demonstrated (n = 4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Partially demonstrated (n = 4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clearly demonstrated (n = 15)</td>
</tr>
<tr>
<td>One-dimensional graphical conventions apply to all vertical axes or number lines.</td>
<td>Student understands that moving up corresponds to increasing age, while moving down corresponds to decreasing age.</td>
<td>Never (n = 5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sometimes correct (n = 11)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Always correct (n = 7)</td>
</tr>
<tr>
<td>One-dimensional graphical conventions apply to all horizontal axes or number lines.</td>
<td>Student understands that moving right corresponds to increasing height, while moving left corresponds to decreasing height.</td>
<td>Never (n = 4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sometimes correct (n = 12)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Always correct (n = 7)</td>
</tr>
<tr>
<td>Quantities do not require numerical values to be relatively positioned along an unscaled axis.</td>
<td>Student can compare and order relative heights and/or ages that do not have assigned numerical values.</td>
<td>Not demonstrated (n = 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clearly demonstrated (n = 22)</td>
</tr>
</tbody>
</table>

Table 2. Bus Stop Task Summary of Student Reasoning (n = 23)

While we conducted our analyses, we again developed a list of potential opportunities for candidate learning as it relates to recognizing (1) differences between students’ bivariate and univariate reasoning, (2) the
evidence of reasoning students’ gestures and verbal explanations provide, (3) how features of tasks can elicit student evidence with potential to be misinterpreted, and (4) how assignment of height quantities to horizontal coordinates can reveal weaknesses in students’ covariational reasoning flexibility. We also wanted the module to reveal the challenges inherent to gauging the difficulty of a task.

This list, combined with our analysis of student approaches, led to the articulation of learning goals for the module. Specifically, in the process of developing the module content, Module II was designed to support candidates’ ability to:

- Listen and attend to students’ mathematics as they reason about bivariate data associated with a static situation involving unmeasured quantities.
- Articulate students’ mathematical reasoning about the relative location of points in two dimensions within a context.
- Recognize correct reasoning expressed via gestures and informal language that describes how the relative location of points in two dimensions can be used to draw contextual conclusions.
- Recognize how features of a task can influence its difficulty and impact the reasoning exhibited by students.

We selected the work of three different middle school students for Module II’s case studies. Because we anticipated that candidates would struggle to accurately gauge the task’s difficulty, the module asks them to identify components of the task they deem easy and challenging and to rank the difficulty on a scale from 1 to 10. We also anticipated that students’ initial assignment of points 7, 6, and 5 might lead candidates to make faulty assumptions about students’ understanding. For this reason, we provided three video clips which feature students starting the task in different ways and then ask the candidates to predict who will be the most successful. We then provide the subsequent video clips for these same three students so candidates can revise their initial hypotheses and also to highlight the ways in which a student can (a) reason correctly and still arrive at an incorrect answer when one of the unmeasured quantities (age) is challenging to estimate, (b) correct errors while progressing through a task, and (c) reason correctly but then falter when cognitive disequilibrium is triggered (vertical measures such as heights can be assigned to horizontal coordinates in the plane). At the end of the module, candidates are again asked to rank the task difficulty and to make a prediction about each student’s approach to a revised version of the task.

Conclusion

The goal of this design-based research project is to develop video-based online learning modules to support secondary mathematics teacher candidates’ ability to attend to students’ mathematical ideas. As with any technological tool for teaching, what matters most is how learners are directed to use the tool (Reeves, 2006). The use of a framework that focuses the intent and selection of video, along with the direction and assessment of teachers’ use of video, is a critical component of success (Santagata, 2014; Star & Strickland, 2008). The study described in this chapter, in particular, provides an example of one way to purposely design video-based instructional modules informed by literature on student thinking and built around authentic examples of student reasoning. The process we described in this chapter contributes not only to forming the basis for module content but also to developing a content framework which, in turn, supports our efforts to clarify candidate learning goals and influences module design.

To iteratively improve the VCAST modules, the research team will conduct a series of design experiments using mixed methods to investigate the development, improvement, and implementation of online modules focused on engaging candidates in recognizing and making connections between patterns in students’ mathematical reasoning. For instance, the modules are being used in an undergraduate course in the fall of 2018 to further test the modules. The content framework for each module, along with other theoretical underpinnings for this work (c.f. Carney, Cavey, & Hughes, 2017), put us in an ideal position to test and refine module content. In a period where programs are looking for ways to integrate subject matter preparation with learning about teaching practices, it is critical to have empirically-based models for such learning.

References


Preservice Mathematics Teachers’ Professional Noticing of Students’ Mathematical Thinking with Technology

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Abstract The purpose of this study is to examine the ways in which preservice secondary mathematics teachers (PSMT) professionally notice middle school students’ mathematical thinking on a technology enhanced mathematical task. The middle school students’ work was captured as a videocase for PSMTs to examine. Findings show that every PSMT included a discussion of the middle school students’ interaction with the technology in their noticing prompts, demonstrating that PSMTs recognized that the middle school students’ mathematical understanding was tied to their interactions with the technology. Additionally, results from PSMTs’ justifications for their predictions of middle school students’ responses to the task, incorporated the middle school students language and described how the middle school students would interact with the technology.

Introduction

Engaging students in meaningful mathematical tasks and capitalizing on available technological tools has been shown to improve attitudes towards mathematics and increase learning (Cheung & Slavin, 2013; Ellington, 2003). Whether or not the use of technology will enhance students’ learning depends on teachers’ decisions when using technology tools to design and implement meaningful tasks. These decisions are informed by teachers’ knowledge of mathematics, technology, and pedagogy. To prepare teachers to implement lessons that draw on such knowledge, the Association of Mathematics Teacher Educators (AMTE) Standards for Preparing Teachers of Mathematics (AMTE, 2017) report discuss the need for PSMTs to engage with technology themselves as learners of mathematics, and to consider how technology can be leveraged to support students’ mathematical learning. Further, they note the importance of opportunities to analyze student work samples with a goal of making sense of different students’ mathematical thinking; this is consistent with the construct of professional noticing (Jacobs, Lamb & Philipp, 2010). Therefore the purpose of this study is to examine the ways in which PSMTs professionally notice students’ mathematical thinking on a technology enhanced mathematical task.

Background and Framework

TPACK

Consider the following example that illustrates three components of teacher knowledge in a lesson on functions. A teacher who is teaching a lesson focusing on parameters’ of function families needs to know how the parameters influence the behavior of the function (knowledge of content), use technology to investigate the influence of parameters (knowledge of technology specific to the content), and design activities that align with approaches
students may take when asked to investigate the influence of parameters on a family of functions (knowledge of pedagogy specific to the content). The intersection of these forms of knowledge has been identified as technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2005; Mishra & Koehler, 2006; Niess, 2005), a type of knowledge several authors have characterized as necessary for teachers to understand how to use technology effectively to teach specific subject matter. Niess (2005) has articulated four components of TPACK: 1) an overarching conception of what it means to teach a particular subject integrating technology in the learning; 2) knowledge of instructional strategies and representations for teaching particular topics with technology; 3) knowledge of students’ understandings, thinking, and learning with technology in a specific subject; and 4) knowledge of curriculum and curriculum materials that integrate technology with learning in the subject area. It is the third component, knowledge of students’ understandings, thinking, and learning with technology in a specific subject, that is the focus of this study.

Professionally Noticing

Jacobs, Lamb & Philipp (2010) developed the professional noticing of children’s mathematical thinking framework which expounds that novices in any profession must learn to notice in ways unique to the profession. The three components of the professional noticing framework (Jacobs et al., 2010) are attending to students’ strategies, interpreting of students’ mathematical thinking, and deciding how to respond on the basis of students’ understandings. With the goal of eliciting PSMTs’ knowledge of students’ mathematical thinking with technology, designing learning experiences by drawing on these professional noticing frameworks seems fruitful. Research on professional noticing has shown that knowledge influences what PSMTs notice (e.g., Dick, 2017; Hiebert, Morris, Berk & Janson, 2007; Jacobs et al., 2010; Wilson, Lee, & Hollebrands, 2011). Hiebert et al. (2007) explained that noticing student work “requires a set of competencies or skills that draw directly on subject matter knowledge combined with knowledge of student thinking” (p. 52). In the case of a technological mathematical task, this knowledge needed is TPACK.

In studying PSMTs’ development of the skill of professional noticing, three different types of approaches have been employed: 1) noticing researcher selected artifacts from other teachers’ classrooms; 2) retrospectively sharing noticing about one’s own lesson/classroom; and 3) researchers observe teachers and infer what teachers notice (Sherin, Russ, & Colestock, 2011). Our study follows the first approach and most of the research employing this approach has focused on whole class video (e.g., Krupa, Huey, Lesseig, Casey & Monson, 2017; Leatham, Peterson, Stockero, & Van Zoest, 2015; McDuffie et al., 2013) with less research on preservice teachers’ noticing of student written work (e.g., Dick, 2017; Goldsmith & Seago, 2011) and even less on the act of professional noticing in the context of artifacts of students’ technological mathematical work (e.g., Chandler, 2017; Wilson, Lee, & Hollebrands, 2011). Wilson et al. (2011) did not situate their work within the professional noticing framework, but they did discover four different categories of ways PSMTs made sense of students’ work with technology: describing, comparing, inferring and restructuring and called on others to design tasks for PSMTs that provided opportunities to analyze students’ technological work. To address the limited knowledge of PSMTs’ professional noticing in technological contexts, we designed a lesson to engage PSMTs with professional noticing through analyzing middle school students’ (MSS) work. Similar to the work of Wilson et al. (2011), the PSMTs examined the written work and a video-recording of MSS’ mathematical technological work. Thus, we specifically address the following research questions:

How do PSMTs professionally notice middle school students’ thinking with technology through analyzing middle school students’ technological work?

Context of this Study

Given the importance of function in 6 – 12 mathematics and as a foundational topic in college-level mathematics we chose to focus on the concept of function for this lesson. Five “big ideas” related to function are outlined Cooney, Beckman, and Lloyd’s (2010) Developing Essential Understandings of Functions, Grades 9-12: the first of which is the function concept. The function concept includes the understanding of functions as single-valued mappings from one set to another (in which the domain and range do not have to be numbers) and as applicable to a wide range of situations. There is substantial evidence that students often have incorrect or incomplete views of the function concept. This includes a view of function that is limited to algebraic expressions and their associated graphs (e.g., Carlson 1998; Even, 1990) and that such understandings typically result in a “vertical line test” related definition of function (e.g., Breidenbach et al., 1992; Fernandez, 2005). To address this, we designed a lesson that used a
preconstructed GeoGebra applet to introduce and problematize the function concept (McCulloch, Lovett, & Edgington, 2017).

Technology can be effective in helping students’ develop the function concept and make connections between different representations of function (e.g., Dick & Hollebrands, 2011; Garofalo, Drier, Harper, Timmerman, & Shockey, 2000). As a result, both research and standards documents often suggest that technology tools be used to study functions. To this end we developed a set of activities in which PSMTs examined their own understanding of the function concept through interacting with an online applet, as well students’ mathematical thinking through professionally noticing artifacts of students’ engaging with a similar applet.

During the class session prior to the lesson of study, PSMTs were then given a homework assignment to engage with the Vending Machine applet (described below), complete a worksheet to record their answers, and screen record themselves following a talk aloud protocol while engaging with the applet. During the next class the PSMTs examined the MSS version Vending Machine applet and examined authentic MSS’ definitions written following engagement with the applet. For homework, PSMTs engaged in a noticing assignment specifically focusing on the first two aspects of the Jacobs et al. (2010) noticing framework, attend and interpret. The decision was made to focus on these aspects and not the “decide” aspect as research has shown that PSMTs struggle making next-step decisions, especially when they are new to noticing (Gupta, Soto, Dick, Broderick & Appelgate, 2018). During the noticing assignment, PMSTs watched and analyzed video recordings of two different pairs of MSS’ engagement with the applet. After analyzing the video recordings, the PSMTs completed a written reflection (see Figure 1) in which they were asked to attend to how the pair of MSS decided which machine was or was not a function and interpret the MSSs’ understanding of function. Along with these two noticing components we included a third component of the reflection that asked the PSMTs to predict how the MSS would identify each of the other eight machines as functions or non-functions and to provide a justification for their predictions. This final component was included since PSMTs need to be able to predict and anticipate different strategies students might employ to solve mathematical tasks (Hiebert et al., 2007; Smith & Stein, 2011) prior to making decisions about what to do next (i.e., the third component of the noticing framework).

Watch the video of students engaging with Machines I and J, following along with the transcript. While watching the video, focus on the students’ language. Based on their responses, predict the students’ responses for the rest of the machines in the student version of the applet. Provide evidence from the video to justify your responses.

How did Group 1 decide which machine was or was not a function?

Explain Group 1’s understanding of function. Use examples from the screencast as evidence to show how you know what they do or do not fully understand.

Predict (using language you believe the students will use) how Group 1 will answer each machine from the middle school student version of the applet and how Group 1 will engage with each machine. Your justification should include evidence from the video.

**Figure 1.** Noticing reflection assignment directions

The Vending Machine Applet

The Vending Machine applet (version 2.0) was designed to trigger a dilemma in PSMTs’ understanding of function as it contains no numerical or algebraic expressions, but instead was built on the metaphor of a vending machine. Our Vending Machine applet ([https://ggbm.at/qxQQ7GP](https://ggbm.at/qxQQ7GP)) is a GeoGebra book that asks the user to identify if each vending machines is a function or non-function. Each machine was designed to address misconceptions from the literature on distinguishing functions and non-functions. In the design of the applet, we are trying to disrupt are the notion of what represents an element in the range (Machines B, I, & J), students occasional use of the term “unique” when thinking about outputs (Machines B & I), and the notion that onto functions should be “predictable” (Machines A, C, I, & J) - meaning that if one knows the function rule and is given an input, it is possible to predict the output. A similar version of the applet was designed for MSS to develop a definition of the concept of function.
(https://ggbm.at/wcuPt43b). The MSS applet’s directions on each page are slightly different than the PSMT version but all the machines in the MSS Vending Machine applet also appear in the PSMT version.

**Method**

For this study, we sought to develop PSMTs’ knowledge of students’ mathematical thinking with technology through engaging in a lesson (described above) that included opportunities for PSMTs to professionally notice MSS’ thinking with technology. To do so, we conducted a study with eight PSMTs at a southeastern university. These PSMTs were juniors enrolled in a mathematics methods course. All were seeking a bachelor’s degree.

**Data Collection and Analysis**

Even though the lesson had several components, for this paper we focus on PSMTs’ written work on their noticing reflection assignment (Figure 1). Each PSMT was asked to explain how each group of MSS determined whether or not the machine was a function (attend) and to discuss the MSS’ understanding of function (interpret). This resulted in a total of 16 attend and interpret statements, two for each PSMT that were recorded in a spreadsheet for analysis. Since each PSMT was asked to justify their predictions on how the MSS would classify the additional eight machines that were not shown in the video, there is a total of 14 predictions and justifications for each PSMT. (Note there are 14 and not 16 since the one MSS group did not finish the assignment). PSMTs’ worksheets from completing the task themselves as learners, were also used to compare their language as learners to the language they used on the noticing reflection assignment. This allowed use to identify when PSMTs were drawing on their own language or MSS’ language.

A team of three researchers began by analyzing individual PSMT’s responses together to develop the codebook. Coding began by examining each reflection for evidence of attending to and/or interpreting the MSS' mathematical thinking. However, since the videocase of the MSS’ work incorporated technology, an additional code for evidence of attending to and/or interpreting the MSS’ interaction with technology emerged. To analyze PSMTs’ justifications of their MSS predictions, we used content analysis through open coding with constant comparison (Creswell, 2007). Specifically we focused on the ways in which the PSMTs drew on their noticings (i.e., attention to and interpretation of student thinking) to anticipate what students might do next and make predictions. From this open coding, three overarching prediction themes emerged regarding PSMTs’ language used in the prediction and manners in which they discussed the MSS’ engagement with the machines (Figure 2).

<table>
<thead>
<tr>
<th>Attend</th>
<th>Interpret</th>
<th>Predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence of attend to interaction with technology</td>
<td>Evidence of interpretation of interaction with technology</td>
<td></td>
</tr>
<tr>
<td>Evidence of attend to MSS’ mathematical thinking</td>
<td>Evidence of interpretation of MSS’ mathematical thinking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Used MSS’ language</td>
<td>Used own language</td>
</tr>
<tr>
<td></td>
<td>Discussed engagement with machines</td>
<td>Discussed engagement with machines</td>
</tr>
</tbody>
</table>

**Figure 2. Codes for noticing reflection assignment**

To establish reliability in our coding, responses were coded independently by all members of the research team (n=3) and the number of agreements were divided by the number of assigned codes. The team were in agreement over 90% of the time, so the codebook was considered reliable (Miles & Huberman, 1994). Differences in coding were reconciled through discussion. We examined these codes for themes relating to evidence of PSMTs’ knowledge of students’ mathematical thinking with technology. These themes are presented in the results section.

**Results**

To answer our research question, we first discuss how the PSMTs professionally noticed the MSS’s technological work including how they attended to and interpreted the MSS’ mathematical thinking and/or their
interactions with the technology. Then, we discuss themes that emerged in the ways the PSMTs predicted and justified how they believed the MSS would engage with the applet.

PSMTs’ Professional Noticing of students’ mathematical thinking with technology

When asked to attend to how the MSS decided whether or not the machines were functions, three of the eight PSMTs discussed both how the MSS interacted with the machines as well as described the MSS’ ideas of function for at least one of the MSS groups. It was more common for the PSMTs to either describe how the MSS decided function or non-function in terms of interactions with the machines or in terms of how the MSS were thinking about functions. For example, with MSS Group 1, PSMT 6 stated, “They did one machine at a time; while working on each machine they selected each soda 3 or 4 times to see if the outputs were different.” This description was focused only on interactions with the technology. In contrast PSMT 3 explained, “Group 1 looks at each input and makes sure there is only 1 output and that it’s the same one each time” which is focused on the MSS’ ideas of function.

For interpreting the MSS’ understanding of function, seven of the eight PSMTs discussed both how the MSS interacted with the machines as well as described the MSS’ ideas of function for at least one of the MSS groups. For example, PSMT 7’s interpretation of MSS Group 1’s thinking included both aspects,

They fully understand that if an input is has same output each time then it is a function. They are thinking that if a function puts out 2 sodas with a different color each time and that colors are same every time then it is a function. I know this because they used word, ‘constant’, ‘random’, and ‘pattern’.

In general, the PSMTs’ interpretations of the MSS’ understanding of function were based both on how the MSS were using the technology and how their interactions with the technology influenced their understanding.

PSMTs’ knowledge of students’ mathematical thinking with technology seen through their Prediction Justifications

Through an examination of PSMTs’ predictions of MSS’ answers and justifications, two themes emerged relating to PSMTs’ noticing of students’ mathematical thinking with technology: incorporating MSS’ language; and considering MSS’ interactions with the applet.

Incorporating MSS’ language.

Overwhelmingly, PSMTs abandoned their own mathematical language and justified their predictions of the MSS’ answers using the MSS’ language (Table 1.).

<table>
<thead>
<tr>
<th>PSMT</th>
<th>Used MS language</th>
<th>Used Own Language</th>
<th>Discussed Engagement with Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14 (100%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>2</td>
<td>11 (79%)</td>
<td>0 (0%)</td>
<td>6 (43%)</td>
</tr>
<tr>
<td>3</td>
<td>4 (29%)</td>
<td>8 (57%)</td>
<td>6 (43%)</td>
</tr>
<tr>
<td>4</td>
<td>9 (64%)</td>
<td>0 (0%)</td>
<td>2 (14%)</td>
</tr>
<tr>
<td>5</td>
<td>9 (64%)</td>
<td>0 (0%)</td>
<td>11 (75%)</td>
</tr>
<tr>
<td>6</td>
<td>9 (64%)</td>
<td>0 (0%)</td>
<td>2 (14%)</td>
</tr>
<tr>
<td>7</td>
<td>9 (64%)</td>
<td>1 (7%)</td>
<td>4 (29%)</td>
</tr>
<tr>
<td>8</td>
<td>14 (100%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Total</td>
<td>83 (74%)</td>
<td>9 (8%)</td>
<td>31 (28%)</td>
</tr>
</tbody>
</table>

Table 1. Occurrence of themes in PSMTs’ prediction justifications.

All eight PSMT incorporated the MSS’ language in at least 4 of their 14 justifications, with some PSMTs including the MSS’ language in all of their justifications. Overall, of 112 justifications, 74 percent of those incorporated the MSS’ language from the video and/or written artifacts. To illustrate, PSMT 1, justified all of his own answers to the
vending machine task by explaining whether or not the machine would pass the vertical line test (i.e., he justified all responses by saying “passes the vertical line test” or “fails the vertical line test”). However, when predicting how MSS Group 1 would decide whether the machines were functions each of his justifications used the MSS’ terms “constant” and “random.” For example, PSMT 1 correctly predicted that MSS Group 1 would classify Machine L as a function and justified his response by stating “even though all the buttons put out green its not random but a constant output.” There was no mention of the vertical line test; he abandoned his language and adopted that of the MSS. Even though all PSMTs adopted the MSS’ language for some of the justification, there were two PSMTs who still relied heavily on their own mathematical language when justifying the MSS’ answers. For example, instead of using the words “constant” and “random” as the MSS did, in his justifications of MSS’ predictions, PSMT 3 discussed the inputs and number of outputs, which is the language he used in his own machine classifications from when he completed the task as a learner.

Considered MSS’ interactions with the applet.

In considering the PSMT’s justifications for their predictions of the MSS’ responses, 6 of the 8 PSMTs included a description of how they predicted the MSS would interact with the machine applet. Their discussions of the MSS’ interactions with the applet fell into two categories: assuming the MSS would continue to interact with the applet in the same manner as they did for Machines I and J. In MSS Group 1’s video, the pair of students checked each button on the machine more than once. PSMT 5 used the evidence he saw in the video to justify his predictions for the other machines for 79% of his justifications. For example, PSMT 5 predicted that for Machine H, “The group will check each button multiple times to ensure the outputs are consistent for each input and conclude that it is a function.” PSMT 5 also applied this in his justifications for Group 2. In Group 2’s video, the pair of students did not check each button more than once before identifying the machine as a function or non-function which PSMT 5 used as part of his justification predictions. One example of this is below:

After watching their approach for I and J, I can’t be certain that they will check each button's output enough times to classify this machine correctly as not a function...Even if they check each button only once, they would still be able to correctly classify this as a function. Their answer would be correct even though their justification might be flawed.

PSMT 5’s predictions for Group 2 referenced interactions with the applet for all but one justification.

For the second category, both PSMT 2 and 3 assumed that the MSS would pay close attention to the directions which stated that only one machine on each page is a function and would therefore figure out whether or not one of the machines was a function and effectively ignore the other. For example, for MSS Group 1 PSMT 2’s predicted, “In comparison to G, H must be a function. And they will see that the output is consistent.” Here PSMT 2 had already predicted that the MSS would say G is not a function, so based on the instructions H would have to be a function. While this type of predication of how the MSS would interact with the machines may have made sense to the PSMTs based on their own interactions, in reality neither group of MSS discussed the directions or made a decision identifying a machine as a function or non-function based on the fact that the only one on the page could be a function.

Overall, 5 of the 6 PSMTs who discussed MSS’ interactions with the machines in their justification predictions did so for two to six machines. There was not a machine that seemed to elicit this type of justification more than others.

Discussion

To support PSMTs as they learn how to teach with technology, we designed a multi-part lesson to engage PSMTs with professionally noticing researcher-selected video and written artifacts of MSS’ thinking with technology. Findings from our analysis of how the PSMTs professionally noticed the MSS’ thinking showed every PSMT included a discussion of both the MSS’ interactions with the applet and the MSS’ understanding of the function concept for either the attend or interpret prompts. Thus, the PSMTs recognized that the MSS’ understanding of function was tied to their interactions with the technology. Results from the analysis of the PSMTs’ justifications for their predictions of the MSS’ responses to each machine included a prevalence of justifications that incorporated the MSS’ language...
and described how the MSS would interact with the technology either by making assumptions that the MSS would continue to interact with the applet in the same manner as they continued with the technological task or incorrectly assuming the MSS would interact with the technology in the same ways they themselves did.

Our findings closely mirror those of Wilson et al. (2011) in that PSMTs’ professional noticing responses included instances of describing, comparing, inferring and restructuring. Wilson et al. (2011) explained describing as when PSMTs explicitly refer to or utilize “students’ actions with the technology, words students have written or said, or mathematical terminology and symbols used by students” in their analysis of the students’ work (p. 53). Comparing includes instances where the PSMTs compare the students’ interactions with the technology to their own interactions with the technology either by implicitly or explicitly referring to a difference between the two. Inferring includes instances when PSMTs “use their technological, pedagogical, and/or mathematical knowledge to interpret students’ work and make inferences about what students [are] thinking (p. 57). Finally restructuring includes instances where PSMTs expand their own understandings to include those of the students’ whose work they analyzed.

When the PSMTs in this study were initially attending and interpreting how the MSS interacted with the technology, they tended to describe either the students interaction with the technology or to describe the MSS’ mathematical understanding of function. Wilson et al. (2011) considered these in the same category, but we found that attention to and interpretation of the MSS’ technological work to both to be necessary for a full evaluation of the MSS’s thinking with technology. The PSMTs’ attention to and interpretation of the MSS’ thinking with technology did not include comparisons, inferences or restructuring. This is likely due to the manner that the professional noticing assignment asked the PSMTs to first explain how the MSS determined whether or not the machine was a function (attend) and then to discuss the MSS’ understanding of function (interpret).

The final part of the professional noticing assignment in which PSMTs’ predicted MSS’ answers and interactions with the applet did elicit the other three ways (i.e., inferring, comparing, and restructuring) PSMTs make sense of students’ work with technology as described by of Wilson et al. (2011). The task the PSMTs completed asked them to make predictions (i.e. infer) as to how the MSS would classify the remaining machines as function or non-function. The PSMTs had to use their TPACK to make these predictions. Their predictions often adopted the MSS’ language (describe) and seemed to indicate an understanding of the ways the MSS were developing the concept of function. Because seven of the eight PSMTs included the MSS’ language in the majority of their prediction justifications, we see that almost all of the PSMTs demonstrated knowledge of students’ mathematical thinking with the applet to the extent that they understood their words, and used them to justify predictions about what the MSS would do with the other machines.

Additionally, the PSMTs sometimes assumed the MSS would interact with the technology in the same ways they interacted with it themselves (compare); for these instances it seemed that the PSMTs were not demonstrating an understanding of how the MSS would interact with the applet or the relationship of how interacting with the applet influenced the MSS’ mathematical thinking. Finally, the PSMTs showed some evidence of altering their own understanding of function (e.g., PSMT 1 whose initial understanding was only based on the vertical line test) based on their attention to and interpretation of the MSS’ work on the technological task (restructuring).

Wilson et al. (2010) claim that the fourth component, restructuring, “requires a reconciliation of PSTs’ observations and inferences with their own understandings” (p. 61) and call for others to provide opportunities for PSMTs to reflect on their own understandings in light of their noticing of students’ technological work. In this study, we did not have the PSMTs reflect on how their own understandings of function changed as a result in engaging in this professional noticing task, but will include a reflection component in the next iteration of the lesson in the hopes of seeing more explicit evidences of PSMTs restructuring their own understandings of function.

Overall, through attending, interpreting, and predicting the PSMTs showed evidence of making sense of both students’ language and their actions with the technology itself. This is evidence of the PSMTs are able to engage in professional noticing of students’ mathematical thinking with technology. In addition, this suggests that drawing on the noticing framework in technological contexts might be a powerful way to understand and develop particular aspects of PSMTs’ TPACK. However, this study was focused on PSMTs’ noticing of researcher-selected artifacts and thus we expect that these results would differ if the PSMTs were noticing in-the-moment.
The findings here (in addition to other studies that have utilized the vending machine applet - e.g., Sherman et al., (2018)) indicate that this particular lesson and its accompanying applet should be improved and further tested before it is widely used with the mathematics education community. The lesson has since been revised to provide PSMTs with an opportunity to design a middle school version of the applet prior to engaging with the version the instructor created for MSS. The purpose of this addition is to address another component of TPACK - knowledge of instructional strategies for teaching with technology. Additionally, since we did not specifically ask the PSMTs to include both a discussion of the MSS’ interactions with the applet and the MSS’ thinking for the attend and interpret prompts of the noticing assignment, we have changed the assignment to elicit both. This should provide a deeper understanding of how PSMTs draw on their knowledge of students’ mathematical thinking with technology when noticing. Finally, we have added in a reflection component to capture how PSMTs feel their knowledge has been impacted through engaging in this lesson.

Implications for Teacher Educators

As technology tools are becoming more ubiquitous in our schools, using them to teach mathematics should be as well. Thus it is important that PSMTs have opportunities to engage with technology in their teacher education programs and learn how to design lessons using technology tools. But maybe even more importantly, PSMTs need to be able to make sense of students’ mathematical understandings as they engage with technology-based mathematics tasks and how students’ interactions with the technology influences their mathematical understandings. It has been shown that attending to student thinking is not trivial, this is especially true in technological contexts. The results of this study suggest that designing opportunities for PSMTs to engage in professional noticing tasks that include making predictions along with attending to and interpreting students’ thinking will further support their development related to instructional decision making. Given the promise of these results, mathematics teacher educators need to provide PSMTs more opportunities to reason about students’ understandings, thinking, and learning with technology.

References


The Digital Learning Framework: What Digital Learning can Look Like in Practice, An Irish Perspective

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Abstract: This paper describes the evolution of a Digital Learning Framework (DLF) from November 2016 to July 2017, to help Irish schools embed digital technologies more deeply into their classroom practice. A census of digital technology usage in Irish schools (Cosgrove et al., 2014) had identified that teacher practices had undergone little change since the launch of the initial policy for schools, Schools IT2000 (DES, 1997). Building on this research and a consultative process the Department of Education and Skills developed a Digital Strategy for Schools, 2015-2020. This strategy decided to adapt the UNESCO ICT Competency Framework for Teachers (UNESCO, 2011) so that all schools would have greater clarity around embedding digital technologies. This paper will outline the process engaged in to review and adapt the UNESCO ICT-CFT, detailing the literature reviewed and how it was used to inform the design, development, initial evaluation (50 schools) of the Irish DLF.

Background and Context

This paper will present the evolving Irish Digital Learning Framework for Schools (DES, 2017a), referred to hereafter as DLF, which is designed to help schools embed digital technologies more deeply into their practice. A census of digital technology usage in schools (Cosgrove et al., 2014) identified that teacher practices had undergone little change since the launch of the initial policy for schools, Schools IT2000 (DES, 1997). Stemming from this research and a through consultative process the Irish Department of Education and Skills (DES) developed a new Digital Strategy for Schools, 2015-2020 (DES, 2015), to embed digital technologies into teaching, learning and assessment practices in schools, referred to subsequently as the Digital Strategy. Cognisant that the majority of teachers’ practice had been identified as being at the “technology literacy” stage (Cosgrove et al., 2014) the DES wanted to develop and implement a policy that would ensure practice moved beyond this basis level. Towards this end, the strategy selected the UNESCO ICT Competency Framework for Teachers (UNESCO, 2011) which outlines a developmental progression from Technology Literacy to Knowledge Deepening and on to Knowledge Creation, as a core resource to assist schools gain greater clarity around the concept of embedding digital technologies within their practices. However, the Digital Strategy noted there was a need “to review and adapt the ICT Competency Framework in its current form, to make it more directly relevant to the Irish context” (DES, 2015, p. 21). This paper details the process engaged in to review and adapt the UNESCO ICT Competency Framework (UNESCO ICT-CFT) for the Irish school system. It outlines the literature reviewed and how it was used to design and develop the Irish Digital Learning (DLF) Framework. To conclude, the next steps for piloting and reviewing the DLF are discussed.

Literature review: First steps to adaptation

While there has been an influx of digital technologies into schools over the past twenty years, there has been for the most part only incremental, or first order, changes in teaching style (Ertmer, 2005). It is challenging for practising teachers to embed digital technologies into their teaching and learning practices (see Cosgrove et al., 2014).
All too often, the concept of embedding or integrating digital technologies into school practices is ill defined or not defined at all. The consultative paper for the Digital Strategy for Schools (Butler et al., 2013) recommended that the UNESCO ICT CFT (2008, 2008a and 2011) should be used to guide schools in the implementation and review of the Strategy at school level. The framework is comprised of six aspects of a learning system, and it “provides a lens to conceptualise what being digital in learning can look like” (Butler et al., 2013, p. 2), as depicted below in Table 1.

However, there was a recognised need to localise the UNESCO ICT CF (2011) for the Irish context. By so doing it would allow the DES, their professional support services and others, to provide more targeted support to schools on embedding digital technologies into their practice. Consultations with principals and teachers during the development of the Digital Strategy highlighted that they wanted more explicit support on what embedding digital technologies could look like in a range of school settings.

### Table 1: UNESCO ICT Competency Framework for Teachers

<table>
<thead>
<tr>
<th>TECHNOLOGY LITERACY</th>
<th>KNOWLEDGE DEEPENING</th>
<th>KNOWLEDGE CREATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNDERSTANDING ICT IN EDUCATION</td>
<td>Policy awareness</td>
<td>Policy understanding</td>
</tr>
<tr>
<td>CURRICULUM AND ASSESSMENT</td>
<td>Basic knowledge</td>
<td>Knowledge understanding</td>
</tr>
<tr>
<td>PEDAGOGY</td>
<td>Integrate technology</td>
<td>Complex problem solving</td>
</tr>
<tr>
<td>ICT</td>
<td>Basic tools</td>
<td>Complex tools</td>
</tr>
<tr>
<td>ORGANIZATION AND ADMINISTRATION</td>
<td>Standard classroom</td>
<td>Collaborative groups</td>
</tr>
<tr>
<td>TEACHER PROFESSIONAL LEARNING</td>
<td>Digital literacy</td>
<td>Manage and guide</td>
</tr>
</tbody>
</table>

The DES established a design team to review and adapt the ICT Competency Framework for Teachers. This group comprised of representatives from the DES ICT Policy Unit, schools' inspectorate, National Council for Curriculum and Assessment, Professional Development Service for Teachers and the university teacher education sector (Author #1). This group immediately commissioned a review of the literature and practices worldwide in relation to competency frameworks, which informed the design process of the DLF that was subsequently developed. The literature review (Hallissy & Hurley, 2016) and the design phase was led by H2 Learning (Author #2 & Author #3).

The starting point for the review was the UNESCO ICT-CFT and it focused on issues such as teacher competency, competency frameworks, ICT competency frameworks, and how the UNESCO ICT-CFT has been adapted in other jurisdictions.

**Teacher Competency**

There is a significant amount of work taking place at a European level around the subject of teacher competences (European Commission, 2013). The European Commission has noted that it is a complex issue that ranges from our assumptions about learning to the broader societal context and environment in which teaching and teacher education occur.

The Commission also notes that a distinction needs to be made between definitions of teacher competences and professional standards. A professional standard “endeavours to describe what teachers believe, know, understand and are able to do as specialist practitioners in their fields” (Ingvarson, 1998 in European Commission, 2013; p.15). It states that “professional standards for teachers focus on what teachers are expected to know and be able to do” and that professional standards can further be defined “as shared representations of visions of practice, i.e. means for
describing a consensus model of what is most valued in teaching knowledge and practice” (p. 15). Professional standards can be viewed as, measuring tools for professional judgement, i.e. tools for making judgements and decisions in the context of shared meanings and values (Sykes and Plastrik, 1993), and/or instruments for providing specifications of levels of achievement (Kleinhenz & Ingvarson, 2007).

Thus, professional standards can exemplify what practices teachers should ideally engage in when teaching and they have the potential to develop shared meanings and values among the teaching profession. In addition, they can also capture proficiency levels or levels of achievement in relation to teaching, so that professional practice is exemplified for the entire profession. Like all standards, professional standards can be used in a variety of ways. They can either support a bureaucratic, technical approach for accountability purposes or a developmental approach with loose definitions of competences indicative of performance, stressing principles and codes of practice (Ingvarson, 1998 in European Commission, 2013). In Ireland, such frameworks are used to support a developmental approach with loose definitions of performance and underpinned by a set of principles, a point we will return to later.

In considering the UNESCO ICT CF, teacher competence is described as “a complex combination of knowledge, skills, understanding, values, attitudes and desire which lead to effective, embodied human action in the world, in a particular domain” (Crick, 2008, p.313). In contrast, a skill is defined as the ability to perform complex acts with ease, precision and adaptability (European Commission, 2013, p.9). However, all too often it appears as if competences are overly equated with knowledge and skills, and issues such as values, attitudes and desire are not to the fore. Typically, the identification of competences, (University of Limerick, 2008) can:

- Provide staff with clear expectations about what is required to be successful in their jobs;
- Provide a foundation for professional development planning.

Teaching competences are thus complex combinations of knowledge, skills, understanding, values and attitudes, leading to effective action in a situation. Like other professions teaching is complex and involves values and/or assumptions concerning education, learning and society, [and therefore] the concept of teacher competences may resonate differently in different national contexts. This is an important factor in adapting the UNESCO ICT-CFT, as it needs to reflect the national priorities in Ireland and the ways in which teachers are currently using digital technologies in their practice.

Competency Frameworks

Competences are typically contained with an overall framework, known as a competency framework. For example, the Consortium for Participatory Arts Learning’s, (2017) definition below states that:

A competency framework is a model that broadly defines the blueprint for ‘excellent’ performance within an organisation or sector. Generally, the framework will consist of a number of competencies, which can be generically applied to a broad number of roles within the organisation or sector. Each of these competencies is then defined in a way that makes them relevant to the organisation or sector, using language that is clear enough to ensure that everyone has a common understanding of what ‘excellent’ job behaviour looks like within the generic context. This common understanding then becomes the benchmark against which the performance of an individual, team, project, or even entire organisation, can be assessed (para. 2).

A competency framework describes what excellent job behaviour should look like in a particular profession and this common understanding can be used to benchmark the performance of an individual or an organisation. In this way, the framework can articulate a range of behaviours that are seen as desirable within a profession.

Ertmer (2005) suggests that teachers comparing and contrasting their digital learning practices in relatively simple ways, can be a more productive path to achieving teacher change than expecting teachers to use digital technologies, from the outset, to achieve high-end instructional goals. She suggests that the following approach can help teachers change their beliefs by:

- Questioning one’s own practice and the practices of others,
Making assumptions explicit,
Using classrooms as sites for inquiry.

Bearing Ertmer’s suggestions in mind, when designing a competency framework for teachers, it would appear that for it be to an enabler for change it needs to be grounded in classroom practice and should be organised so that teachers identify their existing practices and compare it to a range of other practices.

**ICT Competency Frameworks in Education**

There is limited research on the use of ICT competency frameworks in education. What research that exists primarily relates to pre-service teacher education and the need for teacher education providers to develop the ICT competences of future teachers (Foulger et al., 2016). The literature recognises that many teachers, both pre-service and in-service, struggle to embed ICT into their practice and there is a need to develop their ICT competency.

The literature notes that teachers’ beliefs and attitudes to what characterises meaningful learning are inextricably linked to an institution’s vision of how to use digital technology (Ertmer, 2005). In order to change teachers’, use of digital technologies, it requires changing their beliefs about digital technologies and this can be done by making our assumptions around the effective use of digital technologies explicit (Russell et al. 2003). Furthermore, research has found that many school leaders do not have a good sense of the many ways in which teachers are using digital technologies and how to evaluate these uses of digital technologies (Butler et al., 2013). Therefore, there is a need to articulate what effective practice looks like when using digital technologies, so that teachers and school leaders can enhance their existing practices. In an effort to understand how to articulate clearly what effective practice could look like at different proficiency levels a review of existing frameworks was undertaken.

**Organisation of existing frameworks**

The UNESCO ICT-CFT has three level proficiency levels, as noted above. It is arranged around three different approaches to teaching (mirroring three successive stages of a teacher’s development):

1. *Technology Literacy*: enabling students to use ICT in order to learn more efficiently.
2. *Knowledge Deepening*: enabling students to acquire in-depth knowledge of their school subjects and apply it to complex, real-world problems.
3. *Knowledge Creation*: enabling students, citizens and the workforce they become, to create the new knowledge required for more harmonious, fulfilling and prosperous societies.

In addition, the review considered a number of other frameworks, such as ISTE (ISTE, 2017), DigComp 2.1 (Carretero et al., 2017), DigCompOrg (EU Science Hub, 2017a) and DigCompEdu (EU Science Hub, 2017b). DigCompEdu is the most recent framework and it has been developed by the Joint Research Centre on behalf of the European Commission. The DigCompEdu Framework is specifically designed for educators and is based on the DigComp Framework, which was developed originally in 2013 and updated in 2016 and again in 2017.

**Design and Development of the Irish Digital Learning Framework**

The review established that the UNESCO ICT CF is not, as currently developed, a competency framework in the true sense of the word. However, it is an extremely important document that lays out a set of guiding principles or standards on how digital technologies should be used in education. Furthermore, it captures the complexity of embedding digital technologies and it provides a set of principles that informed its localisation for the Irish context. The review also identified that the existing DES quality framework for schools, Looking at Our School 2016: A Quality Framework for Schools (The Inspectorate, 2016a, 2016b). This framework, as depicted in Table 2, met many of the characteristics of a competency framework. However, it is a generic document that covers all aspects of school life, and it does not explicitly mention digital technologies.
Thus, the review recommended that the DES create a new but complementary framework, the Digital Learning Framework for Schools, built around the existing two dimensions of the Quality Framework, that is Teaching and Learning and Leadership and Management. The Quality Framework contains 8 domains and 32 standard statements with each standard having at least one example of effective and highly effective practice (see Figure 2 above). The review established that the standards, as written, could accommodate statements in relation to the effective and highly effective use of digital technologies in schools.

The Design Team, (comprised of representatives from the DES ICT Policy Unit, schools’ inspectorate, National Council for Curriculum and Assessment, Professional Development Service for Teachers and the university teacher education sector (Author #1)) which was led by H2 Learning, then began the process of developing a new set of effective and highly effective practice statements for each of the 32 standards that were focused specifically on the use of digital technology (see Table 3 below). In defining and wording the practice statements, the Design Team drew from number of other frameworks, such as ISTE, DigComp 2.1, DigCompOrg and DigCompEdu while always considering the three different levels of the UNESCO ICT-CFT to ensure there was a movement towards Knowledge Deepening and Knowledge Creation as outlined in Table 1 above. As each set of standards were developed, the Design Team received feedback from an internal review group within the DES.

<table>
<thead>
<tr>
<th>Domain 3: Teachers’ Individual Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standards</strong></td>
</tr>
<tr>
<td>The teacher has the requisite subject knowledge, pedagogical knowledge and classroom management skills</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*Table 2: A section of the Looking at Our School 2016: A Quality Framework for Schools*

<table>
<thead>
<tr>
<th>Domain 2: Learner Experiences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standards</strong></td>
</tr>
<tr>
<td>Pupils engage purposefully in meaningful learning activities</td>
</tr>
<tr>
<td>Pupils grow as learners through respectful interactions and experiences that are challenging and supportive</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*Table 3: A section from the Digital Learning Framework for Schools*
Two versions of the DLF were developed (DES, 2017b), one for primary and one post-primary schools. In addition, the DES developed a set of guidelines, Digital Learning Planning Guidelines (DES, 2017c) to assist schools in using the DLF to review their current digital practices and provide guidance on how the DL Framework can support the creation of a Digital Learning Plan (DL Plan) for each school. They provide schools with a process and a set of questions that can assist them in reflecting on their current use of digital technology and identifying areas for improvement. Though the guidelines refer to schools they note that they can also be used by individual teachers or groups of teachers to review their practices also.

The DL Planning Guidelines encourage schools to consider the following questions:

- How well are we doing?
- How do we know how we are doing?
- What evidence do we have in support of our view?
- How can we find out more about our practices in relation to learning, teaching and assessment?
- What are our strengths?
- What are our areas for improvement?
- How can we improve?

Schools are encouraged to use the DL Planning Guidelines to engage in a process of reflection that culminates in action, the creation of a Digital Learning (DL) Plan that outlines how they will enhance their existing digital learning practices. There are six steps in the planning process as indicated in Figure 1 below. To begin they must identify a focus for their DL review. Though the DLF consists of 32 standards it is not envisaged that schools will focus on all standards, but instead they will select a number of key standards and focus on these. Once they have selected their focus they are then expected to gather evidence on their existing practices before they analyse these and make judgements. Having conducted their analysis they are to create a written report that includes an action plan, which they will implement and subsequently evaluate.

Figure 1: Digital Learning Framework Planning Process
In summary, schools will use the DLF to review their digital learning practices and create a DL Plan that articulates how they will embed digital technologies across their school over a defined period of time. The plan will articulate a vision for the use of digital learning technologies and will capture the current situation with regard to their use. Furthermore, it will describe how DL practices will be improved over a specified time-period. In this way schools can embed their use of digital technologies across all aspects of school life using a co-ordinated developmental evidence-based approach.

Towards Evaluating and Reviewing Irish Digital Learning Framework

The DES is currently in the process of piloting the DLF and the associated guidelines with 50 schools (DES, 2017c) over the coming months (October 2017 – June 2018). These schools will be helped with a series of professional learning supports to assist them identify an area of digital learning they wish to enhance. The Professional Development Support Team (PDST) from the DES will make between two and five visits to schools as well as providing support online and by phone. A formal evaluator has been appointed to document the process and the DES will hold a Cross-Sectoral Forum to share experiences and consolidate learning. This evaluation process will then be used to inform the revised DLF which is planned to be circulated to all Irish schools in September 2018.

Early indications suggest that schools are finding the DLF useful in reviewing their practices and in helping them to better understand what embedding digital technologies looks like in a range of school settings. In addition, the DLF Planning Guidelines appear to be a key resource in assisting schools apply the DLF in their varying school contexts (Cosgrove et. al., in press). This is just the beginning of this process and undoubtedly the DLF and the guidelines will evolve in light of the feedback garnered during the evaluation period. However, what is of critical significance is that the DLF, together with the planning guidelines, is providing teachers and schools with a planning tool and a process that is designed to assist them transform their digital learning practices by giving them a blueprint for how to developmentally progress towards knowledge deepening and knowledge creation within their organisation. They also have a common language of what “effective” and “highly effective” embedding of digital technologies is within a learning eco-system. In addition, the DLF can act as a benchmark against which the performance of an individual, team, or even entire organisation, can be assessed. This is to be welcomed and it is the first step in attempting to transform how digital technologies are embedded in schools so that in future schools are characterised as learning organisations that are more reflective of Knowledge Deepening and Knowledge Creation learning eco-systems, rather than in Technology Literacy activities, as has been the case to date in Ireland.

References


Fostering Children's Creative Thinking: A Pioneer Educational Robotics Curriculum

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Abstract: Creative thinking is considered as one of the 21st century key competencies. Meanwhile, there is an overwhelming argument that educational robotics can foster students' creative thinking skills. However, few empirical studies examine the potential of a robotics curriculum for developing creative thinking skills in the context of non-formal education. The research paper examined pre/post changes in the creativity level of thirty-two school students who participated in a non-formal educational robotics intervention. The Torrance Test of Creative Thinking (TTCT) was employed to measure students’ level of creativity. Significant statistical differences in the pre and post creativity tests were found. The findings reveal initial evidence supporting the idea that educational robotics can serve as promising cognitive tools in advancing students’ creative thinking. Further implications and directions for research and practice are provided.

Introduction

The notion that digital technologies are known as cognitive or ‘mind tools’ was profoundly advocated in the early 90s by a number of other educational researchers (e.g. Jonassen, 1991; Jonassen & Reeves, 1996; Lajoie & Derry, 1993) who claimed that computers and software computing devices could support constructivist learning as they can serve as facilitators in various cognitive activities. Educational robotics is an effective tool for facilitating students’ learning. Robotics in the classroom has taken a global momentum due to its encouraging contributions in the teaching of science, technology, engineering and mathematics (STEM) (Author, 2019). Previous studies revealed that learning with robots help students to obtain knowledge and acquire 21st century skills such as collaboration, critical thinking, creativity and communication (Eguichi, 2014; Breuch & Fislake, 2018). Educational robotics are increasingly integrated in education as knowledge modelling tools. Robotics are used as an extracurricular activity which EU students to STEM learning through coding, making, tinkering and play in formal and non-formal learning settings. The study builds on educational technologies which, today, can be found in public schools and makerspaces open to the public. Robotics Academy will force new directions in learning that will allow elementary school students to undertake authentic math and science investigations in non-formal educational settings. In robotics interventions, children are actively engaged, they collaborate and contribute on meaningful learning outcomes. Educational Robotics is a growing field with numerous researchers to have endorsed Robotics as educational tools (Frangou et al, 2008; Glăveanu, 2010). Previous studies integrated robotics as an effective teaching method in the educational processes. These studies highlighted that in order to transform and improve the educational environment, robotics activities need to be appropriately designed and henceforth implemented in the teaching and learning practices (Bauerle, & Gallagher, 2003; Papert, 1993). Besides, Benitti (2012) identified the potential contribution of the incorporation of robotics as educational tool in schools. The learning theories which apply in robotics
education are constructivism and constructionism (Alimisis, 2013). Robotics education follows the constructionist educational approach developed by Papert (Papert 1980, Vygotsky 1980, Eguchi, 2010, Alimisis 2013). Constructionist learning, known as “learning through design” is based on the idea that individuals learn better when they are engaged in building and manipulating artefacts that are significant to them (Eguchi, 2010). The use of robots for educational purposes enhances the acquisition of different personal abilities (Miller, Nourbakhsh & Siegwart, 2008) and the 21st century skills (Alimisis, 2013; Khanlari, 2013). One of the greater values of educational robotics relies on its potential to inspire curiosity and creativity in students (Breuch & Fislake, 2018). Creativity in educational robotics has been related with the constructionist learning approach and the processes of building, programming and manipulating robotic platforms (Zawieska & Duffy, 2015; Breuch & Fislake, 2018). The current research intervention evaluates the application of a pioneer educational robotics curriculum delivered, in a non-formal educational setting (primary school sector) for the development of students’ creativity. It investigates the impact of robotics integration as a cognitive-learning tool for the development of students’ creative thinking.

Main Aim and Research Objectives

While the benefits for educational robotics programs are plentiful, the purpose of this study was to explore whether the development of the educational robotics curriculum may advance and instill students' creative thinking. Henceforth, this research study has a two-fold objective: (1) To explore the potential of the educational robotics curriculum in advancing students’ creative thinking; and (2) To examine students’ changes in creativity level after the completion of the educational robotics interventions. The objectives are addressed through the following research question: How was the students’ level of creativity affected after the completion of the educational robotics interventions based on the 5 creativity components and 13 creative strengths?

Theoretical background

Creativity and 21st century skills

Creativity is defined in two ways. Firstly, researchers define creativity as the production of useful and novel ideas, products or solutions (Amabile, Conti, Coon, Lazenby & Herron, 1996; Burleson & Selker, 2002; Sternberg, 1988; Woodman, Sawyer & Griffin, 1993). Secondly, it describes the mental procedure that permits people to think of new and useful ideas (Mayer, 1999; Klijn & Tomic, 2010). Withal, creativity is the process of incorporating seemingly unrelated and irrelevant information to solve problems (Runco, 2004). Novelty and usefulness are often referred to as the standard definition of creativity, which was first introduced by Stein (1953). Creativity, is an important twenty-first century skill; essential for learning, work and daily life (Trilling & Fadel, 2009). The 21st century skills have been and described by numerous scholars (e.g. Ananiadou & Claro, 2009; Trilling & Fadel, 2009; Rotherham & Willingham, 2010; Griffin & Care, 2014), and can be namely outlined as: communication, collaboration, critical thinking, problem solving, knowledge construction, creativity, innovation, self-directed learning, global citizenship and digital literacy. It is therefore of vital importance that students, being the future citizens of the Information Society, to equipped with various 21st century skills in order to thrive in this digitalized, globalized, and interconnected rapid-changing society and hence, to succeed in their career aspirations. How best to cultivate students’ creativity in the twenty-first century is next in demand with technology playing a crucial role in fostering these skills. Emerging technologies such as robotics provide challenges and opportunities to the learners to develop innovative ideas, disruptive thinking and higher order learning skills.

Creativity and robotics

Creativity skills are considered important characteristics for today’s globalized, interconnected world due to the rapid technological changes and information growth. The workforce needs have changed and shifted the labor market demands leading to the development of new required skills. Technology integration is vital knowledge for today’s learners as it enables them to advance into the 21st century in a more creative way. In addition, it expands students’ opportunities to think differently leading to innovative
solutions to problems. Fluency, flexibility, originality, and elaboration are the four key abilities which are embedded in the creative process; essential for promoting creativity (Shively, 2011). Loveless, Burton, and Turvey (2006) stated that a number of teachers lack experience and knowledge in the creative process, which makes it difficult for them to instill and boost creativity in their students. In virtue of the aforementioned confronts, it is of imperative need to identify new pedagogical means to foster creativity skills in students. Robotics has been used as an educational tool from K-12 to graduate college (Mataric, 2004). Learning with robotics enables the development of creativity in children as this positive relationship was found to be closely related with activities which required problem solving and idea creation skills (Sullivan, 2017). Scholars has shown that robotics integration in the teaching practices, stimulates the development of student higher-order thinking skills such as application, synthesis, evaluation, problem solving, decision making, and scientific investigation (Papert, 1980; Miglino, Lund & Cardaci, 1999; Williams, Ma & Prejean, 2010; Author, 2015; Author, 2019). Creativity in educational robotics has been associated with the constructionist educational approach developed by Papert (Papert 1980, Vygotsky 1980, Eguchi, 2010, Alimisis 2013) and the processes of building and programming (Zawieska & Duffy, 2015). Constructionist learning, known as “learning through design” is based on the idea that individuals learn better when they are engaged in building and manipulating artefacts that are significant to them (Eguchi, 2010). Other scholars found that the employment of robots in education fosters creativity in students (Alimisis, 2013, Botelho, Braz & Rodrigues, 2012; Khanlari, 2013). Despite the growing body of research in formal education, there is still room to exploit the potential of a non-formal educational robotics program to effectively enhance students’ creative skills and introduce them to programming. Thus, in an endeavor to expand and enrich this area of research, the Educational Robotics Curriculum developed by the Robotics Academy aimed to embrace all the above under its innovative umbrella. The robotics academy program is designed for primary school students with the intention of nurturing their creative ability. It is based on Piaget’s cognitive development theory, and Vygotsky’s social construction theory. The program designed and developed activities for 1st grade to 7th grade students in primary schools. Every grade has its specific manual, including 2 activities each.

**Method**

The sample consisted of a total number of thirty-two students (30 boys and 2 girls) aged 5-12 years old from kindergarten to 7th grade were enrolled in the educational robotics program. The overall mean age was 8.31 years (SD = 1.71 years) (See Table 1).

**Table 1. Students’ demographic characteristics**

<table>
<thead>
<tr>
<th>Age</th>
<th>Grade</th>
<th>Pre-&amp; Post Measurements</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency (N)</td>
<td>Percentage (%)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Kindergarten</td>
<td>2</td>
<td>6.3</td>
</tr>
<tr>
<td>6</td>
<td>1st Grade</td>
<td>4</td>
<td>12.5</td>
</tr>
<tr>
<td>7</td>
<td>2nd Grade</td>
<td>3</td>
<td>9.4</td>
</tr>
<tr>
<td>8</td>
<td>3rd Grade</td>
<td>6</td>
<td>18.8</td>
</tr>
<tr>
<td>9</td>
<td>4th Grade</td>
<td>10</td>
<td>31.3</td>
</tr>
<tr>
<td>10</td>
<td>5th Grade</td>
<td>4</td>
<td>12.5</td>
</tr>
<tr>
<td>11</td>
<td>6th Grade</td>
<td>2</td>
<td>6.3</td>
</tr>
<tr>
<td>12</td>
<td>7th Grade</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

The current study was composed of two phases: (a) Design of the educational robotics curriculum and interventions; (b) Students level of creative thinking through the completion of the Torrance Test of Creative Thinking (TTCT). Besides, the methodology employed the pedagogical approach of constructionism theory (Papert, 1980, 1993) where students can learn better by doing. The methodology employed views educational robotic technologies not as mere tools, but rather as cognitive and learning tools that can serve as potential vehicles of new ways of thinking in the educational practices arena.
Development of the Educational Robotics Curriculum and Interventions

The Robotics Academy for elementary school students, launched by the Frederick University Cyprus, was developed with the core intention to establish and stimulate robotics mainly to the Cypriot educational system and society. It is a research and educational unit that aims to promote and conduct research in the area of robotics education. Specifically, it investigates how to best integrate robotics in the educational practice as a cognitive-learning tool within the educational process and impact of robotics in the development of various skills. The 66 activities of the academy are multidimensional. More precisely, it includes the following: Educational robotics courses, Educational Robotics Program/Visits for Schools, Professional Development Training sessions to educators, Research Activity, Frederick University Events, Collaborations with various educational and social organizations, Social Charity Events and Volunteering.

The above activities along the scientific findings of the experiments and the classroom interventions formed the theoretical and practical basis for the design of the educational material of the robotics curriculum. The philosophy and the pedagogical framework developed by the Robotics Academy serve as the backbone of the design of the educational robotics curriculum. The program of the robotics academy developed an innovative curriculum for students in elementary school levels, which offers students the opportunity to learn math and science through educational robotics design and programming in a non-formal educational setting. The goals of the robotics academy program/curriculum were to: (a) develop and test the curriculum materials and supplemental resources, (b) to examine the use of practical applications for the technology within an informal educational environment. Therefore, the focus of the curriculum is driven by two elements: 1) Learning by Playing: building and Programming robots, and where 2) Robotics as partners in Learning (Examine, Explore and Discover through Construction and Programming). The courses start on October and finish in May every year. Students attend one-hour educational robotics course each week (36 hours within an academic year). The academy accepts students from six years old (1st elementary graders). The curriculum is divided in six levels, in order to cover all three elementary group of students namely: (1) Beginners, (2) Juniors and, (3) Seniors. Table 2 illustrates the number of activity/projects (in parenthesis) together with the different educational robotics packages per group of students. Throughout the curriculum, the students experience a great variety of educational robotics packages and programming platforms: Bee Bots, Blue Bots, Robot – Mouse, Pro-Bot, Kibo Robotics Kit, Lego Mindstorms NXT, Lego Mindstorms EV3, Lego WeDo 1.0, Lego WeDo 2.0, Botley Robotics Kit, Little Bits, Grove, Edison Robot EdCreate Constructors Kit, Engino, mbot, Meet Edison. The exercises of the curriculum were developed based on the aforementioned packages and are intertwined with the following: presentations, educational games, documentaries, interactive audiovisual material, hands on activities, unplugged activities, and use of interactive educational software.

The educational robotics curriculum employs innovative approaches which trace on the learning theory of constructionism where students are expose to their own learning construction when engaging in the making of concrete artifacts. The curriculum includes six structured 60- to 90-min activities and culminating interdisciplinary projects. Lessons are organized to gradually introduce more complex tasks, but also to show case different science fields or problems that can be solved using robots or programming and foster creativity. The first parameter of the robotics curriculum is based on the relationship of Robotics and Constructivism (Bauerle & Gallagher, 2003; Williams, Ma & Prejean, 2010). The learning theory that supports constructivism highlights the educational value of such exercises as the ones the integration of robotics in the educational practice can provide. Such exercises are based on the philosophy of “learning by constructing”, giving students the opportunity to develop interactive “thinking objects” (Bers, Flannery, Kazakoff, & Sullivan, 2014; Papert, 1993). The second element of the pedagogical is based on the following philosophy: Robotics integration in the teaching and learning practice is defined as the use of robotics by students as a tool that enhances their learning experience and supports the achievement of specific learning objectives (Bers, et al., 2014; Bernstein, et al., 2016, Eteokleous, Demetriou & Stylianou, 2013). This approach is related to the learning with computers or computers as mindtools, initially introduced by Jonassen (1999a), where computers and overall technology is introduced as students’ partners within the teaching and learning process.

1 http://akrob.frederick.ac.cy
The educational robotics curriculum aims to develop participants’ knowledge and skills in robotics (theory), in constructing various robotics models and in programming the robots. Various educational robotics packages and visual programming platforms are used. Through the curriculum the participants are engaged in hands-on, technology-based as well as unplugged activities related to robotics, based on the grounds of gamification, project, problem and inquiry-based learning. Specifically, the educational robotics curriculum includes presentations, educational games, documentary, rich audiovisual material, hands-on activities, technology-based (educational software & simulations as well as unplugged activities, interactive activities (building & developing robots). The lessons are divided into several small tasks, giving students a sense of progress, and essentially gamifying the learning experience. Students need to use their creativity and communicate ideas with other student to find possible solutions. Gradually, different concepts from mathematics and science are introduced and incorporated in lessons. During the programming interventions students were introduced to and even master high level programming concepts. Many lessons were focused on support of creativity process with productive outcomes such as: students built a robot that created different drawings or played. The educational robotics activities are integrated in an interdisciplinary was and allow the learner to engage in a collaborative and creative approach, integrating complex-activities which require high cognitive skills such as problem solving and creative thinking skills. The activities were created with the objective to introduce basic programming and foster students’ creativity in the context of science and math subjects. It was assumed that participants do not have any previous knowledge; were naive in robotics or programming. To provide participants with necessary knowledge to implement the story, the activity was divided in two sessions. The first session focus on letting participants to get familiar with the robot and introducing them basic programming concepts.

Torrance Test of Creative Thinking (TTCT)

One of the broadest psychometric instruments used to measure creativity is the Torrance Test of Creative Thinking (TTCT), developed by Torrance in 1966. The Scholastic Testing Service, Inc., holds the copyright of the TTCT (Hee Kim, 2010). It is composed of verbal and figural subtests and it is the most well-known and widely used tool for measuring creativity (Baer, 1993; Kim, 2006; Jo, Lee & Lee, 2014). Based on widespread analyses the TTCT forecasts creative attainment better than any other divergent-thinking tests or creativity measurement, thus it can be determined as the best creativity test which is currently available (Razumnikova, 2013). Creative thinking tests were done before and after learning (pre-test and post-test) to know whether by. A Pre and post activity creativity psychometric tests were used to collect quantitative information for capturing students level of creative thinking. The Torrance Test of Creative Thinking (TTCT) is a well-known and widely used tool for measuring creativity (Baer, 1993; Kim, 2006; Wechsler, 2002; Author, 2015). TTCT was employed to measure individuals’ level of creativity and the impact of educational robotics curriculum in relation to creativity skills. The Figural Form of the Torrance Tests of Creative Thinking, the pre-test and post-test (TTCT; Torrance, 1974) were employed. The TTCT was developed by Torrance (1966) and it is one of the most commonly tools used to measure the five dimensions of creative ability (Fluency, Originality, Abstractness of titles, Elaboration and Resistance to premature closure) and 13 creative strengths. In addition, there are 13 creativity strengths that were added to the average creativity score, that are considered the more complete overall creativity assessment, which are called the creativity index. The 13 creativity strengths consist of: (a) emotional expressiveness, (b) storytelling articulateness, (c) movement or action, (d) expressiveness of titles, (e) synthesis of incomplete figures, (f) synthesis of the lines, (g) unusual visualization, (h) internal visualization, (i) extending or breaking boundaries, (j) humor, (k) richness of imagery, (l) colorfulness of imagery, and (m) fantasy (Shavinina, 2009). The TTCT is available in two versions; the TTCT-Verbal and the TTCT-Figural, each one consists of Form A and B. For the requirements of this study, the TTCT-Figural Response Booklets A & B (Torrance & Ball, 1984; see also Torrance, 1966) were administered and scored according to the guidelines in the instruction manual and scoring guide (Torrance, 1966; Torrance & Ball, 1978, 1984). The tests are divided into 3 non-verbal activities: Picture Construction, Picture Completion, and Lines and Circles (repeated figures). The completion of the tests requires a total working time of 30 minutes with a 10-min to complete each activity. Fluency is the number of relevant responses a person provides given a problematic prompt; flexibility is the variety of solutions and how diverse they 33 are; originality refers to the unique nature of ideas; and elaboration is the depth of the description given for each solution (Torrance, 1974). The pre-measurement took place in October 2016 and the post-measurement took place in May 2017. The students attended the Educational Robotics Courses from...
October to May 2017, a total of 32 lessons. Students attend one-hour educational robotics course each week (36 hours within an academic year).

Results and Discussion

Creative thinking based on the TTCT Performance

The Torrance Test of Creative Thinking is designed to measure 5 norm-referenced scores of principal cognitive processes of creativity and thirteen mental characteristics (known as creative strengths) (Torrance, 1974; Torrance & Ball, 1984; Torrance, 1990). The 5 norm-referenced measures include: (a) Fluency - the number of relevant ideas, (b) Originality - uncommon or novelty responses (the scoring procedure counts the most common responses as 0 and all other legitimate responses as 1) (Shavinina, 2009), (c) Abstractness of Titles - abstraction of thought, (d) Elaboration - number of details / added ideas used, and (e) Resistance to Premature Closure - variety of information when processing information. The thirteen creative strengths are emotional expressiveness, storytelling articulateness, movement or action, expressiveness of titles, synthesis of incomplete figures, synthesis of lines or circles, unusual visualization, internal visualization, extending or breaking boundaries, humour, richness of imagery, colourfulness of imagery, and fantasy (Shavinina, 2009). The TTCT was scored according to the guidelines in the Streamlined Scoring Guide (Torrance & Ball, 1978) and results in an overall creativity index. To obtain an overall creativity index, the aforesaid five normalized measures are averaged and then the bonus is added. The overall creativity index has a mean of 100 and a standard deviation of 15 (Torrance & Ball, 1984). Specifically, to count the CI, the standard scores of each of five variables are used according to the TTCT Norms-Technical Manual (Torrance, 1998; Hee Kim, 2010). Raw scores are converted into standard scores with means of 100 and standard deviations of 20 (Hee Kim, 2010). The standard scores of each subscale can be ranged as follows: Fluency, 40–154; Originality, 40–160; Elaboration, 40–160; Abstractness of Titles, 40–160; Resistance to Premature Closure, 40–160. The standard scores for each of the five norm-referenced measures are averaged to produce an overall indicator of creative potential. For the frequency of creative strength, a + or ++ is awarded as a bonus score for extensive use of the other sub-measures on the basis of the scoring guide. The number of +s’ is added (range for Creative Strengths: 0–26) to the averaged standard scores to yield a Creative Index (Torrance, 1998; Hee Kim, 2010). Two undergraduate research assistants received training by the researcher to score the 1/3 of the tests for reliability and validity purposes. The researcher has chosen to evaluate the tests in this way because of the high inter-rater reliability shown in previous research (Torrance, 1974). Moreover, based on the TTCT-figural manual of 1990, the inter-rater reliability was above .90 (Torrance, 1990). The results from the Torrance Test of Creative Thinking (TTCT) revealed students’ level of creative thinking (see Table 2).

Statistics

The impact of the educational robotics interventions against students’ creative thinking tests were done before and after learning (pre-test and post-test) to examine whether by integrating robotics knowledge in the robotics curriculum/ program will affect students’ level of creative thinking. SPSS was used to analyze the data gathered. Descriptive (frequencies, percentages, means, and standard deviations) and inferential statistics (paired-sample t-test) were conducted to compare students’ pre-test and post-test creativity scores. The study statistically examined the relationship between the robotics and the development of creativity skills when the educational robotics curriculum is employed. A paired-samples t-test was conducted to examine if there was a difference between the students’ pre-test and post-test scores in “TTCT-Figural, Form A and B. The means of the students’ scores in pre-test and post-test relating to the 5 creativity components and the thirteen creative strengths are presented in Table 2.

Table 2. Descriptive Statistics and paired sample t-test Results for the five Creativity Components
The comparison between the pre-test and the post-test showed statistical significant differences, at the \(p < .05\) significance level, in 3 out of the 5 components, namely Originality, Elaboration and Resistance to premature closure. Besides, great increase was observed in the total index of the 13 creative strengths compared to their scores in the pre-test and post-test. Statistical significant differences emerged between the pre- and the post-tests in regards to age for the creativity component of Elaboration (Mean = 67.19, SD = 11.67 and Mean = 6.16, SD = 11.02; respectively), \(t(31)= 3.16, p=0.004\), showing the positive impact of the educational robotics curriculum experience on students creative thinking. There was a significant difference at \(p<.05\) level between the means of the scores the students performed in the pre-test (Mean = 67.19, SD = 11.67) and the post-test Mean = -14.72, SD = 24.08, respectively) with regards to age for the creativity dimension of Resistance to premature closure, \(t(31)= -3.46, p=0.002\). Additionally, there was a significant difference in the scores for pre- test (M= 10.81, SD= 3.65) and post-test (M= 2.13, SD= 3.92) conditions relating to creative strengths, \(t(31)=3.54, p=0.004\). However, it should be noted that there were no statistically significant differences between the creativity subscale measures; Fluency, Originality and Abstractness of Titles. This result can be supported by a recent study that determines the fluency component as less important creativity measurement than originality (Runco & Jaeger, 2012). Overall, the findings of this research revealed the potential of educational robotics for the development of students’ creativity skills in non-formal education. In addition, the analyses revealed that is possible to employ robotics within the educational practice within a well-designed educational robotics curriculum where students experience various hands-on, technology-based as well as unplugged activities. Educational robotics are considered a useful supporting tool for the development of cognitive skills, including Computational Thinking (CT), for students of all ages.

### Concluding remarks and Future Work

Creativity does not happen by chance. Creativity is a skill that been recognized as essential element of problem solving and critical thinking. With the objective to understand if robotics could be used to foster creativity, a non-formal educational program was developed in the context of a makerspace for children between 6 to 12 years old in Cyprus. A total of 32 courses were implemented in the year 2016-2017, with a total of thirty-two participants. Quantitative data were collected and analyzed. The results showed the great potential of integrating robotics as a cognitive-learning tool, promoting research in the field of educational robotics. Additionally, it adds to the body of literature related to robotics integration within the teaching and learning practice and its impact on specific skills development. The results of the study revealed the great potential of integrating robotics as a cognitive-learning tool, promoting research in the field of educational robotics. The study exemplified the necessity to further examine and define the appropriate learning pedagogies and teaching approaches to be employed in the educational robotics curriculum.
curriculum. By engaging in these types of robotics projects, young children play to learn while learning to play in a creative context (Resnick, 2003). An additional suggestion is to train pre-service teachers in educational robotics by equipping them with confidence to integrate robotics for the design and development of innovative curricula. Foremost, there is an imminent necessity to advance the tools and methods employed in the educational arena and exploit the affordances of the emerging technologies that will lead to the construction of new knowledge. In order for students to become active citizens ready to respond to the demands of the labor market, they should be provided with those opportunities and experiences that will adequately prepare them for the future (Jagust, Cvetkovic-Lay, Krzic, & Sersic, 2018). Henceforth, the transformation and improvement of the educational practice will promote the development of creativity skills needed for future citizens. Learning which aim to develop creativity is next in demand, thus, instructional designers and educators must carefully design environments that will maximize students’ potential creativity. Ongoing work aims to expand the number of participants and investigate how educational robotics can influence students’ creative thinking in STEM related subjects on a range of demographic characteristics such as gender, age and grade. The ambition is to suggest a set of guidelines on how teachers can integrate this new emerging technology in the curriculum that will support and enhance students’ 21st century skills in formal and non-formal education settings.

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Author (2015)


Opportunities and Challenges of Using Technology to Teach for Global Readiness in the Global Read Aloud

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Abstract: Digital technologies create opportunities for learning with and from people of other cultures, not just about them. The Global Read Aloud (GRA) project offers an example of such learning possibilities. The GRA is a project that connects classrooms via digital technologies to discuss common texts. This exploratory study investigated the pedagogical opportunities and challenges associated with technology use in teaching for global readiness in the GRA. Our findings are based upon the survey responses of 516 teachers who participated in the GRA and the observation in two schools of 16 lessons during the GRA. While technology broadened how and with whom GRA students read and discussed literature, the nature of technology-facilitated teaching specifically for global readiness was somewhat unclear. We discuss implications for teaching and teacher preparation for global readiness in a digital era.

Keywords: social media, global education, videoconferencing, Skype, international education, ICT, Twitter

Introduction

While schools have often been conceptualized as serving primarily local and national needs (Tye, 2009), globalization has rendered a narrow local focus outdated. Technological advances have the potential to decrease distances between groups and cultures, and education therefore must seek to prepare students for a future defined by globalization (Darling-Hammond, 2010; Walsh, 2016). This chapter analyzes the Global Read Aloud, a free, organic, teacher-driven project that leverages digital technologies to facilitate collaboration across schools and classrooms (see https://theglobalreadaloud.com). Created in 2010 by U.S. educator Pernille Ripp, the Global Read Aloud offers an example of some of the opportunities and challenges for teaching for global readiness in a digital era. After hearing a radio story about an online book club, Ripp posted to her blog proposing that teachers from across the globe connect their classrooms to read and discuss a common book (Ripp, n.d.). While the first year of Global Read Aloud included only one book, in subsequent years Ripp has selected multiple texts at different reading levels, allowing teachers to decide which book is most appropriate for their classrooms. Each year, participation in the Global Read Aloud has steadily grown, with classrooms from more than 60 countries having participated by end of the 2017 Global Read Aloud.

Each year, the Global Read Aloud occurs during six weeks in October and November. Educators register with Ripp via an online form, and subsequently receive Global Read Aloud e-mail updates. Before the six weeks of the Global Read Aloud, educators are encouraged to access Global Read Aloud Edmodo or Facebook groups to find partner teachers. Participating educators link their students with peers from other schools to read and discuss a common book. The depth and scope of collaboration between classrooms varies depending on the participants. For example, some educators pair with a single class, while others partner with multiple classes. Ripp outlines a reading schedule for each of the Global Read Aloud books, and Global Read Aloud teachers are encouraged to create, discuss,
and share lesson plans, resources, activities, and ideas via the technologies of their choice. The Global Read Aloud often features students reading and discussing the GRA text both within their individual classes and with their partner classes. Students often communicate via both synchronous and asynchronous tools including Skype, Twitter, Padlet, and blogs. Many teachers arrange at least one videoconference session for their students to meet their partner classes. Teachers also commonly have their students respond in writing to blog posts and questions created by peers from partner classes (Carpenter & Justice, 2017).

**Theoretical lens**

The construct of teaching for global readiness, as defined by Kerkhoff (2017), framed our understanding and analysis of the Global Read Aloud. Based upon theories of educational cosmopolitanism (Hansen, 2010; Hull & Stornaiuolo, 2014) and multiliteracies (Cope & Kalantzis, 2000; 2009), Kerkhoff (2017) defined global readiness as “global citizenship with the multiliteracies necessary in the 21st century to participate, collaborate, and work in a global society” (p. 92). Kerkhoff’s research suggests teaching for such a vision of global readiness includes four elements: situated practice, integrated global learning, critical literacy instruction, and transactional experiences. These elements offer a helpful lens for considering opportunities and challenges associated with technology use during the Global Read Aloud.

*Situated practice* refers to teaching that responds to the contextual nature of learning by attending to the people and place involved. Situated practice considers the community within the classroom as well as the society within which learning occurs. Situated practice is authentic, relevant, and social. In order to be responsive to their context, teachers should build relationships with students, and endeavor to understand them as social and cultural beings. Situated practice assumes that it is normal and appropriate that teaching and learning varies some across contexts.

To teach for global readiness, educators design curriculum and instruction that features integrated global learning. Global education should not occur as a special or extra event, or be limited to a single course, but instead be integrated across grade levels and academic disciplines. Teachers integrate global learning with existing curricula and local issues. Teaching for global readiness demonstrates how the local is already global, and helps students understand how communities around the world are interconnected.

Teaching for global readiness also develops students’ critical literacy. Educators who teach critical literacy use texts from multiple perspectives and help students learn to analyze and critique those various perspectives. Global readiness education allows students to “develop the capacity to question the authority of the source of information, analyze the authors’ purposes, and locate primary sources” (Kerkhoff, 2017, p. 103). Finally, transactional experience refers to exchanges of perspective through “reading, writing, listening, speaking, and inquiry experiences … with diverse others” (Kerkhoff, p. 103). Students who engage in cross-cultural discussions can learn directly from each other's perspectives. Such direct experiences, either face-to-face or virtual in nature, can contribute to the development of students’ intercultural competency. For this first-hand learning to be optimal, young people must exchange ideas and information with others in ways that require give and take from all sides.

**Literature Review**

Given how economies and societies are changing in response to our more interconnected world, schools too need to prepare global ready students (Ford & Glimps, 2008; Walsh, 2016). There is, however, no clear consensus regarding the goals of a more global educational approach (Peters, 2009; Reynolds, 2015). Arguments for global education range from emphasizing the need for preparation for global economic competition, to the importance of learners developing “world mindedness” (Merryfield, Lo, Po, & Kasai, 2008), to the necessity to prepare citizens who engage with global issues (Harshman & Augustine, 2013; Leduc, 2013). Education for global readiness is further complicated factors such as difficulties with integrating global content into local curricula, the controversial nature of some global education topics, and the limited international experience of many educators (Reynolds, 2015; Tye, 2009). Global education endeavors must attend to various concerns, such as the need to engage students in critical thinking about global relationships, power dynamics, and systematic inequalities, and situate these matters in relation to local
issues. Education for global readiness must function in ways that counteract potentially ethnocentric or paternalistic attitudes (Leduc, 2013). So while support for the value of some kind of education for global readiness is fairly consistent, it remains a complicated and contested undertaking.

Limitations of time and place have historically constrained the types of teaching and learning activities that occur in schools. Students in some cases have only had easy direct access to the perspectives of peers from quite similar backgrounds. In recent years, new possibilities have emerged as Web 2.0 technologies have expanded when, where, and with whom students learn (Carpenter & Green, 2017; Carpenter, Tur, & Marin, 2016; Trust, Carpenter, & Krutka, 2017). Students today do not necessarily have to travel beyond their own communities to have meaningful cross-cultural experiences (e.g., Leask, 2004; Lindsay & Davis, 2013). Digital technologies facilitate interactions with distant peers that have reportedly led to increases in students’ cross-cultural awareness (Krutka & Carano, 2016), decreases in ethnocentrism (Union & Green, 2013) consciousness of misconceptions (Pitts & Brooks, 2016), and greater awareness of one’s own identity and culture (Myers & Eberfors, 2010).

Prior research has chronicled various instances of higher education students in two countries interacting through required and structured course activities (e.g., Pitts & Brooks, 2016). For example, Krutka and Carano (2016) described the experiences of students from Gaza and the United States (N=16) who interacted via social media and videoconferencing. For the U.S. participants, interacting directly with their Gazan peers heightened their awareness of the human implications and costs of global events; matters in far away lands “no longer felt like foreign issues because these conflicts involved people who were now near and dear to their heart” (p. 216). Instances of small-scale projects that utilize technology to connect K-12 learners have also been documented in the literature (e.g., Barnatt et al., 2014; Union & Green, 2013). In particular, videoconferencing has been credited with allowing for face-to-face exchanges that bring diverse perspectives into the classroom and facilitating cross-cultural interactions (Dressman & Journell, 2011; Gerstein, 2000).

Educators often lack relevant experiences from their own schooling and/or personal lives to inform their teaching for global readiness (Leask, 2004). The extant literature warns that educators should avoid certain pitfalls commonly encountered with global educational collaborations. Technological affordances cannot guarantee the success of such collaborations. Pitts and Brooks (2016) asserted that global education projects yield the most benefits if learners are “guided through a controlled process of self- and cultural-awareness” (p. 13). Exposure to global opportunities does not inevitably enhance global readiness (Leask, 2004). Rather than broadening students’ perspective, interactions with those perceived as other can potentially lead to the entrenchment of existing stereotypes (Pitts & Brooks, 2016). To prevent such negative outcomes, learners must be helped to challenge us vs. them binaries, critically examine positions of privilege, and consider differences in the relative power of their respective countries or cultures (Sancho, 2008). Furthermore, while digital tools can facilitate global education activities, teachers sometimes do not have access to the necessary technologies or technology support (Leduc, 2013). Thus technology appears to present both opportunities and challenges for teaching for global readiness. Prior research that has explored education for global readiness has been limited by the small scale of many of the studied programs, and the shortage of studies in PK-12 settings (Cushner, 2012). Research on a program of the Global Read Aloud’s scale and nature has previously been missing from the literature.

Method

Research questions

This research aimed to contribute to understanding of the teaching and learning possibilities arising from technology-intensive global education projects. The research questions we addressed were as follows:

RQ1. What opportunities for teaching for global readiness are associated with technology use in the Global Read Aloud?

RQ2. What challenges for teaching for global readiness are associated with technology use in the Global Read Aloud?
Data Sources

To address our research questions, we drew upon data collected from two sources: an electronic survey completed by teachers and classroom observations.

Survey Instrument

We designed an anonymous online survey that collected data regarding participants, their Global Read Aloud experiences, and their perceptions of those experiences. The survey included 27-items, divided into three sections: informed consent, demographics, and Global Read Aloud-related items. The survey included open-ended, close-ended, and Likert scale items. We collected responses to the survey during five weeks after the Global Read Aloud. We shared multiple survey invitations to social media sites commonly used during the Global Read Aloud. We posted invitations via Twitter, including Global Read Aloud-related hashtags (#), and shared invitations with the main Edmodo groups that were created as collaboration spaces for educators working with the different Global Read Aloud texts. We systematically distributed invitations at multiple times to increase the visibility of the survey with potential participants in different time zones and with varied online habits.

Classroom Observations

We conducted observations during sixteen Global Read Aloud lessons. During the lessons, we took field notes using a semi-structured format for our notes. After each lesson, we reviewed the notes and wrote a brief narrative reflection on the observation.

Survey Sample

In total, 516 educators representing 14 countries responded to the survey, with the largest numbers coming from the U.S.A. (76.2%) and Canada (18.1%). In terms of gender, ninety-five percent of these educators identified as females, while 5% identified as males. Regarding prior experience, 59.4% of respondents were first time Global Read Aloud participants in 2015. Although almost 38% of the respondents were the only individuals in their schools who took part in the Global Read Aloud, the majority of respondents had colleagues at their school involved with the Global Read Aloud. For 7.4% of respondents, there were 10 or more Global Read Aloud participant peers in their schools. The Global Read Aloud educators in our sample worked with learners from as young as two to as old as 20, but most commonly taught students aged 7 to 11.

Observation Settings

We observed at two schools within the same large public-school district in the southeastern United States. Eastside Middle school is a middle school located in the suburbs of a mid-sized city. The school offers a curriculum based on the state’s standard course of study, and most recently received a “B” grade according to the state’s accountability system. At this school we observed in a 6th grade language arts class. This teacher was one of two teachers in the school who participated in the Global Read Aloud. Westside Elementary is located in the urban core of a mid-sized city, and is an international magnet school. As a part of the magnet program, students can choose from a variety of international electives, such as five foreign languages. The school most recently received a “C” grade according to the state’s accountability system. We observed in two different Westside classrooms that were participating in the Global Read Aloud, one in the third grade and the other in fourth grade.

Data Analysis

This chapter combines findings from our analysis of both survey data and classroom observations. We engaged in thematic analysis of the qualitative data with the goal of identifying and exploring themes and patterns. We followed a six phases process of analysis defined by Braun and Clarke (2006): becoming familiar with the data, generating initial codes, searching for themes, reviewing themes, defining themes, and producing a summary report. In order to familiarize ourselves with the data and generate initial codes, we conducted multiple cycles of individually coding a batch of responses, followed by discussion of similarities and differences of interpretation. We engaged in eight such cycles of coding. Due to the interpretive nature of the qualitative coding we conducted, we reached agreement on codes through intensive discussion, rather relying upon an interrater reliability statistic (Saldaña, 2016). Our collaborative coding and discussion led to consideration of various approaches to interpreting the data (Saldaña, 2016; Sandelowski & Barroso, 2007). After coding, we created a summary report for each of the qualitative prompts that included analysis of code frequencies and data exemplars for individual codes. After discussing each of these
reports, we identified themes that spanned various survey items and codes. We then revisited and discussed each individual report in light of these themes, before shifting to the writing of the holistic analysis of survey results.

Findings

Participants generally reported positive perceptions of their Global Read Aloud experiences. For their overall Global Read Aloud rating, almost 65% of respondents selected “Outstanding” and 33.2% chose “Good.” In addition, participants overwhelmingly (96.5%) indicated that they were interested in participating in the Global Read Aloud in the future. In the context of these overall positive educator perceptions, we present below various opportunities and challenges for teaching for global readiness associated with the use of technology during the Global Read Aloud.

RQ1. What opportunities for teaching for global readiness are associated with the use of technology in the GLOBAL READ ALOUD?

Data analysis most clearly indicated that digital technologies provided opportunities for Global Read Aloud transactional experiences. Participants described and we observed multiple ways in which digital tools facilitated student reading, writing, listening, and speaking experiences with peers from beyond their schools and districts. Videoconferencing with partner classes via Skype or Google Hangouts appeared to be a common and valued transactional component of the Global Read Aloud. Just under 80% of the respondents reporting that their students engaged in videoconferencing with another Global Read Aloud class. Videoconferencing activities that were described in the survey included discussing questions and/or prompts related to the Global Read Aloud texts. These questions and prompts were both teacher-generated and student-generated. We observed several videoconferences between the middle school class and their partner class that featured discussion of both predetermined and spontaneous discussion prompts and questions. We saw one videoconference session in which individual students from each class took turns asking the other class questions. The two classes had independently generated these questions prior to the videoconference. We also observed a videoconference in which each class was presenting to the other the outcomes of group projects related to the Global Read Aloud reading.

Classroom observations and survey responses suggested a great deal of student enthusiasm for Global Read Aloud videoconferencing experiences. For example, 29 respondents used the word “love” or “loved” to describe student feelings about Global Read Aloud videoconferencing. In one elementary classroom observation, students in the partnered classes broke into spontaneous dancing when it became apparent that both groups were familiar with a dance move associated with a popular hip hop song. In survey responses, educators frequently indentified videoconferencing as a motivational component of the Global Read Aloud experience. For example, a U.S. middle school media specialist commented, “The students were able to interact with other students in Canada; it helped to motivate them [students] to create questions and respond to the other students’ blogs.” Multiple participants also credited videoconferencing with contributing to the quality of the connections that occurred during the Global Read Aloud, as evidenced in the following respondent comment: “It seemed to impact the students the most when they were able to see the people they were participating within the program.” By allowing peers in partner classes to see each other and interact more directly, videoconferencing appeared to contribute to overall engagement with the Global Read Aloud. A Canadian elementary school teacher commented, “It showed my students that you can connect with the world, with students anywhere and discuss a book.”

In particular, 11% of respondents identified “Mystery” Skype and Google Hangout sessions as an important element of the Global Read Aloud experience for students, and many students showed signs of visible excitement and enthusiasm before and during the mystery calls. For example, in one of our classroom observations at the middle school, the students engaged in a mystery call with a partner class, and when the class finally identified that the other class was in Ontario, Canada, the majority of the students jumped up from their desks, pumping their fists and high-fiving their neighbors. In mystery videoconference calls, the teachers of the two participating classrooms plan the experience and are aware of each other’s locations, but the students initially do not know where their peers are. The classes alternate asking each other questions in order to try to determine their respective locations. In the mystery call we observed, the teachers had also assigned a group of students to present some basic information about their town once the partner class had correctly identified it.
In addition to such synchronous videoconferencing, participants described and we observed the use of multiple digital tools to support asynchronous transactional experiences. For example, blogs and Padlets allowed students to post their questions and comments regarding the Global Read Aloud texts and receive feedback whenever their partner classes or other participants were online. The widespread use of a several Global Read Aloud-related Twitter hashtags also meant that students’ Global Read Aloud tweets regularly attracted responses. Several Padlets were widely shared during the Global Read Aloud, and sparked responses from classes that were not officially partnered. For example, one of the elementary classrooms we observed, the teacher posted a prompt via Padlet and shared the link to it via other social media spaces. Her own students responded to the prompt, and by the following day a large number of students from two other classes that were not officially partner classes had left their own responses to the prompt. The teacher then had her students read and discuss the responses left by the students from the other classes.

Extended writing and discussion related to the Global Read Aloud texts were facilitated by a variety of digital technologies including Edmodo, Google Drive, and Kidblog. In contrast to the public nature of Twitter and Padlet, these tools offered more teacher control and student privacy. Numerous participants described activities that involved Global Read Aloud students regularly posting their responses to their reading to a common online space where peers from partner classes would subsequently respond. These students would in turn comment on posts written by peers from their partner classes. Technology thus provided Global Read Aloud students a larger audience with which to share their writing and from which to receive feedback. For example, one teacher wrote that it “was powerful for my reluctant readers and writers to see their ideas shared with others.” Another participant commented, “[Students] were very interested in reading other students’ ideas or predictions about the books and felt very proud when someone responded to their own.” By providing facilitating synchronous and asynchronous communication, and supporting both initial and ongoing interactions between participants, technology expanded the possibilities for how and with whom Global Read Aloud students could exchange perspectives through reading, writing, listening, and speaking experiences.

Although not as common as descriptions of transactional experiences, participants did refer to examples of *integrated global learning* related to the Global Read Aloud. Various respondents identified connections between the Global Read Aloud and their overall curriculum and explained how the Global Read Aloud did not function as an entirely isolated unit of instruction. For example, one teacher described a videoconference with an Australian partner class “where we discussed not only the book, but also made science and geography connections with the other class. It was wonderful to have a meaningful connection that included the book but also went beyond the reading.” Another respondent commented, “The impact of the book and connections leave a mark throughout all subject areas as we often refer back to the book.” A handful of participants specifically mentioned connecting social studies standards and geography content with Global Read Aloud activities, in part because of how videoconferencing piqued their students’ interests in partner classes’ locations.

**RQ2. What challenges for teaching for global readiness are associated with the use of technology in the GLOBAL READ ALOUD?**

Technology clearly created some valuable opportunities for teaching for global readiness in the GLOBAL READ ALOUD, but our data suggested that educators also experienced challenges. Participants most commonly mentioned encountering challenges related to *integrated global learning*. Almost one-third of respondents (32%) mentioned experiencing curricular barriers during their implementation of the Global Read Aloud. The two most frequently mentioned curriculum challenges to the integration of the Global Read Aloud with other content and local matters were time pressures and the rigid nature of curriculum and associated mandates. For instance, one teacher wrote, “I would have loved to do even more with it than I did but other curricular demands wouldn't allow it.” Many participants mentioned feeling that they lacked the time to give the Global Read Aloud the full attention it deserved.

Participants noted how standardized testing, pacing guides, and other curricular mandates competed with their interest in dedicating time to the Global Read Aloud. One respondent saw opportunities to “teach the weekly grammar, phonics, fluency, writing, and comprehension skills and strategies required in our reading curriculum through the Global Read Aloud books,” but could not do so because “our time and what we teach is typically very dictated to us.” Another teacher commented, “We are tasked with an immense number of things we must accomplish each day, combined with the ever-present push of standardized testing almost every four weeks.” When the Global Read Aloud felt like an extra activity, other curricular demands made many respondents feel they could not dedicate
sufficient time to it. Policies around curriculum may therefore have limited opportunities for teachers to use technology to teach for global readiness during the Global Read Aloud.

Participants also reported challenges associated technology’s use to facilitate Global Read Aloud transactional experiences. The most commonly mentioned obstacle was time zone differences that made participation in synchronous videoconference activities difficult in some cases. For example, a teacher from Australia wrote, “Unless it's a New Zealand school we have next to no chance to Skype people.” School calendars and schedules sometimes presented more general challenges to Global Read Aloud partnerships between classrooms, with school systems in different regions and countries featuring varied class period and term lengths, as well as observing different holidays. One of the teachers we observed explained that at one point she did an enrichment activity during her language arts block in order to allow for her partner class to catch up in their reading. Some Global Read Aloud participants thus faced obstacles in coordinating the synchronous and/or asynchronous technology-facilitated interactions that appeared to be so beneficial for many Global Read Aloud students. One of the elementary school teachers we observed engaged her students in a number of rich in-class activities related to the Global Read Aloud text, but admitted to “keeping it simple” in terms of her attempts at using technology to connect with other classes. Another teacher we observed had planned back up activities for her students in case there were problems with the videoconferencing.

A handful of participants also directly mentioned policies around technology as presenting challenges during their Global Read Aloud experiences. Respondents mentioned regulations or administrator decisions that prevented them from using particular digital tools during the Global Read Aloud, including Skype, Edmodo, and Kidblog. One teacher explained, “I wasn't allowed to blog outside of an approved platform,” and another said of her administrators, “They fear private information being used and children being placed at risk.”

Discussion

These findings describe educators’ perceptions of opportunities and challenges associated with a technology-rich approach to global education. The digital technologies used in the Global Read Aloud showed the potential to bridge divides between people by facilitating the sharing of different perspectives across time and space. Videoconferencing’s important role in the Global Read Aloud is consistent with prior studies that have suggested the contributions videoconferencing can make to community building and social presence in cross-cultural projects (Krutka & Carano, 2016; Wang, 2011). The Global Read Aloud demonstrates how technologies can support a low-cost, participant-driven initiative that opens up more classrooms to direct interaction with diverse peers. However, it was apparent that participants experienced both supports and barriers as they sought to integrate transactional Global Read Aloud experiences with the rest of their curricula. While the Global Read Aloud is designed to allow participants a great deal of flexibility, the contexts within which teachers work may include rigid expectations. In some cases, curricula and associated mandates may not be keeping up with the pedagogical possibilities offered by new technologies.

The participants’ survey responses and our classroom observations did not clarify if or how technology was employed in support of situated practice and critical literacy instruction. Only limited participant comments mentioned either challenges or opportunities related to these components of teaching for global readiness. Considering that nearly 60% of the sample were first time Global Read Aloud participants, perhaps many teachers were not yet experienced enough with the Global Read Aloud to pursue instruction that included situated practice and/or a focus on critical literacy.

Teachers who partnered their classes for the first time may not have felt immediately comfortable or knowledgeable enough to tackle potentially thorny issues related to critical literacy. Technology can make it relatively easy for two partnered classes to engage in an introductory Mystery Skype call, but their teachers might feel less equipped to lead Skype discussions among their students that touched upon more complicated content. For example, partnered classes could end up discussing a past conflict in which their respective countries were on opposing sides. Or, a contentious current event might lead to strong disagreements between students in the two classes. More professional development and support is likely necessary to help maximize the benefits of projects such as the Global Read Aloud. For instance, while one participant might need help with the technical features of a certain
videoconferencing tool, a second participant could require support to engage students in meaningful dialogue during a videoconference session, and a third might need assistance in reflecting upon cultural differences that emerged during a videoconference session.

Limitations

This research is limited by its use of a convenience sample and a self-report survey. Participants may not represent trends in the general educator population and were possibly among the more enthusiastic Global Read Aloud participants. The fact that participants were overwhelmingly from the United States and Canada could also limit the applicability of these findings to the experiences of teachers in contexts outside of North America.

Implications for Practice and Research

Despite its limitations, this study’s findings have implications for the field and suggest topics for further research. Given participating teachers’ generally positive experiences, educators interested in teaching for global readiness may want to consider participating in future Global Read Aloud. It is likely, however, that many educators will need professional and technical support as they seek to manage such interactions, particularly educators who are not as tech-savvy and globally minded as our participants. Participants will require multifaceted and individualized support to meet their varied needs. Curriculum facilitators could help teachers determine how to integrate experiences like the Global Read Aloud with curriculum mandates and expectations. Schools may also want to explore ways to approach teaching for global readiness via a “whole-school approach, involving everyone with a stake in educating children, from the children themselves to those with teaching and not teaching roles in the school, parents, school board members, and the wider community” (Young & Commins, 2002, p. 2).

Teacher educators also would be wise to consider how best to prepare the next generation of teachers to be ready to participate in and even create learning opportunities such as the Global Read Aloud. Novice teachers will need guidance to design curriculum and instruction that appropriately and effectively leverages technology in the pursuit of teaching for global readiness. In particular, teacher candidates should consider the affordances and constraints of the social media that play an important role in the Global Read Aloud (Carpenter & Morrison, 2018; Krutka & Carpenter, 2016). Educational technology classes that expose teacher candidates to new technologies should also help unpack the associated pedagogical opportunities and challenges. Many of the obstacles that arise in a project such as the Global Read Aloud could be related to challenges associated with human interactions – both among students and among teachers – rather than technological barriers. Novice teachers knowledge and skills around intercultural competence and global issues must be enhanced if they are to take full advantage of the opportunities for global interaction provided by new digital technologies.

If greater numbers of teachers and students are to experience the apparent benefits technology can offer to teaching for global readiness, further study of the Global Read Aloud and similar projects is needed. There are multiple potential avenues for such research. Future studies might examine whether and how participation influences teaching and learning after the Global Read Aloud. For example, does the exposure to the perspectives of students from other parts of the world affect the nature of classroom discussions in subsequent units of study? Research could explore cases in which classes that partner during the Global Read Aloud subsequently engage in other collaborative activities, or study partnerships between teachers that have spanned multiple Global Read Aloud iterations. How do these extended partnerships impact students’ learning? Researchers might investigate the experiences of Global Read Aloud participants at schools where many teachers take part. Such clusters of teachers may have quite different experiences than individuals who participate in the Global Read Aloud. More broadly speaking, researchers could explore the dynamics at play when educators interact across traditional school and district boundaries in the co-creation of teaching and learning resources (Carpenter, 2016; Krutka, Carpenter, & Trust, 2016).

Conclusion

Teaching and learning approaches that build students’ global readiness are necessary, and technology has shown the potential in supporting such instruction. To become the responsible citizens the world needs, today’s students must learn about and interact with diverse cultures and global issues. Young citizens who have interacted
directly with peers from across the globe would hopefully be less susceptible to rhetoric that plays upon instinctive fears of that which is perceived as foreign. Indeed, Lock (2015) asserted that “connecting, communicating, collaborating and creating knowledge with others beyond our local communities have never been more attainable than we are currently experiencing in today’s digital world” (p. 140). Technology extends the possibilities for learners to share their perspectives, and co-construct knowledge and understanding with peers from around the globe. This can in turn help make the “other” feel less foreign and distant. However, the new opportunities digital tools allow for teachers to welcome the world into their classrooms are also accompanied by certain pedagogical and curricular challenges. Teachers can certainly benefit from preparation and supports that help them identify those challenges and build their capacities to respond to them.

References


Teachers’ Perceptions and Intended Use of Social Media Communication Technologies as a Pedagogical Tool in Teacher Lectures

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Abstract: A number of states and organizations have begun to add cross-content technology elements to their educational standards, providing teachers opportunities to use social media communication (SMC) technology in teaching and learning. Specifically, in Pennsylvania, the PA Core Standards, which are adapted from the national Common Core Standards, require students to use technology, including the Internet, to publish and edit their writing in response to feedback as well as gather, analyze, and critique digital text sources. To support the integration of technology into teaching and learning Pennsylvania has also provided money through the Classroom for the Future grant. The purpose of this study was to examine the attitudes, subjective norms, perceived behavioral control, and intentions of public secondary teachers’ use of SMC technologies as part of their teacher lectures. The results of the study suggest that teachers’ intentions to use SMC in their lectures are low; however, their perceptions of the use of SMC as a pedagogical tool are positive. Teachers’ positive perceptions suggest they view the use of SMC technologies in teaching and learning as appropriate for the classroom.

Introduction

Al-Bahrani and Patel (2015) described social media as “virtual communities or networks that allow participants to interact with each other, develop communities, and share information and ideas” (p. 57). The ability to connect with others and collaborate to foster 21st century skills has helped push many technology initiatives in education in the United States (Capo & Orellana, 2011; Lowther, Inan, Ross, & Strahl, 2012; Windschitl & Sahl, 2002). Additionally, the Constitution of the United States does not give the federal government direct power over all the affairs of individual states’ education systems. Therefore, each state is required to determine how it will develop the 21st century skills needed in a global society in connection with each respective state’s expectations.

Pennsylvania has made economic and teacher development investments to promote technological progress in the public education system. In 2007, under the administration of Governor Edward Rendell, the Classrooms for the Future Grant was created (Pennsylvania Department of Education, 2007). The goal of the grant was to develop 21st century teaching and learning through the provision of money to school districts for the development of technology infrastructures within school buildings. To ensure the funds were not used to only purchase computers and other technology, portions of the grant were available to fund teacher preparation.

In 2014, Pennsylvania adopted the cross-curricular PA Core Standards for writing and reading in English language arts, social studies, and technical subjects (Pennsylvania Department of Education, 2014a, 2014b, 2014c, 2014d). These standards require students to publish, edit, and respond to arguments using the Internet, as well as to gather, analyze, and critique digital text sources. Krutka and Carpenter (2016) propose that standards such as the cross-curricular PA Core Standards present an opportunity to integrate social media communication (SMC) technologies into classrooms to develop 21st century teaching and learning. The use of SMC technologies in education spans a broad range of tools, from Twitter and Facebook to Edmodo and Google Classroom. Before issuing an administrative directive, it is important to understand teachers’ perceptions of social media communication (SMC) technologies as a part of their pedagogical practices. Without an understanding of teachers’ intentions to use SMC as part of their teaching practices, technology initiatives, such as the required cross-curricular PA Core Standards, may struggle to succeed, since teachers are the nexus of policy and practice in the American educational system (Cakır, Yukselturk, & Top, 2015).

Literature Review

Teachers who use SMC in their private lives are more likely to view using social media in educational settings positively and many educators hold positive views of using SMC technologies for teaching and learning (Asterhan & Rosenberg, 2015; Ulrich & Karyonen, 2011). Because educators recognize the benefits that SMC bring to their personal life, they feel similar benefits can be achieved in the classroom.
The influence of teaching experience on teachers’ attitudes is unclear. When comparing the responses of 368 teachers across primary, secondary, and post-secondary assignments, Yuen, Yaoyuneyong, and Yuen (2011) found that the amount of teaching experience had no effect on teachers’ attitudes towards SMC as a teaching tool. However, Shu-Fen, Chu-Liang, and De-Chih (2015) found that of 478 primary school teachers those with five or fewer years of experiences were more positive toward SMC use than their peers with six or more years of experience. Generalizing the results of Yuen et al. (2011) and Shu-Fen et al. (2015) should be done with caution because of their poor sampling methods. Yuen at al. (2011) sampled from willing respondents at a technology conference where many attendees may hold biased positive attitudes, and Shu-Fen et al. (2015) used convenience sampling, potentially limiting how well the sample represents teachers in general.

Subjective norms are the social pressures one feels to act a certain way (Ajzen, 1991). Cakir, Yukselturk, and Top (2015) found that teachers feel pressure to use technology in their teaching practices. Many states and professional organizations are beginning to write standards that incorporate the use of social technology in teaching and learning. Within Pennsylvania, the pressure to use SMC technologies has increased with the adoption of certain PA Core Standards for writing and reading in English language arts, social studies, and technical subjects (Pennsylvania Department of Education, 2014a, 2014b, 2014c, 2014d).

The PA Core Standards are very specific about how teachers are to use technology in the classroom. In Pennsylvania, the use of technology is not reserved for the tested subjects of math, English, and biology. History and social studies, as well as science and technical subjects, have forward language requiring the use of technology. The standards require teachers to take “advantage of technology’s capacity to link to other information and to display information flexibly and dynamically” (Pennsylvania Department of Education, 2014a, p. 25). Teachers are in a difficult position in the ranks of technology adoption in a classroom. And, Students are to interact with print and digital text to “evaluate an author’s premises, claims, and evidence by corroborating or challenging them with other information” (Pennsylvania Department of Education, 2014c, p. 5). Subsequently, teachers are required to use technology by the Department of Education but at the same time teachers are hindered by the internal and external factors that prevent their use. Such a position may lead teachers to feel they have little control over the use of technology in their own teaching practice.

An individual’s perceived behavioral control can be summarized as their perception of how easy or difficult something may be to do (Ajzen, 1991). Regardless of one’s attitude, if a teacher feels a lack of control over what technology to use or how to use it, a teacher will not be able to successfully incorporate the technology into teaching practice. Often, teachers feel hindered by internal and external factors. A notable internal factor that can hinder teachers’ adoption of technology into their classes is a lack of confidence with using technology (Govender, 2012). Teachers are concerned they will lose instructional time to mitigate technology problems. Teachers’ concerns can be escalated if they are not comfortable assuming a technical role to assist students (Maor, 2003).

External factors that hinder teachers’ use of technology vary from school district policies to larger social and economic issues. Carpenter and Krutka (2014) found that only 39 percent of the teachers they surveyed worked in a district that allowed teachers and students to access social media sites. The digital divide is a substantial social and economic issue that some teachers must anticipate when developing their lessons (Albert, 2015). In more affluent school districts access to digital devices my not be a concern, but technical problems such as the school’s infrastructure or choice in computing platform can limit the ability to connect to the Internet (Abulibdeh, 2013; Highfield & Papic, 2015; Hordemann & Chao, 2012).

Finally, a lack of time can hinder the adoption of SMC technologies. Mourlam (2013) found that when a teacher tried to use social media to provide homework reminders to students, she was unable to maintain her school district required webpage in addition to the homework reminders. It was found that the majority of students (67 percent) wanted more interaction from the teacher on the social media site, suggesting it was an engaging tool for students. Even though the students may be more engaged with SMC technologies, Frank, Penel, and Krause (2015) found that when teachers are faced with putting time into a district-mandated tool versus additional tools, if the teacher lacks time, the district-mandated tool will receive the priority from the teacher.

### Theoretical Orientation of the Study

The theory of planned behavior was developed by Ajzen (1991) as an extension of the theory of reasoned action (Fishbein and Ajzen, 2015). The goal of the theory of planned behavior is to predict and explain human behavior. Within the theory of planned behavior, Ajzen (1991) suggests, “behavior is a function of salient information, or beliefs, relevant to the behavior” (p.189). In short, if an individual’s beliefs about a particular behavior can be
understood, it is possible to understand why an individual would perform the behavior and how likely the behavior is to be performed in the future.

The theory of planned behavior (Ajzen, 1991) identifies four constructs to predict an individual’s behavior: attitude toward the behavior, subjective norm, perceived behavioral control, and behavioral intention. An individual’s attitude, subjective norm and perceived behavioral control are thought to directly influence their intention to perform the behavior. The theory requires three criteria to accurately predict human behavior: (1) the measure of perceived behavioral control and behavioral intention must be consistent with the predicted behavior, (2) an individual’s behavioral intention and perceived behavioral control should not change between measurement and behavioral observation, and (3) an individual’s perception of his or her control over the behavior must be accurate. Perceived behavioral control replaces actual control, which represents an individual’s opportunity and resources to perform the behavior. The ability to predict action based on Ajzen’s theory of planned behavior increases when an individual’s perception of control over a specific behavior is equivalent to one’s actual control.

Statement of the Problem

In addition to funding initiatives, states and professional education organizations have added standards that require the use of technologies to be a part of teaching and learning. It is important to understand teachers’ intentions and perceptions to integrate digital technology into teaching and learning to ensure technology initiatives succeed. The purpose of this study was to examine the attitudes, subjective norms, perceived behavioral control, and intentions of public secondary teachers’ use of SMC technologies as part of their teacher lectures. The following research question guided this study:

What is the relationship between teachers’ attitudes, subjective norms, perceived behavioral control of social media communication technologies as a teaching tool and their intended use of social media communication technologies in their teaching lectures?

Methods

A multi-stage cluster sampling procedure was used in the spring of 2017 within the state of Pennsylvania. School districts are classified by the Pennsylvania Department of Education with urban-centric local codes. The four main categories of the urban-centric locale codes are city, suburb, town, and rural. Within each locale code, school districts were randomly sampled, and within each school district secondary school buildings were randomly selected if more than one secondary school building was used within a single school district.

Data

A sample of 251 secondary school teachers within Pennsylvania responded to the survey. Respondents were selected based on the inclusion of their school building in the sampling procedure and site permission granted by the school district administration. The response rate was 21.8%. Cases with missing values on the variables of interest were subject to list-wise deletion, resulting in an analytic sample of 140 teachers.

Each of the four urban centric locale codes was represented in the sample. The most represented locale code was rural (48.20%), followed by suburban (19.42%), town (16.55%), and urban (15.83%). The years of teacher service within the sample had an average of 14.66 years in public education, with 12.15 years at their current schools. The majority of teachers (56.43%) taught PA mandated tested subjects (i.e., math, science, or English language arts). Participants identified as either female (58.57%) or male (41.42%), and reported ethnicities as White (97.86%), African American (0.71%), Hispanic (0.71%), and White/American Indian (0.71%). The highest levels of education reported by the participants were master’s degree (37.86%), post-master’s graduate credits (30.71%), graduate credits/level II teaching certificate (24.29%), four-year college degree (5.71%), and doctoral degree (1.43%).

Measures

Respondents completed the Social Media Communications in Public Education Questionnaire (Tozer, 2017). The survey was based on the constructs of the theory of planned behavior (Ajzen, 1991). Consisting of six sections, the survey collected information about participants’ teaching experience, past use, as well as their current, and intended use of SMC in teacher lectures, in-class assignments, and out-of-class assignments. The remaining sections collected
teachers’ attitudes, subjective norms, and perceived behavioral control of SMC in educational settings as well as demographic information about the participants.

Alpha reliability was used to determine the strength of the scale items used for this study. Teachers’ attitudes toward the use of SMC as a teaching tool received an alpha reliability score of .90. The six items of the attitudes construct were positively related to the scale. Ranging from 1–5, higher scores indicated a more positive attitude toward the use of SMC technologies as a teaching tool. The mean attitude score was 3.58 (standard deviation [SD] = .86).

The participating teachers’ subjective norms toward the use of SMC as a teaching tool received an alpha reliability score of .88. The four items of the subjective norm construct were positively related to the scale. Ranging from 1–5, higher scores indicated that participants felt that important others encouraged their use of SMC technologies as a teaching tool. The mean subjective norm score was 3.75 (SD = .86).

Teachers’ perceived behavioral control toward the use of SMC as a teaching tool received an alpha reliability score of .75. The four items of the perceived behavioral control construct were positively related to the scale. Ranging from 1–5, higher scores indicated that participants felt they had more control over their use of SMC technologies as a teaching tool. The mean perceived behavioral control score was 3.40 (SD = .91).

Teachers’ intended use of SMC in teacher lectures received an alpha reliability score of .92. The 27 items of the intended use construct were positively related to the scale. Ranging from 1–3.63, higher scores indicated that participants were more likely to use SMC technologies as a teaching tool in the upcoming school year. The mean intended use score was 1.51 (SD = .58). Attitude, subjective norms, perceived behavioral control, and intended use had a ratio level of measurement.

Results

Teachers’ attitudes, subjective norms, and perceived behavioral control toward the use of SMC technologies as a pedagogical tool significantly predicted teachers’ intention to use SMC technologies in their teaching lectures. \[\beta_{\text{attitudes}} = .284, t(136) = 3.03, p < .003; \beta_{\text{subjectivenorms}} = 0.002, t(136) = 0.02, p = .987; \beta_{\text{pbc}} = .014, t(136) = 0.14, p = .892.\] Teachers’ attitudes, subjective norms, and perceived behavioral control also explained a significant proportion of variance in teachers’ intended use scores \([R^2 = .08, F(3, 136) = 4.14, p = .008]\].

Controlling for attitudes and subjective norms, there was no difference in teachers’ perceived behavioral control scores and their intended use of SMC technologies in their teaching lectures. Controlling attitudes and perceived behavioral control, there was no difference in teachers’ subjective norms scores and their intended use of SMC technologies in their teaching lectures. Controlling subjective norms and perceived behavioral control, for every additional point in attitudes score, there was a 0.044 points increase in teachers’ intended use score. Controlling subjective norms and perceived behavioral control, for every standard deviation increase in attitudes score there was a 0.328 standard deviation increase in teachers’ intended use of SMC technologies in their teaching lectures.

Discussion

Teachers’ perceptions on the use of SMC technologies as pedagogical tools were moderately positive (attitudes M = 3.58; subjective norms M = 3.75; perceived behavioral control M = 3.40). Although perceptions were moderately positive, the results indicated that the teachers’ intentions to use SMC technologies in their teaching lectures were low. The intention scale score had an available range of 1–5, and teachers reported that they were unlikely to use SMC technologies in their teaching lectures (M = 1.51). It is important to note that even though the regression model could explain 8.36% of the variance in teachers’ intended use, when controlling each of the independent variables, the only significant relationship was between attitudes and intended use. The significance of each relationship between the predictor variables and the dependent variable, when controlling the predictor variables, is not surprising. When the bivariate relationship was tested between the predictor variables and teachers’ intentions independently, only attitudes were significantly related. The relationship between attitudes and intention when investigated independently was moderately weak.

The findings of this current study are similar to those other studies that have linked teachers’ perceptions to their intended use of technology as a pedagogical tool. In their study, de Oca and Nistor (2014) found that in performance expectancy “the degree to which an individual believes that using the system will help him or her attain gains in job performance” could account for 49.6% of the variance in behavioral intention (Venkatesh, Morris, Davis, & Davis, 2003, p. 447). However, in the current study, when intentions were regressed onto attitudes independently, attitudes were only able to explain 8.35% of the variance of teachers’ intentions to use SMC technologies in their
teaching lectures. Shu-Fen, Chu-Liang, and De-Chich (2015) found that optimism, “a positive view of technology and a belief that it offers people increased control, flexibility, and efficiency in their lives” was the most influential predictor of intention ($\beta = 0.44$) (Parasuraman, 2000, p. 311). Although the current study also found that attitude, “the degree to which a person has a favorable or unfavorable evaluation or appraisal of the behavior in question” (Ajzen, 1991, p. 188) was the most influential predictor of teachers’ intentions, it was not as strongly related to intentions as the findings of Shu-Fen et al. (2015).

The findings from the current study also do not support the findings of earlier studies. Lu and Yang (2014) found that, although moderated by social technology fit, social characteristics were significantly related to intention to use social networking sites. In this study, social characteristics were embodied in the subjective norms construct, which “refers to the perceived social pressure to perform or to not perform the behavior” (Ajzen, 1991, p. 188). Although Lu and Yang (2014) found a significant relationship between social characteristics and intention to use social networking sites, in the current study, there was no relationship between subjective norms and intention to use SMC as a pedagogical tool in teachers’ lectures in the full regression model or independently.

There are important aspects of the study to note in order to understand its generalizability to the larger population. According to the Pennsylvania Department of Education (2010), the distribution of public school urban-centric locale codes within the state are urban (3.42%), suburban (41.45%), town (20.12%), and rural (45.16%). The actual sample used to conduct the current study had the following distribution urban (15.83%), suburban (19.42%), town (16.55%), and rural (48.20%). In comparison to the population, urban school districts are overrepresented and suburban school districts are underrepresented by more than 10 percentage points. Another important aspect of the study to note is the analytic sample size. Although the analytic sample size is less than desirable; based on Tabachnick and Fidell (2007), which provided a formula to calculate minimum sample size for multiple regression analysis, the analytic sample size was sufficient for the statistical methods used.

The results of this study suggest that the Pennsylvania Classrooms for the Future grant, while ambitious, did not achieve its full goal. The grant money spent to build a technological infrastructure did not encourage teachers’ intention to use SMC technologies as a pedagogical tool as a part of their lectures. Teachers’ intentions to use are low; however, their perceptions of the use of SMC as a pedagogical tool are positive, which suggests that teachers view the use of SMC technologies in teaching and learning as appropriate for the classroom. The Classrooms for the Future grant may not have fully achieved its goal, but it was an important first step to help Pennsylvania experience 21st century teaching and learning as shown by teachers’ positive perceptions. It is important for policymakers to continue educational funding opportunities that support 21st century teaching and learning with digital technology.

References


We Are Just Expected to Know How:
Unpacking Pre-Service Teachers’ Beliefs about Technology Integration

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Abstract: Today's pre-service teachers are generally considered to be technologically savvy and well-suited for teaching with technology. However, research suggests that that novice teachers are no better at technology integration than their more experienced colleagues. How do pre-service teachers perceive their abilities to teach with technology? And how do they perceive these abilities developing? This paper reports a case study conducted at a private comprehensive college in the upper Midwest region of the United States. Utilizing a convergent parallel mixed-methods design incorporating both a survey as well as semi-structured interviews, this study examines a particular teacher preparation program, and how the pre-service teachers in that program perceive their self-efficacy for technology integration. Notably, this teacher preparation program does not include a stand-alone technology course, which makes it fairly unique. The results of this study indicate that pre-service teachers generally feel confident in their abilities to teach with technology, but also feel a sense of pressure to be effective in technology integration. The results also suggest that there are specific actions teacher educators can take to support pre-service teachers in developing the knowledge and skills required for teaching with technology.

Introduction

Teachers have always had technologies of the day at their disposal. In earlier centuries, handwritten manuscripts were the technology of the day. Later, upon the development of the printing press, printed books became a common and accepted technology for use in education. Through the 19th and 20th centuries, a wide array of new technologies swept through schools, from chalkboards, to overhead projectors, to dry-erase whiteboards. Many of these technologies have continued to be present in schools, but beginning in the 1980s, computer technologies began to appear in schools, and over the next three decades, the digital revolution happening throughout society was mirrored in schools.

While textbooks and chalkboards are certainly technologies, these are perhaps not what most educators first picture when they hear the term “technology.” Therefore, throughout this paper, the term “technology” will be used to describe contemporary digital technologies for information processing, communication, and entertainment, such as computers, tablets, smartphones, and the like. There is an increasing pressure to incorporate such tools into classrooms today (Brown & Green, 2013; Ruggiero & Mong, 2015).

As technological innovations continue to spread through education, teachers at all levels have new and different challenges to consider for selecting which technologies they will utilize in their teaching practices. At this point, few educators are likely to consider how they will integrate tools such as dry-erase whiteboards into their teaching practice. Many educators, however, struggle with integrating digital technologies. Even today’s novice teachers entering the field may be ill-equipped to imagine how to utilize the educational technologies they will have at their disposal.

Theoretical Framework

Novice teachers, due to their relative youth are commonly perceived to be “digital natives” (Prensky, 2001), meaning that they have a natural and intuitive sense of how to use technology, because they have grown up in a world awash with digital tools. They are often considered by older colleagues to be more technologically-savvy, and well-equipped for the challenges of technology integration (Oh & Reeves, 2014). There are questions, however, about the veracity of this assumption of tech savviness (Helsper & Enyon, 2010; Margaryan, Littlejohn, & Vojić, 2011). Pre-service teachers themselves may not feel adequately prepared for today’s technology-rich classrooms.
Today’s pre-service teachers are preparing to enter a technology-infused learning environment that may look very different from their own elementary and secondary school experiences. It is now the norm for K-12 classrooms to be packed with technologies such as computers, tablets, high-speed Internet, digital projectors, and more (Brown & Green, 2013; Gray, Thomas, & Lewis, 2010; Picciano, Seaman, & Allen, 2010). Ruggiero & Mong (2015) have suggested that such technologies are now considered “basic infrastructure” for learning. Correspondingly, there has been a cultural shift in thinking about technology in education; the general view today is that classroom technology integration should lead to deeper learning on the part of students (Barreto & Orey, 2014; Laferrière, Hamel, & Searson, 2013). As a result, there is now an expectation that all teachers should be effective at integrating technology into their teaching practices—including novice teachers just entering the profession. Technology integration is now considered a basic entry requirement for the teaching profession (Ruggiero & Mong, 2015; Teo, 2011).

Current college students are often viewed as technologically savvy (Brooks, 2016; Rashid & Asghar, 2016), and many are avid users of digital technologies in their day-to-day lives for communication and entertainment as well as for their academic work (Bennett & Maton, 2010; Brooks, 2016; Fluck & Dowden, 2013). More experienced colleagues and administrators may place undue pressures on novice teachers due to these misperceptions of their abilities to “natively” use technology. However, questions have been raised by some researchers about the reality of their supposed digital native status (Helsper & Enyon, 2010; Margaryan et al., 2011). College students’ proclivities for using digital technologies in their day-to-day lives likely do not actually translate well into teaching with technology (Kovalik, Kuo, & Karpinski, 2013; Lambert & Gong, 2010). Research suggests that novice teachers, while assumed to have greater technological knowledge than their older colleagues, are actually no better at teaching with technology (Ertmer et al., 2012; Pegler, Kollewyn, & Crichton, 2010).

This fact raises important questions: do today’s pre-service teachers feel prepared for the challenges of technology integration? And, if so, to what do they attribute this preparation? Two research questions guided the inquiry this study:

RQ1: What are pre-service teachers’ perceptions of their ability to integrate technology into the classroom?
RQ2: To what do pre-service teachers attribute their ability to integrate technology into the classroom?

Research Context

This study is an examination of a teacher preparation program at a private, comprehensive college located in the upper Midwestern United States. While most teacher preparation programs include a stand-alone course in educational technology or technology integration (Kay, 2006; Ottenbreit-Leftwich, Glazewski, & Newby, 2010), this program is fairly unique in that it does not include such a technology integration course. Instead, the knowledge and skills required for effective technology integration are embedded into various courses throughout the program. In annual assessment reports, however, faculty in the program noticed a trend that some graduates of the program indicated that they did not feel adequately prepared for the challenges of teaching with technology. Thus, an investigation into the beliefs and experiences of the pre-service teachers currently studying in the program was commenced.

Using a convergent parallel mixed-methods design, a picture of the beliefs and experiences pre-service teachers studying in this program emerged. The TPACK framework (Mishra & Koehler, 2006) and self-efficacy theory (Bandura, 1986, 1997) were utilized as a theoretical framework to understand pre-service teachers’ beliefs about technology integration, and the experiences they perceived as helpful for developing the knowledge and skills for integrating technology into their teaching practices.

Methods

This study is a mixed-methods case study of a teacher preparation program. While some authors consider case study to be only a qualitative methodology (e.g., Stake, 1995), Yin (2014) suggested that quantitative data can be very valuable for elucidating a more comprehensive understanding of the case under consideration. Utilizing a convergent parallel design (Creswell, 2012; Guest, 2013), this study incorporated data from both a survey as well as semi-structured interviews to develop an understanding of pre-service teachers’ perceptions of their preparedness to teach with technology.
The survey instrument was adapted from two existing instruments that have previously been demonstrated to be valid and reliable. The first is an instrument developed by Schmidt et al. (2009) that is aligned to the TPACK domains. This instrument is intended to measure pre-service teachers’ perceptions of their knowledge and skill for teaching with technology. The second instrument was developed by Wang, Ertmer, and Newby (2004), and was designed to measure pre-service teachers’ self-efficacy for teaching with computer technology. For the present study, items from these existing instruments were adapted for use by updating for consistent language. Additionally, only subscales for certain TPACK domains were included (i.e., TK, TPK, and TPACK), as these have been found to have the greatest correlation to technology self-efficacy in pre-service teachers (Abbitt, 2011). The adapted items from these two instruments (i.e., Schmidt et al., 2009; Wang et al., 2004) were combined into one survey instrument comprised of 40 items: 7 demographic items, 17 items related to TPACK knowledge domains, and 16 items related to self-efficacy for technology integration. The adapted survey was piloted with a group of pre-service teachers prior to use for this study, and was found to be valid and reliable. The survey instrument is included in Appendix A. Subscales of this instrument were evaluated for reliability, and the survey was found to be reliable, with all four of the included subscales in the acceptable range (α > .70) (Nunnally, 1978, as quoted in Hatcher, 2011, p. 87). These reliability statistics are presented in table 1.

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Cronbach’s Alpha</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological Knowledge (TK)</td>
<td>.902</td>
<td>7</td>
</tr>
<tr>
<td>Technological Pedagogical Knowledge (TPK)</td>
<td>.774</td>
<td>5</td>
</tr>
<tr>
<td>Technological Pedagogical Content Knowledge (TPACK)</td>
<td>.833</td>
<td>5</td>
</tr>
<tr>
<td>Self-Efficacy for Technology Integration (SE-TI)</td>
<td>.918</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 1. Survey Subscales, Including Reliability Statistics

The semi-structured interviews were conducted according to a protocol described in Richardson et al. (2008). Seven interview questions were developed to understand: 1) formal learning opportunities in the Teacher Preparation Program (TPP) for developing knowledge, skills, and attitudes needed for effective technology integration, 2) informal technology learning opportunities, 3) development of self-efficacy for teaching with technology, and 4) beliefs about the best way for pre-service teachers to learn about technology integration. Because the interviews were conducted in a conversational, semi-structured format, the exact phrasing of the questions varied slightly from one interview to the next. However, all interview participants were asked the same seven questions in the course of the conversation, with their responses being recorded for later analysis. The interview questions are included in Appendix B.

Participants in the study were purposefully selected. As Yin (2013) has noted, case studies are not randomly selected, and Creswell (2013) suggested that participants in a case study should be selected to provide maximum variation. For the survey data, three intact class groupings of students at three different points in the teacher preparation program were invited to participate: a group of first year students taking an educational foundations course, a group of mostly sophomores taking a general teaching methods course, and a group of seniors taking a pre-service teaching seminar. A total of 142 pre-service teachers were invited to participate, and 104 of these completed surveys for a completion rate of 73.2%.

Of the 104 survey completers, a maximum variation sample of pre-service teachers was invited to participate in the semi-structured interviews. A list of 20 potential interviewees was initially developed to ensure saturation. This list included both male and female students, a variety of majors in the TPP, and pre-service teachers at each point in the program. Eleven interviews were conducted to ensure that saturation was met. Table 2 includes a listing of the interviewees with pseudonyms to provide anonymity.

These eleven pre-service teachers were invited to participate in interviews that were each approximately 30 minutes in length. Each consented to have the interview recorded for later transcription and analysis. These interviewees were selected because each was able to offer a unique perspective. It is important to remember that each interviewee related his or her personal beliefs and experiences, and they should not be construed as speaking for all pre-service teachers in the TPP. However, these eleven interviews do provide insight into the thinking and experiences of pre-service teachers with particular characteristics. Taken together, they help to paint a picture of the journey toward becoming professional educators within this teacher preparation program.
Table 2. Semi-Structured Interview Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Year in TPP</th>
<th>Major/Endorsement</th>
</tr>
</thead>
<tbody>
<tr>
<td>An</td>
<td>Female</td>
<td>Senior</td>
<td>Early Childhood</td>
</tr>
<tr>
<td>Bruce</td>
<td>Male</td>
<td>Senior</td>
<td>Secondary Education</td>
</tr>
<tr>
<td>Cleo</td>
<td>Female</td>
<td>Sophomore</td>
<td>Elementary Education</td>
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<td>Drew</td>
<td>Male</td>
<td>Junior</td>
<td>Secondary Education</td>
</tr>
<tr>
<td>Elsa</td>
<td>Female</td>
<td>Senior</td>
<td>K-12 Subject Area</td>
</tr>
<tr>
<td>Fiona</td>
<td>Female</td>
<td>Junior</td>
<td>Middle School</td>
</tr>
<tr>
<td>Gary</td>
<td>Male</td>
<td>Senior</td>
<td>Elementary Education</td>
</tr>
<tr>
<td>Henry</td>
<td>Male</td>
<td>Junior</td>
<td>Middle School</td>
</tr>
<tr>
<td>Ivory</td>
<td>Female</td>
<td>Freshman</td>
<td>Early Childhood</td>
</tr>
<tr>
<td>Julie</td>
<td>Female</td>
<td>Senior</td>
<td>Elementary Education</td>
</tr>
<tr>
<td>Kevin</td>
<td>Male</td>
<td>Freshman</td>
<td>Elementary Education</td>
</tr>
</tbody>
</table>

Results and Limitations

This case study was developed to understand pre-service teachers’ self-efficacy for technology integration, and how it develops through a particular teacher preparation program. After a lengthy process of data analysis and triangulation between the quantitative and qualitative data, six themes emerged:

1) Pre-service teachers generally feel confident in their abilities to teach with technology, regardless of their gender, year in college, or major/endorsement area.
2) Pre-service teachers feel a sense of pressure or expectation to be able to integrate technology into their teaching practices.
3) Modeling effective technology integration is an important part of pre-service teachers developing the self-efficacy to integrate technology into their own teaching practices.
4) Both formal and informal learning opportunities positively impact pre-service teachers’ confidence for working with technology.
5) Technological knowledge is an important component for self-efficacy in technology integration, but pedagogical knowledge and content knowledge are also necessary.
6) Pre-service teachers believe that a practical course in educational technology would help to prepare them to integrate technology in the classroom.

In the quantitative data analysis, pre-service teachers generally expressed confidence in their abilities to teach with technology. There were certainly individual differences between participants, which is to be expected. Descriptive statistics of the overall survey results (not disaggregated by demographic categories) are presented in Table 3. Notice that the mean scores are all above 3.0 on a 5-point scale, indicating a general statement of confidence in their knowledge and self-efficacy for technology integration.

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological Knowledge</td>
<td>1.57</td>
<td>4.86</td>
<td>3.296</td>
<td>.7350</td>
</tr>
<tr>
<td>Technological Pedagogical Knowledge</td>
<td>2.0</td>
<td>5.0</td>
<td>3.692</td>
<td>.5738</td>
</tr>
<tr>
<td>Technological Pedagogical Content Knowledge</td>
<td>1.4</td>
<td>5.0</td>
<td>3.588</td>
<td>.6162</td>
</tr>
<tr>
<td>Self-Efficacy for Technology Integration</td>
<td>2.31</td>
<td>4.94</td>
<td>3.621</td>
<td>.5054</td>
</tr>
</tbody>
</table>

Table 3. Descriptive Statistics for Survey Subscales

In the qualitative analysis, participants comments illustrate the findings outlined above. For example, Elsa brought up her concern that pre-service teachers are expected to be adept at technology integration, but she believes that they are not always as competent as they are expected to be. She commented, “We have grown up with that setting of we just had to figure it out because it's supposed to come naturally to us” (Elsa). In the course of this discussion, Elsa was asked, “Do you feel like there is a cultural expectation for people of your generation, like ‘Well, you guys are supposed to be good with technology?’” She replied, “A little bit. …[People expect] that someone my age should know how to do it. …Most of the time it's okay, but it's a little nerve-racking to realize that in like 20 years that won't...
be the case anymore. It’s like I better enjoy it while I can” (Elsa). However, despite these concerns, Elsa also described herself as “moderately comfortable” with teaching with technology.

Other pre-service teachers felt a sense of pressure for exemplary technology integration, but took it as a challenge. Julie, for instance, noted that she did not have much technology integration in her elementary and high school experience, describing it as “chalkboards all the way through.” She was participating in an internship in an elementary classroom, and commented that her mentor teacher and other colleagues expected her to be technologically savvy, and ready to help them learn more. She shared,

Coming in, like you're the new [person in the school]... [More experienced teachers say things like] ‘Oooo, what did you learn at college with technology? Like, help me with my Smart Board. I don't know how to do this.’ That's part of the pressure I feel to get learning it, which is probably a good thing. If I went in feeling like I don't have to, I could, but I think it’s better for me to have personal growth. If I feel like they're going to expect me to do that, I could just as well be up on it and then I can help. (Julie)

Not all participants were so optimistic, however. Henry, for example, shared his own desire to keep learning, so he would not fall into what he perceived as a shortcoming on the part of the older generation of teachers: stagnation. He wondered aloud about teaching in a one-to-one technology program, feeling pressure to be well-prepared to teach in such a setting:

We talk about [teaching in a one-to-one environment in class], but we never really see what schools are using it for. We talk, ‘Oh yeah, that school is one-to-one.’ Great. What does that actually look like in a literacy classroom? What does that look like in a math classroom? How does that look in science? Yeah, we talk about it. It's great. [Laughs sarcastically.] (Henry)

Henry’s concern is one that all teacher educators should hear and carefully consider. Are we really preparing students for the realities of technology integration? Or are we just talking about technology integration?

Limitations and Implications for Practice

As a case study, these results are specific to the particular institution where this research was conducted. However, teacher educators in other colleges and universities may find these insights useful as they consider the preparation of their own students.

There are several implications for practice that result from this study that are worthy of consideration for preparing pre-service teachers for the challenges of technology integration. First, it seems wise for teacher educators to promote the development of self-efficacy for technology integration. Pre-service teachers simply cannot learn everything there is to know about every contemporary educational technology. Compounding the problem, new technologies are constantly being developed or adapted for use in schools (Davies & West, 2014). In the long run, these pre-service teachers will be better served by learning how to learn about new technologies (Ertmer & Ottenbreit-Leftwich, 2010; Gilakjani, 2013).

Second, teacher educators would be wise to arrange enactive learning opportunities throughout the TPP according to the TPACK domains to support pre-service teachers’ development of the knowledge and skills needed for technology integration. While researchers continue to debate how the TPACK framework can best be utilized within a teacher preparation program, TPACK is broadly supported as an effective way to conceptualize pre-service teachers’ learning about technology integration (Baran et al., 2011; Colvin & Tomayko, 2015; Graham et al., 2012; Harris et al., 2010; Kivunja, 2013; Koehler et al., 2014; Koh & Divaharan, 2011; Tournaki & Lyublinskaya, 2014).

Third, teacher educators and mentor teachers in practicums must model technology integration for pre-service teachers. Modeling is a key aspect of developing self-efficacy (Bandura, 1997), and has been shown to have a strong, positive impact on pre-service teachers’ technology self-efficacy (Wang et al., 2004).

Conclusion

The findings of this study suggest that pre-service teachers generally perceive themselves to be able to use technology, and are developing the abilities needed to teach with technology in ways that will positively impact their students’ learning. However, pre-service teachers also recognize that they must continue to learn more about teaching with technology. The title of this article comes directly from a quote offered by an interview participant in this study: “We’re just expected to know how to teach with technology” (Ivory). It is incumbent on us, as teacher educators, to do everything we can to support pre-service teachers in learning to teach with technology. Entering the teaching
profession is daunting enough, but the challenge of effective technology integration does not need to be an unbearable trial for novice teachers.

References


Hatcher, L. (2013). *Advanced statistic in research: Reading, understanding, and writing up analysis results*. Saginaw, MI: Shadow Finch Media.


Appendix A – Technology Beliefs and Self-Efficacy Survey

Part 1: Demographic Information
1) Gender
• Female  Male
2) Age
• 18-22  23-26  27-32  Over 32
3) Year in College
• Freshman  Sophomore  Junior  Senior  Graduate
4) Major/Endorsement Area:
• Early Childhood
• Elementary Education (General Classroom)
• Elementary Subject Area (Art, Foreign Language, Music, Physical Education, or Special Education)
• Middle School
• Secondary Education
• K-12 Subject Area (Art, Foreign Language, Music, Physical Education, or Special Education)
5) Comfort with computers:
• Not at all comfortable  A little comfortable  Fairly comfortable  Very Comfortable
6) Comfort with using Internet tools:
• Not at all comfortable  A little comfortable  Fairly comfortable  Very Comfortable
7) Comfort with technology in general:
• Not at all comfortable  A little comfortable  Fairly comfortable  Very Comfortable

Part 2: [Items related to Technological Pedagogical Content Knowledge (TK, TPK, and TPCK domains), adapted from Schmidt et al. (2009).]

Technology is a broad concept that can mean a lot of different things. For the purpose of this survey, technology is referring to digital technology/technologies— that is, the digital tools we use such as computers, laptops, iPods, handhelds, interactive whiteboards, software programs, etc. Please answer all of the questions, and if you are uncertain of or neutral about your response, you may always select “Neither agree nor disagree.”

[Strongly Disagree, Disagree, Neither Agree/Disagree, Agree, Strongly Agree]
1. I know how to solve my own technical problems. (TK)
2. I can learn technology easily. (TK)
3. I keep up with important new technologies. (TK)
4. I frequently play around with the technology. (TK)
5. I know about a lot of different technologies. (TK)
6. I have the technical skills I need to use technology. (TK)
7. I have had sufficient opportunities to work with different technologies. (TK)
8. I can choose technologies that enhance the teaching approaches for a lesson. (TPK)
9. I can choose technologies that enhance students’ learning for a lesson. (TPK)
10. My teacher preparation program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom. (TPK)
11. I am thinking critically about how to use technology in my classroom. (TPK)
12. I can adapt the use of the technologies that I am learning about to different teaching activities. (TPK)
13. I can teach lessons that appropriately combine content*, technology, and teaching approaches. (TPCK)
14. I can select technologies that combine content*, technology, and teaching approaches that I learned about in my coursework in my classroom. (TPCK)
15. I can choose technologies that enhance the content* for a lesson. (TPCK)
16. I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn. (TPCK)
17. I can provide leadership in helping others to coordinate the use of content*, technologies, and teaching approaches at my school and/or district. (TPCK)

Note: Consider content in areas such as literacy, science, social studies, or mathematics.
Part 3: [Items related to beliefs about technology and self-efficacy, adapted from Wang, Ertmer, and Newby (2004).]

Below is a definition of technology integration with accompanying examples:

**Technology integration:**
Using computers to support students as they construct their own knowledge through the completion of authentic, meaningful tasks.

**Examples:**
Students working on research projects, obtaining information from the Internet.
Students constructing Web pages to show their projects to others.
Students using application software to create student products (such as composing music, developing PowerPoint presentations, or creating a digital video.)

Using the above as a baseline, please select one response for each of the statements:

[Strongly Disagree, Disagree, Neither Agree/Disagree, Agree, Strongly Agree]

1. I feel confident that I understand educational technologies’ capabilities well enough to maximize them in my classroom.
2. I feel confident I can help students when they have difficulty with technology.
3. I feel confident that I have the skills necessary to use technology for instruction.
4. I feel confident that I can use correct terminology when directing students’ technology use.
5. I feel confident in my ability to evaluate educational technology for teaching and learning.
6. I feel confident that I can successfully teach relevant subject content with appropriate use of technology.
7. I feel confident I can mentor students in appropriate uses of technology.
8. I feel confident I can effectively monitor students' technology use for project development in my classroom.
9. I feel confident I can provide individual feedback to students during technology use.
10. I feel confident I can consistently use educational technology in effective ways.
11. I feel confident I can be responsive to students’ needs during technology use.
12. I feel confident about assigning and grading technology-based projects.
13. I feel confident I can regularly incorporate technology into my lessons, when appropriate to student learning.
14. I feel confident about selecting appropriate technology for instruction based on curriculum standards.
15. I feel confident about using technology resources (such as spreadsheets, electronic portfolios, etc.) to collect and analyze data from student tests and products to improve instructional practices.
16. I feel confident that I can motivate my students to participate in technology-based projects.
Appendix B - Interview Questions

The interviews in this study will be semi-structured and will unfold conversationally, and thus the wording may vary slightly from one interview to the next. The questions below will be used to guide the interviews.

<table>
<thead>
<tr>
<th>Interview Question</th>
<th>General Constructs being Investigated</th>
<th>Connection to Research Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where have you learned about technology integration? (E.g., in a course, in a</td>
<td>Relevant experiences for developing technology self-efficacy</td>
<td>Q2</td>
</tr>
<tr>
<td>practicum experience, observing a teacher)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. How confident are you working with technology? Please explain.</td>
<td>Self-efficacy for technology integration (SE-TI), Technological Knowledge (TK)</td>
<td>Q1</td>
</tr>
<tr>
<td>3. If there were a new type of technology that you wanted to know more about, how</td>
<td>SE-TI, TK</td>
<td>Q1</td>
</tr>
<tr>
<td>would you go about learning about it?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. How confident are you in using technology as part of your teaching practice?</td>
<td>SE-TI, Technological Pedagogical Knowledge (TPK)</td>
<td>Q1</td>
</tr>
<tr>
<td>Please explain.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. What is your favorite subject—the one you would love to teach? How confident</td>
<td>SE-TI, Technological Pedagogical Content Knowledge (TPACK)</td>
<td>Q1 (Follow ups, Q2)</td>
</tr>
<tr>
<td>do you feel about integrating technology as you teach that subject?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow up, if positive: How did you develop the knowledge or skills needed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow up: What would you need to know to feel more confident?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Has the Teacher Preparation Program helped you to learn about technology</td>
<td>Relevant experiences for developing technology self-efficacy</td>
<td>Q2</td>
</tr>
<tr>
<td>integration? Please explain.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. What do you think would be the best way for a pre-service teacher to learn</td>
<td>Relevant experiences for developing technology self-efficacy</td>
<td>Q2</td>
</tr>
<tr>
<td>about technology integration?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Development in Pre-service Teachers’ Readiness to Use ICT in Education – Longitudinal Perspectives

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Abstract: This study focuses on pre-service teachers’ readiness and willingness to use Information and Communication Technologies (ICT) in education. The study was conducted using the Theory of Planned Behavior (TPB) focusing on attitudes, subjective norms, self-efficacy and behavioral intentions related to ICT in education. This paper is a longitudinal study; data were collected in three measurement points during 2014, 2015 and 2016 at three Finnish universities. Results indicate that pre-service teachers’ assessments of each TPB areas rise between the first and second measurement, that between the second and third measurements the only statistically significant gain was for self-efficacy, and with other TPB areas the change was minor or even negative. Results also indicate that the biggest differences among respondents was in self-efficacy.

Key words: pre-service teacher, ICT in education, theory of planned behavior, longitudinal study

Introduction

The role of Information and Communication Technology (ICT) is emphasized within Finnish society and in education. The expectations related to the use of ICT is currently conceptualised as a ‘Digital Leap’ (see. Junger, 2015), where use of ICT is seen as a way to support the economic development in Finland and also education. Within the educational context, the role of ICT can especially be seen in the national curriculum for elementary schools (Finnish National Agency for Education, 2014). Within the curriculum there is a strong emphasis on using ICT in pedagogically meaningful ways, so the ICT is considered as tool for supporting learning and also as a target for learning. Altogether, ICT in education provides a challenging and fast developing possibility for teachers. Based on yearly NMC Horizon Reports that outline the development trends in K-12 education, we can see the fast development in ICT applications and tools for supporting learning and also pedagogies related to ICT supported learning processes (Freeman, Adams Becker, Cummins, Davis, & Hall Giesinger, 2017). This development poses challenges and interesting possibilities for contemporary and future (pre-service) teachers.
In the context of ICT in education, teacher education and pre-service teachers pose an interesting research target, i.e. the future teachers. Pre-service teachers can be seen as a part of the net generation, i.e. different ICT applications and tools are part of their everyday living (Tapscot, 2008). Based on previous studies today’s pre-service teachers seem to have rather positive attitudes towards ICT in education (Sadaf, Newby, & Ertmer, 2012), however there can also be seen variation among pre-service teachers’ attitudes toward ICT in education (Sointu, Valtonen, Cutucache, Kukkonen, Lambert, & Mäkitalo-Siegl, 2017). Altogether, it seems that despite familiarity with current technologies, today’s pre-service teachers seem to have difficulties in seeing the potentials of ICT for teaching and learning. It seems that their skills to take advantage of ICT for supporting teaching and learning should not be taken for granted (Lei, 2009; Valtonen, Pöntinen, Kukkonen, Dillon, Väisänen, & Hacklin, 2011). There is a need for more research in this topic, especially longitudinal studies outlining changes and development of pre-service teachers’ skills and readiness to integrate ICT in education.

ICT integrations and affecting factors have been studied using various theoretical frameworks. One actively used framework is the technology acceptance model (TAM) focusing on perceived usefulness and perceived ease of use of technology (c.f. Venkatesh, & Davis, 2000). Since its introduction the TAM model has been developed further to contain other affecting areas like computer anxiety and subjective norms. Another actively used framework focusing on (pre-service) teachers’ knowledge is the Technological Pedagogical Content Knowledge (TPACK) that is a theoretical framework for studying ICT integrations from the perspectives of technological knowledge, pedagogical knowledge and content knowledge and combinations of these (see. Koehler, Mishra, & Cain, 2013). A third actively used framework, used also within this study is the Theory of Planned Behavior (TPB) by Ajzen (1991). TPB focuses on the use of ICT from the perspectives of attitudes, subjective norms and perceived behavioral control (more details in theoretical background section). According to Teo and Tan (2012), TPB is a valid framework for studying pre-service teachers’ ICT integrations. In addition, TPB combines the attitudes and confidence for ones’ skills with intentions to use ICT, providing a valuable tool for studying the readiness and intentions of using ICT in education. This study provides a longitudinal perspective for pre-service teachers’ TPB areas. The study focuses on the first three years (three measurement points) of teacher education in three Finnish universities. The aim is to outline how the pre-service teachers’ assessments of areas of TPB change and develop during their first three years at teacher education studies.

Theoretical background

This paper is based on a theory of planned behavior. According to the Theory of Planned Behavior (Ajzen 1991) one’s behavior is affected by one’s intention to behave. Again, three elements affect one’s intentions to behave: in the context of this study, the intention to use ICT for supporting teaching and learning (Figure 1). First, there are attitudes toward the behavior i.e. how one assessments certain behavior, whether the behavior is positively or negatively valued. Second, intentions to behave are affected by the subjective norms i.e. the social aspect of the certain behavior. Subjective norms refer to how certain behavior is viewed by important other people, such as friends, teachers and colleagues. The third element affecting intentions to behave is the perceived behavioral control. Perceived behavioral control is an area containing two elements: first, perceived behavioral control focuses on whether there are resources and possibilities to conduct the behavior, in this case ICT resources: computers, tablets, applications, ICT support, software etc. Second, perceived behavioral control focuses on how one assesses his/her skills for conducting the behavior i.e. one’s self-efficacy (Ajzen, 2002). In the current study, where the target group consists of pre-service teachers, the aim is to study pre-service teachers’ self-efficacy because they are not able to assess the resources available in their future workplace.
Theory of Planned Behavior is an actively used framework for studying (pre-service) teachers’ intentions toward using ICT for teaching and learning (see. Teo & Lee, 2010; Lee, Cerezo, & Lee, 2010; Teo & van Schaik, 2012; Sadaf et al., 2012). According to Teo and Tan (2012), TPB is a valid model for explaining pre-service teachers’ intentions to use ICT in education. Previous studies have indicated that the role of attitudes is important, as attitudes have the strongest effect on pre-service teachers’ behavioral intentions to use ICT in education (Teo & Tan, 2012; Teo & Lee, 2010). The other areas of TPB i.e. subjective norms and perceived behavioral control, have had weaker effects on behavioral intentions. Based on previous studies, pre-service teachers’ assessments of the TPB areas have been rather consistent. In a study by Teo (2012) 157 pre-service teachers assessed the behavioral intention and attitudes as highest TPB areas, while subjective norms and perceived ease of use (self-efficacy) were assessed lower. In a study by Valtonen, Kukkonen, Kontkanen, Sormunen, Dillon and Sointu (2015) results were similar. Pre-service teachers (n=109) assessed behavioral intentions and attitudes as highest TPB areas, subjective norms and self-efficacy gained lower assessments. Teo and Tan (2012) also provided aligning results in their study focusing on 293 pre-service teachers. Pre-service teachers’ TPB areas have also been studied by clustering pre-service teachers. In a study by Sointu et al. 2017, 188 pre-service teachers were grouped based on areas of TPB. Their results indicated three clusters: one with low assessments in all areas of TPB (n=44; 24%) and one cluster (n=98; 52%) with high assessments in all areas of TPB. The last cluster (n=46; 24%) respondents assessed other TPB areas high, but their self-efficacy low, as the lowest of all three clusters.

Theory of Planned Behavior has been actively used for studying different behaviors, also with longitudinal approaches. Still, when it comes to the use of ICT in education with pre-service teachers, the amount of longitudinal TPB studies is minimal. Valtonen et al.2015, conducted a quasi-experimental study with pre-test post-test settings targeting 109 pre-service teachers. The aim of the study was to study the effects of a technology rich, 16-week teacher education course on areas of TPB. Results showed that changes could be indicated in pre-service teachers’ assessment of TPB areas and within the relations of TPB areas. The highest gains were for pre-service teachers’ self-efficacy toward the use of ICT in education. This paper provides a longitudinal perspective for the pre-service teachers' study provided a longitudinal perspective on pre-service teachers’ TPB areas within a Finnish teacher education context. This paper outline the changes in TPB areas within the first three years in teacher education in that study.

Methods

The aim of this paper is to provide insights into the development and changes in the areas of TPB during the first three years in teacher education. First, the study focuses on ways in which pre-service teachers assess themselves each year (cross-sectional) i.e. their attitude toward the use of ICT in education, how they see expectations of other people related to the use of ICT in education, how they assess their skills to use ICT in
education and finally their intentions to use ICT in education. The second question is what kind of changes there can be identified between three measurement points (longitudinal), how strong are the changes?

The target group of this study consisted of a cohort of pre-service teachers from three Finnish universities who started their studies in 2014. Data were collected with three measurement points at 2014, 2015 and 2016, at the end of the autumn semester each year. Data were collected as part of teacher education courses, using online questionnaires. The total number of respondents for each measurement point, cross-sectional, varied from 209 to 267 (table 1). The data used for longitudinal sections consisted of 147 respondents i.e. respondents who participated in all three measurements. The 45% response rate was due to voluntary participation and the fact that all expected respondents did not participate in the courses where data were collected. Most of the respondents in the target group were female (76%) while 24% were male, which represents the typical gender distribution in Finnish teacher education programs. The mean age of respondents was 21.7 years. In order to consider the effects of the missing data, the statistical significance of differences between responses of the target group (longitudinal n=147) and the rest of the cross-sectional respondents (2014 n=120; 2015 n=81; 2016 n=62) were studied using independent sample T-test. The only significant difference between the target group of the longitudinal study and the cross-sectional sample was in the second measurement point with subjective norms, assessments for the target group were higher (M=4.60, SD=.63) than the rest of the respondents (M= 4.30, SD=.81), t(133) = 2.84, p <.01.

Three yearly cohorts from three Finnish universities

<table>
<thead>
<tr>
<th>Year</th>
<th>n</th>
<th>Gender Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014:</td>
<td>267</td>
<td>76% female – 24% male</td>
</tr>
<tr>
<td>2015:</td>
<td>228</td>
<td>75% female – 25% male</td>
</tr>
<tr>
<td>2016:</td>
<td>209</td>
<td>79% female – 21% male</td>
</tr>
</tbody>
</table>

Table 1. Target group

The questionnaire used was adapted from TPB questionnaires used in previous studies (see. Teo & Lee 2010 and Valtonen et al. 2015). The questionnaire contains 17 items for four TPB areas: attitude (six items, for example “The use of ICT in education is integral to today’s society”), subjective norms (three statements, such as “My future students will assume that I can use ICT for teaching”), self-efficacy (four statements, for example “I am very skillful in using new ICT when I need it”), behavioral intentions (four statements, such as “Regardless of resources, I will make sure that my students will use ICT in their studies”). The questionnaire used 6-point Likert-type scales (1 = strongly disagree, 6 = strongly agree). The reliability and structure of the questionnaire used has been tested in earlier studies (see. Valtonen et al., 2015). The internal consistency (Cronbach alpha) values for each subscale were sufficient, above .70. The analysis of the data is conducted using descriptive statistics (mean values and standard deviation). Cross-sectional differences between TPB elements were studied using paired-samples T-test, the yearly changes (between 2014 – 2015 and 2015 – 2016) were studied with mean differences and paired sample T-test. Cohen’s d (d) effect size (ES) was used to evaluate the magnitude of the ES between measurement points: values < 0.20 are considered as no effect, between 0.20–0.50 small effect, between 0.50–0.80 intermediate effect and > 0.80 as large effect (Cohen, 1988).

Context of the study

The context of the study is Finnish teacher education. Finnish teacher education consists of the Bachelor of Arts (Education) degree (180 credits, three years) and the Master of Arts (Education) degree (120 credits, two years). This study covers the Bachelor studies program i.e. the first three years. The teacher education curriculum of Bachelor studies contains courses for educational science, educational psychology and sociology. In addition, studies contain courses for research methods, communication skills, languages and the use of ICT in education. Bachelor studies also contain two practice periods. An important area of the first years of teacher education are the so-called Multi-disciplinary studies (60 to 65 credits) i.e. courses for each subject taught at grades 1 to 6 in elementary school: mathematics, biology, Finnish and literature, arts, music etc. These courses combine content areas of various disciplines with different pedagogical practices, providing also more and more examples of ICT supporting learning within specific contexts.

Courses within Finnish teacher education vary from face-to-face courses to blended courses to courses only online. Currently the role of ICT is emphasized, as demands come from the elementary school curriculum where ICT is in a central role. Three universities participating in this study provide their pre-service teachers with access to the Internet within campus buildings and cloud services (Office 365, GAFE, PedaNET) with personal online environments.
Results

In the following section, the results of assessing TPB areas are described with cross-sections i.e. outlining results each year (Table 2). After this, the changes between three measuring points are discussed (Table 3).

<table>
<thead>
<tr>
<th>Factor (items)</th>
<th>2014 Mean (sd; alpha)</th>
<th>2015 Mean (sd; alpha)</th>
<th>2016 Mean (sd; alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitudes (6)</td>
<td>4.16 (.760; α=.87)</td>
<td>4.38 (.634; α=.82)</td>
<td>4.32 (.625; α=.78)</td>
</tr>
<tr>
<td>Subjective norms (4)</td>
<td>4.28 (.701; α=.79)</td>
<td>4.60 (.619; α=.74)</td>
<td>4.56 (.749; α=.79)</td>
</tr>
<tr>
<td>Self-efficacy (3)</td>
<td>3.55 (1.023; α=.88)</td>
<td>3.77 (1.086; α=.89)</td>
<td>4.04 (1.049; α=.89)</td>
</tr>
<tr>
<td>Behavioral intentions (4)</td>
<td>4.01 (.767; α=.83)</td>
<td>4.30 (.683; α=.76)</td>
<td>4.33 (.669; α=.74)</td>
</tr>
</tbody>
</table>

Table 2. Descriptive statistics based on three measurement points

Results indicate that at the first year measurement point (2014) subjective norms were assessed highest; the lowest assessments were for self-efficacy, indicating that first year pre-service teachers assessed the expectations of other people for using ICT in education rather high, while their confidence for their own skills to take advantage of ICT in education was assessed lower. Attitudes and intentions to use ICT in education were assessed slightly above four i.e. agreeing with items within these factors. Altogether, the assessments for all TPB areas were rather high, the lowest mean value was in self-efficacy (M=3.55; neither disagreeing nor agreeing), and the highest for subjective norms (M=4.28). The differences between all the elements of TPB in the first measurement point were statistically significant (see. Appendix 1), except between attitudes and behavioral intentions (t (146) = 1.28 p>.05) and attitudes and subjective norms (t (146) = -1.94 p>.05). At the second measurement point (2015), the pattern of differences between TPB factors remained rather similar. Subjective norms gained the highest assessments, whereas self-efficacy was assessed again lowest, revealing that pre-service teachers acknowledge well the social expectations of the use ICT in education while they are just about to assess having some rather weak confidence in their own abilities to use ICT in education (Self-efficacy M=3.77). Attitudes and behavioral were assessed similarly, the difference between these areas were not statistically significant (t (146) = 1.66 p>.05), also both attitudes and behavioral intentions differed from all other areas (see. Appendix 1). At the third measurement point (2016), the pattern of differences between factors was nearly identical to the second measurement point. Attitudes and behavioral intentions to use technology were assessed at the same level, no statistically significant differences (t (146)= -0.13 p>.05). Altogether, all the assessments stayed below five (somewhat agreeing). During the first three years of teacher education studies the subjective norms were assessed as the highest of all TPB areas at all measurement points and similarly self-efficacy, even though growing, as the lowest of all TPB areas.

In addition to mere mean values, results indicated differences with standard deviations of TPB areas. Standard deviation values were moderate, below .90, in all TPB areas except self-efficacy. With self-efficacy, the standard deviation varied between 1.02 and 1.09, indicating bigger differences in how pre-service teachers assessed their skills to use ICT in education.

The changes in mean values were biggest between the first and second measurement points (Table 3). All changes were statistically significant: the biggest gains were in subjective norms (change in mean value: 0.32), the lowest gains were for self-efficacy and attitudes (change in mean value: 0.22). Between the second and third measurement points the development was more moderate, even negative. Only with self-efficacy the growth was statistically significant, other areas remained at the same level. With attitudes and subjective norms, the changes were even slightly negative i.e. assessments at the third point were lower than at the second. Altogether, the biggest gains were with self-efficacy – for this factor, all changes were positive.
Table 3: Changes in mean values

<table>
<thead>
<tr>
<th>Factor</th>
<th>2014 Mean/SD</th>
<th>Mean change</th>
<th>d</th>
<th>2015 Mean/SD</th>
<th>Mean change</th>
<th>d</th>
<th>2016 Mean/SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitudes</td>
<td>4.16 (.76)</td>
<td>0.22</td>
<td>.32</td>
<td>4.38 (.63)</td>
<td>-0.06</td>
<td>-.09</td>
<td>4.32 (.63)</td>
</tr>
<tr>
<td>Subjective norms</td>
<td>4.28 (.70)</td>
<td>0.32</td>
<td>.48</td>
<td>4.60 (.62)</td>
<td>-0.04</td>
<td>-.06</td>
<td>4.56 (.75)</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>3.55 (1.10)</td>
<td>0.22</td>
<td>.20</td>
<td>3.77 (1.09)</td>
<td>0.27</td>
<td>.25</td>
<td>4.04 (1.05)</td>
</tr>
<tr>
<td>Behavioral</td>
<td>4.01 (.77)</td>
<td>0.29</td>
<td>.40</td>
<td>4.30 (.68)</td>
<td>0.03</td>
<td>.04</td>
<td>4.33 (.67)</td>
</tr>
</tbody>
</table>

Conclusions and discussions

The aim of the study was to outline how pre-service teachers assess the areas of TPB during the first three years of teacher education, as well as what kind of changes and development can be indicated. The high values in subjective norms in all measurement points indicate that pre-service teachers are well aware of the expectations related to their future work as a teacher who is assumed to use ICT as part of their work. Currently ICT is well emphasized within the Finnish core curriculum for grades 1 to 6 (Finnish National Agency for Education, 2014). In addition, the role of ICT in education is under active discussion in Finland, typically referred to as the ‘Digital Leap’ (see. Junger, 2015). Results also align with previous studies concerning the ‘net generation’ students. Even though there are positive expectations concerning the net generation students’ skills to use ICT (Tapscott, 2008), still the previous studies have indicated that net generation pre-service teachers have often difficulties in taking advantage of different technologies familiar to them from their leisure use, and applying them for teaching and learning practices (Lei, 2009; Valtonen et al., 2011). The results of this study align with these previous studies, indicating that despite the expectations of others and rather positive attitudes towards the ICT in education, they still need more first-hand experience, skills and confidence to take advantage of ICT in education.

Even though the lowest assessments were for self-efficacy, the results also indicate that self-efficacy gained the strongest growth during the three years in teacher education. According to Tondeur, van Braak, Sang, Voogt, Fisser and Ottenbreit-Leftwich (2012) and Ertmer and Ottenbreit-Leftwich (2010) it is important for pre-service teachers to gain personal experiences of learning with ICT, as these experiences are vital for the development of their readiness and ability to use ICT in education. In addition, results by Valtonen et al. (2015) indicated that learning with various ICT applications and tools in pedagogically meaningful ways resulted in gains in pre-service teachers’ self-efficacy. We assume that aligning with results by Tondeur et al. (2012) and Valtonen et al. (2015) especially the courses in the multidisciplinary studies which are conducted during the first years in teacher education studies, these results are substantiated. Within these multidisciplinary courses, the ICT is typically integrated as a tool for supporting learning in pedagogically meaningful ways. In addition, within these courses ICT is often used as a tool of certain disciplines (physics, literature, math etc.), aligning with technological content knowledge from TPACK studies (see. Koehler, Mishra & Cain, 2013) i.e. ICT tools and applications are similar as those used by the disciplinary professionals. We assume that these learning experiences are important in the development of pre-service teachers’ ICT in education self-efficacy.

Results also align with the previous results by Sointu et al. (2017) with the difference among pre-service teachers’ self-efficacy. Results indicate that the strongest differences between pre-service teachers in all TPB areas were within self-efficacy toward the use of ICT in education and that the differences remained strongest through the first three years in teacher education. Despite the positive development of TPB during the first three years in teacher education, it seems that there are groups of pre-service teachers, who are unable to take advantage of the learning experiences with ICT in similar ways as other pre-service teachers.

Limitations of the study and possibilities for future research

Results indicate needs for further research and demands for developing teacher education in Finland. Based on these results we can see that the assessments concerning attitudes, subjective norms and behavioral intentions rise between first and second measurement. Between the second and third measurement points, the development ends, and it turns even negative. This needs further research to establish what causes the end of the positive development,
which is important especially with attitudes and behavioral intentions in order to support the use of ICT in education. Better knowledge of factors behind this phenomenon would provide us with tools to develop teacher education, to find ways to support the development of pre-service teachers’ positive attitudes toward the use of ICT in education and with stronger intentions to use ICT in their future work. In addition, more research is needed for studying the possible sub-groups of pre-service teachers based on their self-efficacy assessments. It will be important to identify and describe the sub-groups in order to develop ways to meet the different needs of different pre-service teachers, especially the ones with weak self-efficacy.

This research focused on three cohorts of pre-service teachers. Instead of three complete cohorts, the target group contained 147 pre-service teachers. As mentioned in the methods section, the differences between the respondents who participated in all three measurements and all respondents were not statistically significant, except with the subjective norms at the second measurement point. This gives us reason to assume that results are reflecting the results of the whole cohort. Only the results from the second measurement focusing on subjective norms need to be considered with caution. Another limitation is that the data are gained only from numeric self-assessments. In order to overcome this limitation, it will be necessary to consider more qualitative methods, to provide a deeper insight into pre-service teachers’ readiness and willingness to use ICT in education, to gain more insight behind the numbers and mean values. This can be done for example by implementing classroom observation, lesson planning and pre-service teacher interviews. In addition, the integration of the TPB model with the TPACK model focusing on pre-service teacher’s knowledge related to ICT integration would be important. Relations between TPB and TPACK elements would provide us with information on how attitudes and intentions affect or are affected by each other.

References:


Acknowledgements

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## Appendix 1. Paired sample tests

<table>
<thead>
<tr>
<th>Year</th>
<th>M</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
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<tr>
<td>2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitudes – Self-efficacy</td>
<td>.59</td>
<td>.74</td>
<td>9.68</td>
<td>146</td>
<td>.00**</td>
</tr>
<tr>
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<td>-1.94</td>
<td>146</td>
<td>.05</td>
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<tr>
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<td>-7.62</td>
<td>146</td>
<td>.00**</td>
</tr>
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<td>.17</td>
<td>.63</td>
<td>3.30</td>
<td>146</td>
<td>.00**</td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitudes – Self-efficacy</td>
<td>.73</td>
<td>.89</td>
<td>9.88</td>
<td>146</td>
<td>.00**</td>
</tr>
<tr>
<td>Attitudes – Behavioral intentions</td>
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<td>.53</td>
<td>1.66</td>
<td>146</td>
<td>.10</td>
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<td>Self-efficacy – Subjective norms</td>
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<td>Self-efficacy – Behavioral intentions</td>
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<td>1.00</td>
<td>-7.91</td>
<td>146</td>
<td>.00**</td>
</tr>
<tr>
<td>Subjective norms – Behavioral intentions</td>
<td>.30</td>
<td>.64</td>
<td>5.81</td>
<td>146</td>
<td>.00**</td>
</tr>
<tr>
<td>2016</td>
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<td></td>
<td></td>
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<tr>
<td>Attitudes – Self-efficacy</td>
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<td>.95</td>
<td>5.24</td>
<td>146</td>
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<td>1.27</td>
<td>-6.28</td>
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<td>Self-efficacy – Behavioral intentions</td>
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<td>4.45</td>
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<td>.00**</td>
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</tbody>
</table>
International Teachers’ Evolving Relationships with Educational Technology

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Abstract: Using narrative inquiry, this study examines how a technology-related professional development experience influenced three secondary school international teachers from Kenya, India, and Brazil. The results, written as stories, describe the desire and determination of the participants to deliver technology-infused instruction despite scarce resources. The narrative also depicts the changes in their perceptions regarding educational technologies. Additionally, the importance of context in technology professional development becomes clear through the lived experiences of the participants.

Introduction

The benefits of learning in a multicultural context are well documented. Multicultural classrooms with diverse perspectives and outlooks afford direct interaction to learn about different parts of the world, exchange views and ideas, and understand the human experience (Howe and Xu, 2013; Myles, Cheng, & Wang, 2006). With these known benefits, many schools, colleges, and universities across the world have encouraged international student exchange or study abroad programs (Charney, 2009; Kabilan, 2013).

Since 2007, one such initiative, the International Leaders in Education Program (ILEP) has been conducted by the International Research & Exchanges Board, a non-profit organization established with the help of U.S. Department of State (IREX, 2017). ILEP brings exceptional secondary school teachers from select developing nations to the United States, not only to foster international education and development, but also to cultivate leaders and bridge geopolitical divides. The program involves a semester long academic professional development (PD) experience at one of four participating universities. The PD comprises of coursework in advanced teaching methodologies, curriculum development, leadership competence, and technology skills, along with field experiences at a local secondary school.

The present study is situated within an ILEP technology course experience that took place during the spring, 2016 semester at one of the host universities. Our intent behind the study is to examine the evolution of the international teachers’ technology adoption, capacity, and proficiency as influenced by the PD experience. A well-established body of literature has focused on the technology-related professional development of teachers and related student-centered pedagogy (Harris & Hofer, 2011; Kim, Kim, Lee, Spector, & DeMeester, 2013; Minshew & Anderson, 2015). However, recent studies suggest that teachers from developing nations are still struggling with technology access issues and are required to use teacher-centered learning despite the best of intentions (Dalal, Archambault & Shelton, 2017; UNESCO, 2015; Voogt & Plomp, 2010). How are these international teachers then preparing their students for the growing complexity of social, economic, and technical interrelationships in modern society? What, if anything, should be done so that the efforts of education reforms in international context are transpiring in the right direction?

We attempt to answer these queries through the current study looking at the phenomenon of technology integration in the international education context. It should be emphasized that the aim of the study is not to examine the success or failure of the PD per se, but to understand the changes in the perceptions of the international teachers regarding educational technologies as a result of the PD experience. Since every individual’s experience is unique, we decided to conduct a qualitative narrative inquiry in order to showcase “multiple truths” of international teachers’ technology adoption (Creswell, 2013). Research questions driving the study include:

1. How do international teachers from different technology backgrounds experience a semester long technology professional development opportunity at a US university?
2. What outcomes do international teachers from different technology backgrounds experience in such a program?
Methodology

With the goal of sharing individual technology PD experiences and transformations of international teachers, the present study was designed as a narrative inquiry. Narrative inquiry is grounded in the belief that storytelling is a means of knowledge production. Usually the researcher focuses on a small number of participants, listens to or looks for the stories of participants, and attempts to understand the relationship between the experiences and the social world through their stories (Creswell, 2013). Though narrative research originated from literature, anthropology, and sociology, it is increasingly used by educational researchers as narrative stories can be analyzed in many different ways (Connelly & Clandinin, 1990). Riessman (2008) defines narrative analysis as a “family of methods for interpreting texts that have in common a storied form” (p. 11). The data could be analyzed for chronology of events, turning points, plots, categorical content, or interaction between personal and social space.

Accordingly, we decided to use a holistic-content narrative analysis approach (Lieblich, Tuval-Mashiach, & Zilber, 1998). Holistic-content approach goes beyond descriptions and themes and aims for “interpretive data analysis based on the central feature of restorying a story from the original raw data” (Ollerenshaw & Creswell, 2002, p. 330). Since the stories occur in a specific time or place, context becomes of paramount importance.

Context

The current study took place over a semester long technology course at a large U.S. university, one of the designated host centers of the ILEP project. The cohort included 16 international teachers (8 male and 8 female) from Bangladesh, Brazil, Egypt, India, Indonesia, Kenya, and Tanzania. The technology course was divided into 10 face-to-face sessions, each three hours in length, from mid-January to April 2016. The course, co-taught by the authors, focused on methods of effectively integrating computer-based technology in teaching and learning. The topics included learning theory and technology, digital citizenship, instructional software, student and teacher productivity tools, web-based applications, and mobile/online learning.

In addition to basic computer literacy skills for those who needed it given their limited prior experience, building ICT skills for the classroom was a focus of a significant portion of the course. We discussed and applied the National Education Technology Standards for Teachers (ISTE, 2014) and the technological pedagogical content knowledge (TPACK) framework (Koehler & Mishra, 2005) as practical classroom application strategies for integrating technology effectively into teaching. ILEP fellows explored the use of technology, together with a consideration of the affordances a particular tool might offer, to enhance learning. Throughout the PD, a key emphasis was the effective integration of technology as a tool to enhance/support student engagement, motivation, supplemental instruction, and productivity with a focus on instructional purposes. Participants engaged with a wide variety of technology tools. A few examples include Edmodo (a Web 2.0 social networking we used as our primary learning management tool), Photopeach (an easy to use slideshow tool to create and share “All About Me” presentations), Twitter as an online communication tool that could foster their Personal Learning Network, in addition to Google Docs, Forms, and Slides for online collaboration.

Each session involved instruction time and demonstrations followed by hands-on learning tasks and practice activities. In addition, participants were also asked to submit individual or group assignments (e.g., create a slideshow, participate in online discussion group, or produce a digital story) to demonstrate their understanding and comfort level with the technology. As part of the program, all participants were allotted funding to purchase a laptop. Moreover, the teachers received instruction in teaching methodologies and curriculum development. They also participated in a weekly field experience at a local high school, enrolled in other university courses of their choice, and formed an informal professional learning community among themselves.

Participants

Participants were purposively sampled for the narrative inquiry in order to gather information-rich data set (Creswell, 2013). The present study focused on three participants from the cohort of 16 international teachers in an attempt to better understand varied perspectives of the technology PD experience. To make the PD a meaningful and relevant experience, a survey was sent to all ILEP participants well before their visit to understand their backgrounds, comfort levels with various technologies, and availability of technology tools in their schools. During the PD, often the researchers, who were also the instructors, engaged in open-ended conversations with participants. Moreover, the
The research team had also examined participant’s technology integration abilities using a pre-post instrument based on the TPACK framework (Dalal et al., 2017). All this information was used to select three participants based on gender, geographical location, varying levels of technology access, their technology use, and maximal growth observed within the program. Each participant was assigned a pseudonym to ensure anonymity. Table 1 provides a summary of participants’ backgrounds.

Table 1. Participant details

<table>
<thead>
<tr>
<th>Teacher name</th>
<th>Emily</th>
<th>Ronaldo</th>
<th>Sameer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
<td>Male</td>
<td>Male</td>
</tr>
<tr>
<td>Age</td>
<td>39</td>
<td>50</td>
<td>38</td>
</tr>
<tr>
<td>Nationality</td>
<td>Kenya</td>
<td>Brazil</td>
<td>India</td>
</tr>
<tr>
<td>Content area</td>
<td>Science</td>
<td>Language</td>
<td>Social Studies</td>
</tr>
<tr>
<td>Teaching experience in years</td>
<td>10</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Type of school</td>
<td>Government/Rural</td>
<td>Government/Urban</td>
<td>Private/Semi-urban</td>
</tr>
<tr>
<td>Started using technology</td>
<td>After age 20</td>
<td>After age 20</td>
<td>After age 20</td>
</tr>
<tr>
<td>Years of exposure to computer technology</td>
<td>1</td>
<td>25</td>
<td>18</td>
</tr>
</tbody>
</table>

Data Collection

Data sources for the study primarily included interviews with the participants which were recorded and transcribed. The interviews were semi-structured and conversational in style. For example, each participant was asked the same structured questions such as, “Could you describe your first encounter with a computer?” However, as the interview progressed and participants started narrating their stories of technology encounters and ILEP experiences, a more conversational tone was adopted to encourage participants to offer their narratives. Together with the interviews, artifacts from the technology course such as online posts and assignments were used to triangulate the findings. Five primary questions used to capture participants’ varied experiences with technology and ILEP PD included:

1. What does the word ‘technology’ mean to you?
2. Could you describe your first encounter with a computer?
3. Why did you apply for the ILEP fellowship?
4. What are your plans for using educational technologies upon return?
5. Could you describe one special experience from the ILEP PD that you will always remember?

Data Analysis

The narrative analysis was conducted in two different phases. The first phase involved a preliminary analysis to identify the narratives or sub-stories from the transcripts. Heffer (2010) states that narration is “linked to a set of grammatical and lexical narrative cues” (p. 207). Reading and re-reading the transcripts, one researcher looked for phrases such as “I remember...” or “let me tell you...” or “My earliest memory is...”. These phrases provided narration cues that aligned with the interview questions. Thus, the sequence of events by temporality were identified and named. Then, the sub-stories from the transcripts related to the research questions were highlighted for secondary analysis. In addition, the researcher created memos to record her thoughts and interpretations while reading the transcripts. The secondary analysis involved interpretive data analysis with holistic-content followed by the creation of each participant’s restory. For interpretation of participants’ sub-stories and then to create restories, we used what Polkinghorne (1995) termed “narrative cognition,” a move from “elements to stories” to produce “individual emploted stories” (p. 11-12). Additionally, to construct restories from holistic-content interpretations, we also relied on Labov and Waletzky’s model (1967/1997) that helped unearth the core elements of the story. Labov and Waletzky (1967/1997) suggested that participant’s storytelling may not be linear, but it always contains a structure, which communicates the meaning. The core elements of the structure unfold particular events in the participants’ lives and help the researcher synthesize data by means of a structure into a story. Labov and Waletzky outlined six elements that create the structure: 1) abstract which refers to the essence of the story summarized in one or two clauses; 2) orientation identifying the time, place, people, their activity, and an overall assimilation of the situation; 3) complicating action specifying the event that changes the direction of the story; 4) evaluation that leads back to the abstract focusing on why this story is being told; 5) resolution or the result suggesting the termination of the series of
event; and 6) coda that ends the story many a times with a parting message. Table 2 explains the process of narrative cognition and creation of structure as we interpreted participants’ sub-stories, identified the structural elements, and recreated a narrative for each participant. This narrative then consists of a restory that seeks to convey the situated meaning of the technology PD experience.

**Table 2. Identification of narrative structures in the participants’ sub-stories**

<table>
<thead>
<tr>
<th>Narrative structure</th>
<th>Participant’s sub-story example</th>
<th>Interpreted contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Sameer’s “realization of possibilities with technology”</td>
<td>An international teacher embraces technology after realization that technology can be used in many different ways for student-centered teaching and learning.</td>
</tr>
<tr>
<td>Orientation</td>
<td>Emily’s “one computer with the secretary of the school, slow mobile network”</td>
<td>Description of Emily’s school for the context and plot setting of her narrative.</td>
</tr>
<tr>
<td>Complication</td>
<td>Sameer’s “students had their own blogs, some were even hacking”</td>
<td>An international teacher finds out that his students are very comfortable using technology while he is trying to impart knowledge from old textbooks.</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Emily’s “going to administration, getting the computer, typing for myself and applying for ILEP”</td>
<td>An international teacher embraces computer technology with determination out of her own interest.</td>
</tr>
<tr>
<td>Result</td>
<td>Ronaldo’s narrative of “changed person, using Facebook and online tutorial, very good technology class”</td>
<td>With appropriate scaffolding, the international teachers can overcome their discomfort with technology.</td>
</tr>
<tr>
<td>Coda</td>
<td>Emily’s plans of using technology upon return - “download while here, paint white wall, principal agreeing to buy projector”</td>
<td>International teachers coming from under-developed nations with almost no exposure to computer technology and scant resources make the best use of PD and resources available to them out of their own determination and desire to make learning engaging for their students.</td>
</tr>
</tbody>
</table>

The analyzed interview data were triangulated with online group posts and the assignments submitted by the participants to verify the interpretations and to strengthen the restories.

**Results**

To understand international teachers’ varied experiences with technology and how ILEP may have impacted in changing their perceptions of educational technologies, the results present a restory of each participant.

**Emily**

Emily is a science teacher from Kenya in her late thirties. She teaches in a government funded boarding school at the high school level. While students and some of her colleagues live on the school premises, Emily prefers to stay in her village with her three children and husband. She commutes to school on a daily basis. Teaching resources at the school are scarce, particularly those related to technology. There is only one computer in the school, used for administration purposes. Unfortunately, the school’s access to electricity is intermittent, and the internet and cellular network are highly unreliable. There are a variety of students who come from urban and rural areas to attend and live at the boarding school. They have rarely used any form of computer technology and are not allowed to have mobile phones on the school campus.

**Emily’s restory.** After teaching one day, the principal of Emily’s school gathered everyone to make an announcement: “I have come to know about a fellowship program in America from a friend of mine, who is a professor in a university there. If anyone is interested, here is the information on how to apply.” When Emily saw the application details, she was intrigued that the form mentioned technology, laptop, and even “money for technology.” In her
perception, technology meant “applying the tools and then using them to advance the minds of people.” She wondered how she would love to learn this technology to help her students who do not have “an essence of using a computer in school.” Emily considered her options and debated the dilemma: “I wanted to have the technology tools, to understand them but I had no laptop. I had not used computer, I didn't know how to place the fingers and then move to type.”

The fellowship program details shared by her principal also mentioned different method of teaching and learning. While the traditional education system in Kenya is “structured” for lecture-based, teacher-centered pedagogy, being a science teacher Emily was always looking for “new methods” for teaching physics and chemistry concepts to her students. Ultimately, the desire to learn technology and new pedagogical approaches prevailed over her fear and doubts. Emily applied for the ILEP fellowship, along with four other teachers from her school. She was the one selected after multiple rounds of interviews. Thus, Emily’s first encounter with technology happened to coincide with her upcoming ILEP experience: “That is now the time I started doing my typing for the application. I was going to the administration getting their computer and then typing for myself.”

Once a part of ILEP, Emily traveled to a major U.S. university in the desert southwest with 15 other international teachers from seven different nations around the world. Emily needed help from her peers whenever there were online forms to be filled out using the computer. She struggled when assignments from ILEP courses had to be submitted online. At times, she was embarrassed by her lack of technical knowledge: “I'm not very good and then you must be thinking, this person is bothering so much, why she can’t be knowing technology.”

Emily struggled in class and needed additional one-on-one support. On numerous occasions she communicated her challenges on the online group posts:

• “Can anyone help with Edmodo code because I need this to open Edmodo in my phone. Thank you.” (Group post, 3.13.2016)
• “Professor, I am unable to post my photopeach” (Group post, 1.25.2016)

Despite her challenges, Emily was cognizant that her students and principal back in Kenya were ardently awaiting her return so that she could bring back the new ways of teaching with technology. That was the goal behind this endeavor, “to have the technology tools, to bring back technology.” Emily immersed herself in all the ILEP professional development opportunities. She even requested to double the technology classes: “This course is helping a lot. Instead of having the three hours one day, we can have 6 hours so that we learn much more.”

Emily also wanted to understand the student-centered teaching practices of inquiry learning and guided discovery to teach science. As a result, during her time in the ILEP PD, she enrolled in a course focused on physics education. She was excited that modelling the approaches from her course, her students would be able to “discover things by doing practical themselves” and “realize the theoretical bit of the concept.”

At times during the technology course, Emily experienced the child-like wonder of discovering new abilities and possibilities of technology. She was fascinated by Google. While she had consistent internet access, Emily wanted to download “everything” on her laptop in order to take it back with her and be able to use the resources for her students. Emily said the most useful tool she learned from the course was Hot Potatoes (an offline software tool for creating multiple-choice, jumbled-sentence, crossword, matching/ordering, and gap-fill exercises) because it did not “require network.” Not only did she make plans to use this tool for assessments, she also intended to teach the tool to her colleagues back home.

While Emily was enthusiastic about offline tools, the resource and policy constraints in her home-school diminished the utility of online technologies for her. The boarding school did not allow students to keep phones on school premises. There was only one computer in school for administrative use and it was not readily available for teachers as “sometimes they [administrators] were typing confidential things”. The modems and mobile network were always slow. But Emily’s spirit was intact. She was “going to cope with the challenge”, Where she had seen obstacles, she now say opportunity: “Now, I have my laptop, I will design a wall to be painted white to act as a screen. My principle has agreed to buy one projector forgoing other supplies. Then from that I will be able to show videos and other things I have downloaded here”.

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As the ILEP program concluded, Emily reflected back on the experience with a smile on her face and explained that earlier she had thought five months for training was a “long duration” but with “so many things to learn, five months is very short.” Apart from technology, this international experience “broadened the mind” and expelled the “stereotypes” she had “against other countries and communities.” She was out of her “small world” with a “diverse kind of thinking” after all.

**Ronaldo**

Ronaldo is a 50 years old, English teacher from Brazil. He works in a public school in the urban area of Parana. The school premises have been recently renovated with a new building and two computer labs equipped with 25 computers each. However, the internet access is unreliable. The principal of the school welcomes new ideas of teaching and learning. Students are allowed to use mobile phones with teacher’s permission for educational purposes.

**Ronaldo’s restore.** Encouraged by a friend, Ronaldo bought his first computer, at the age of 25. He slowly learned to type, use Word, and connect to the internet. The first time he connected to the internet all by himself, using his telephone dialing service, he “started laughing and crying” in awe. He had everything, right there! That day he “sat in front of the computer for almost nine hours, just looking at the new world and then, printing piles and piles of papers.”

However, unknown to him, along with the awe, somewhere there was a fear of technology. Ronaldo could not get past his initial exposure to Word and basic internet search. Now, at the age of 50, having used the computer technology for 25 years, Ronaldo was still uncomfortable connecting to websites, creating personal accounts and complicated passwords. His computer use stayed limited to typing Word documents for his school papers.

The renovated school facilities had two computer labs, but he did not use them for instruction because, “to use them I have to know how they work. I was afraid of it, clicking and touching and doing it.” Ronaldo was aware of the importance of technology and knew that he had to embrace it despite his fear or he will be “an old-fashioned teacher, an obsolete teacher.” Being 50 years old was not an excuse in today’s technology-driven world. So one day, when he received a letter from the State Secretary of Education, sent to all public school English teachers informing them about the ILEP fellowship, Ronaldo applied right away. This was a great opportunity to “improve his abilities with technology and learn how to use it for students.” Moreover, spending time in an English speaking country was an added bonus for this English teacher from Brazil. Ronaldo cried with joy when he was selected as one of the two participants from Brazil.

As an ILEP participant, Ronaldo was always forthright asking for help while making fun of his old age and discomfort with technology. He vigorously joined class discussions and took active interest in field experiences arranged for the participants. After visiting a local high school and seeing a demonstration of how technology is used in the classroom, Ronaldo posted on the course platform:

- It was really interesting and very inspiring - the use of technology in the classroom. I am getting more motivated in learning more about it.” (Group post, 2.16.2016)

Ronaldo learned that with the plethora of information on the web, “everything is there but everything is not everything.” This was the first thing he wanted to teach his students upon his return - being mindful with technology and websites, being able to filter right from wrong, and good from bad. Ronaldo seemed to have a correct sensitivity to the integration of technology, balancing it appropriately with content and pedagogy. He explained, “because students are using a computer, that is not technology. You have to put the technology inside something so they can go further. Without a clear learning objective, you're not working with technology properly.”

While enthusiastic about making changes in his instructional practices with the help of technology, Ronaldo was aware of the barriers and resource constraints back home. He told us, “we don't have a very quick and developed internet access. When they are all logged in together, they start falling down, they don't work.” He talked about making small changes, such as conducting research using technology or watching tutorials on YouTube for himself first. As for students, “most of them have a financial condition. Many of them go to a LAN House and pay to use computer and printer. But they do have a smartphone so I'm preparing a class, a lesson plan to apply mobile technology when I go back to my country.”
By the end of the ILEP program Ronaldo was a changed person by his own admission. He had changed his mind about technology, “I am not so afraid as I were in the beginning.” He was using Facebook now and friends were teasing him that he was “getting modern.” He felt inspired and a lot more confident: “Now, when I don’t know anything, I just go to a site, like YouTube, and I watch a tutorial.” He had clearly conquered his “technology fear,” and he attributed this achievement to the “very clear and useful ILEP technology course taught with many examples.” When he left for Brazil, he was looking forward to “do something with technology in his class, with different eyes, in a different way.”

Sameer

Sameer teaches social studies in a private school in a semi-urban neighborhood in India. He is 38 years old and has been teaching for 8 years. He started using computer after the age of 20, like other ILEP participants. However, what makes him stand apart from other participants is that after high school graduation, he took a vocational computer training course and is very comfortable using computers. He uses Whatsapp, Skype, Google Drive, spreadsheets, presentation tools, and social media platforms such as Facebook or Twitter. So why is he an ILEP participant?

Sameer’s restory. For Sameer, the ILEP journey started with an epiphany. Yes, he knew and understood that his students were interested in computers and were “intuitive with technology.” However, it was a revelation that his students in eighth and ninth grade “had created their own blogs, learned programming by themselves, contacted companies, and some were even hacking!” He realized that the knowledge he was trying to impart using “textbooks gave a limited view.” There was a whole “world out there” with “much knowledge” that could be accessed using technology. Thus inspired by his students, Sameer applied for the ILEP fellowship to embrace technology in classroom instruction, beyond his personal use.

During ILEP technology sessions, Sameer learned that technology can be used in multiple different ways in the teaching and learning process – “for critical thinking and capacity building of the students, for assessments, as a survey tool to understand the learning needs of students, and of course, for research.” He was excited at the endless possibilities. With eight years of teaching in a private school he was cognizant that, “in the classroom, when 30 or 40 students are there, they don’t learn in a same pace.” Providing individual attention and support was difficult when “most of the classes were didactic instruction based.” He came to believe that “technology was the reliable source, to aid his students. The computer and the internet could be used strategically in the classroom to provide the intellectual input for all the students.”

Sameer carried a small notebook with him and jotted down ideas and strategies he saw in the U.S. classrooms. For example, he realized that “social networks can be used as a platform for education, not for the just fancy personal use.” The concept of a professional learning community for teachers intrigued him: “A professional community could be started back home.” He became aware of the responsible use of the internet, He noted “one of the things that I never thought of - digital citizenship.” He sent the information to his colleagues right away to ensure that they all make safe, smart, and ethical decisions online. He was eager to use the “thinking tools,” mind maps, concept maps, and problem-based learning to build the critical thinking skills of his students. When he designed a lesson plan on the topic of waste management as part of ILEP technology course assignment, he created a group project that required students to gather information from the web, evaluate, and then suggest a waste management plan for the school.

For a host of reasons, Sameer recognized that some of these teaching and learning strategies may not work back home. He mentioned that his “school cannot provide the resources that every classroom in the United States has.” The internet back home was slow, and his school was fortunate to have 25 computers, thanks to the donation from a private trust. “Luckily students had high speed internet access at home.” The school policy forbade the use of social media, but Sameer had plans to present his ideas nonetheless to the school committee and parents: “It would be challenging but I’m going to see the usefulness of the social media. I am going to organize training on Edmodo, Twitter, and digital citizenship.”

Reflecting back on the ILEP experience, Sameer told us that “if there was no technology course, I would not have come to the ILEP.” His objective “to capture the learning, and how it is being done, and why it is being done” was met, and every day he had “some big take-aways.” Thanks to educational technology tools, he was ready to become the “facilitator” for his students, “who deserved to succeed in their performance in life.”
Concluding Remarks

The use of narrative inquiry and restories highlight the centrality of context. As Lewthwaite, Knight, and Lenoy (2015) point out, outcomes of teacher education programs are highly dependent on understanding the context of the participants, and these elements become even more crucial in the international context. While basic digital competence is often taken for granted in many professions of developed countries (Ertmer & Ottenbreit-Leftwich, 2010), the present situation in developing nations tells a different story. We attempted to tell this story through the lived ILEP experience of the international teachers as they learned to integrate technology in classroom instruction.

We acknowledge that narrative analysis is often ambiguous (Josselson, 2011) and individual-focused (Connelly & Clandinin, 1990). It is possible that with another sample of participants, a different interpretation of the PD experience could emerge. However, as Clandinin and Connelly (2000), explain, “certainty is not the goal” of narrative work (p. 9). Taken together, the results suggest that the semester long coursework may have changed international teacher participants’ technology adoption, capacity, and proficiency. At the completion of the ILEP, Emily and Ronaldo could be at the beginning technology literacy level, and Sameer may have moved up to the knowledge deepening level as outlined under the “ICT Competency Framework for Teachers” (UNESCO, 2008).

Moreover, the restories convey that by the completion of the PD, the international teacher participants were eager to infuse technology in classroom instruction and move toward more student-centered learning practices. Given their desire and strong determination, the teachers managed to find an alternative to work around the technology access issues in their home schools. Sameer decided to leverage the affinity and comfort of his students with social media to use Twitter and Edmodo and implement problem-based learning. Emily, on the other hand, came up with an indigenous solution to download terabytes of digital content while she had access and then use the resources offline in her classroom. Ronaldo chose to leverage mobile technology. These strategies suggest that if the international teachers are provided with appropriate knowledge of the affordances of technology in instruction and availability of various educational technology tools, they are willing to become agents of change.

Fisher (2006) has explained that in any discussion of technology integration, it is the teacher who acts as the agent of change, not the technology. For instance, Sameer planned to organize multiple training sessions for his peers and students and talk to the school committee and parents regarding restrictive policies. Emily worked to convince the school administration to use some of the funds for technology equipment. These examples are evidence of small but an important grassroots level change. This change is the first step of creating awareness among stakeholders regarding benefits of technology in the bigger picture of education reform (Hofer, Lee, Slykhuis, & Ptaszynski, 2016). Hence, we see value in this model of a semester long international professional development as these teachers return to their homeland and act as agents of change at an opportune time when governments of developing nations are slowly but steadily investing in technology infrastructure (UNESCO, 2015; Voogt & Plomp, 2010). We anticipate positive contribution from the study toward the motivation and design of international teacher exchange programs specifically emphasizing context-based technology education.

References


New Content for New Times: Pre-Service Teachers’ Exploration of Computer Programming in Educational Technology Coursework

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Abstract: This study investigates the development of computational thinking skills and knowledge in pre-service teachers after they were exposed to an educational technology course focused on the integration of computational thinking in K-8 contexts. In particular, the study examines one aspect of computational thinking, namely programming. Quantitative data were collected through pre-post surveys on pre-service teachers’ attitudes and understanding of computational thinking. Qualitative data were collected through course artifacts such as pre-service teachers' reflections and lesson plans related to the integration of programming in K-8 disciplinary instruction. Results revealed that the majority of the participants successfully integrated programming into suitable content areas. Yet, they struggled to indicate supported computational thinking concepts and practices in their proposed lesson plans. This research has implications for designing educational technology courses that focus on computational thinking skills among pre-service teachers for the purpose of enhancing K-8 student learning.

Introduction

Recent policy efforts such as Computer Science for All emphasize the importance of helping all students acquire concepts and skills from computer science (CS). These expectations have frequently been described under the term computational thinking (CT) (Wing, 2006). Broadly speaking, CT is a problem-solving methodology that can be implemented with a computer and can be automated, transferred and applied across subjects (Barr & Stephenson, 2011). Wing (2006) suggested that CT is a fundamental skill of analytical thinking for everyone, not just for computer scientists. Indeed, in the United States new reforms that include standards and curricula are underway seeking to infuse CT knowledge and skills across K-12 contexts. For instance, the newly released National Educational Technology Standards for Students from the International Society for Technology in Education (ISTE, 2016) as well as the Next Generation Science Standards (NGSS Lead States, 2013) include CT as a key construct. These reform efforts have prompted a number of states to champion their own CT initiatives. Virginia, for example, is making education in “coding” a requirement, Delaware passed a bill requiring all high schools to offer a CS course by 2020, while NYC has mandated every school to provide computing education to all students by 2025. Outside of the United States, many countries are also moving towards efforts to support the development of students’ CT knowledge and skills. Countries such as England, Australia, New Zealand and Finland all now include CS as a compulsory secondary school subject.

Despite the attention and promise of CS education, teacher preparedness is a major barrier to ensuring that every student acquires CT knowledge and skills (Code.org, 2017). Specifically, few teachers at the elementary and
middle school level have the knowledge and skills to embed CT into existing school curricula, while at the high school level two-thirds of all CS teachers do not have a degree in CS (Barr & Stephenson, 2011; Century et al., 2013). To date, most of the efforts to support teachers in infusing CT into school curricula included in-service professional development led by curriculum providers or university researchers. While these efforts are important, pre-service education is the sustainable path to a pipeline of well-prepared teachers (Guzdial, 2017). In particular, a recent report indicates that education schools provide a natural “home” for computing education since educational faculty are more equipped to address pedagogy for teaching CS content, research new and improved ways of teaching across disciplines, and provide broad and equitable access to CS teaching and learning (Delyser, Goode, Guzdial, Kafai, & Yadav, 2018; Yadav & Korb, 2012). Despite the promise of pre-service education to serve as a natural path to teacher preparation in computing, identifying which courses can include such content remains an open question. According to Code.org, one possible pathway is to update existing pre-service educational technology courses for teacher preparation to include modern CS content (Code.org, 2017).

In this work, we present the re-design and impact of an educational technology course for pre-service teachers specific to incorporating CT in K-8 settings. We focus on K-8 settings because at this level CT is not intended to serve as a stand-alone CS course; rather, it is intended to serve as an interdisciplinary initiative that can help support existing standards (CSTA & ISTE, 2011). Given the interdisciplinary nature of CT, all teachers at the K-8 level should be responsible for integrating CT into their curriculum, recognizing and highlighting CT skills already embedded in their teaching, and using CT tools and practices when appropriate to address problems and find solutions (Barr & Stephenson, 2011; CSTA & ISTE, 2011). In particular, the course re-design focused on core CT-related skills such as: (a) problem decomposition: breaking down complex problems into manageable parts; (b) algorithmic thinking: using a precise sequence of steps or instructions to solve problems; (c) abstraction: reducing complexity to define a main idea/applying abstraction to develop models of natural or artificial phenomena; (d) data collection, analysis and representation; (e) automation (i.e., programming): using digital tools to automate solutions; (f) parallelization: making things happen simultaneously towards a common goal; and (g) simulation: representing a process (Barr & Stephenson, 2011; CSTA & ISTE, 2011; NRC, 2010).

One area of CT that has received less attention among pre-service teachers is programming. Thus, here we pay particular attention to programming, an aspect of CT that we have previously found to be particularly challenging for pre-service teachers (Mouza, Yang, Pan, Yilmaz Ozden, & Pollock, 2017). While we recognize that CT involves more than programming, there is growing interest and discussion related to the teaching of programming for all students, which necessitates teacher preparedness (e.g. Goode, Chapman, & Margolis, 2012; Grover & Pea, 2013). Specifically, we explore two research questions: (1) How does participation in an educational technology course that focuses on the integration of CT in curricular content influence pre-service teachers’ knowledge, skills, and attitude towards the application of CT in teaching? and (2) What are pre-service teachers’ perceptions of programming and its application in their own curricular context?

Research Context

This study was conducted in the context of a four-year undergraduate teacher education program in the U.S. Graduates of the program are eligible for both elementary (K-5) and middle school (6-8) teacher certification. The program curriculum is divided in three areas: (a) the general studies courses which help develop subject matter knowledge; (b) the professional studies courses (e.g., methods) which prepare pre-service teachers for their future classroom; and (c) the concentration courses which help develop expertise in a middle school content area. Additionally, the program curriculum is designed to provide pre-service teachers with a range of field experiences (e.g., tutoring) in a variety of classroom settings. These experiences culminate with student teaching.

Course Description

Integrating Technology in Education is a 15-week course required for all pre-service teachers during their junior or senior year. This course introduces participants to technologies available for use in classroom content areas, pedagogical considerations with these technologies, and teaching and learning practices that combine these technologies with content and pedagogy. The specific technologies utilized in the course periodically change, but typically include tools that support communication, content representation, collaboration and professional planning. Concurrent with the course, pre-service teachers complete methods courses and accompanied field experience for
three full weeks within a classroom setting. During their field experience, they are asked to assist in instructional activities, share planning and teaching strategies with a clinical educator, support the learning of students, and gradually assume the role of a teacher. All pre-service teachers work under the supervision of clinical educators as well as university field instructors who offer them necessary guidance, coaching, and feedback. During this period, teacher candidates are also given the opportunity to examine, document, and interact with educational technology resources available in their field placements as well as observe ways in which clinical educators integrate technology in their own lessons. As the pre-service teachers become increasingly adept with course content and activities, they engage in the design and application of authentic classroom materials that embed technologies in the context of disciplinary instruction. In essence, the field experience allows participants to both situate and implement their course assignments in an authentic context with an identified student population, thereby helping bridge theory and practice.

For the purpose of this work, we have re-designed the course to support the development of CT skills among pre-service teachers. Specifically, we have targeted the use of CT-related concepts, computing tools, and practices across course activities as a way of modeling how CT could be integrated with specific content and pedagogy across disciplines and with a range of technologies to help support existing standards. The course was offered in a hybrid format, whereby some of the sessions were conducted online and some face-to-face. During the face-to-face sessions, participants had opportunities for hands-on learning where they experienced a variety of low-tech and high-tech tools that support CT (e.g., board games, electronics, and robotics). Table 1 illustrates the alignment of CT with technologies and activities utilized in the course. The selected technologies are frequently utilized in educational technology coursework for pre-service teachers. The unit on programming (see Table 1), served as the focal area of this study.

The unit on programming lasted three weeks and targeted interaction with the Hour of Code (the most popular block-based programming environment) and Scratch, a cloud-based visual programming language. The aim was to promote pre-service teacher engagement and knowledge in programming tools and practices. Hour of Code, presents a series of activities on block-based coding in the form of games and puzzles of increasing difficulty. These activities are designed for different grade bands (e.g., 2-5 or 6-8). The culminating activity in each unit deals with creating a game or story using all or any of the commands learned and a set of characters encountered in earlier puzzles. In this progression, learners gain experience with simple coding commands while figuring out solutions to puzzles. At the end, learners are encouraged to engage in creative expression by creating authentic puzzles, games, and stories that can be solved using computational tools (Lee, Martin, & Apone, 2014). Each unit can be completed within one hour, which justifies the name of the environment.

Scratch has quickly gained prominence as one of the most effective tools for fostering CT. Scratch is a programming language developed by the MIT Media Lab that uses a syntax-free, drag and drop interface with sophisticated graphical elements to create programs that provide instantaneous feedback to the student in the form of animated sprites. Hence, Scratch provides a programming experience suitable for young learners that is less cognitively taxing with an immediate visual feedback system. Scratch also has a large user community with shared projects that can be repurposed and redistributed alongside publicly available, crowd-sourced resources (Lee et al., 2014; Mugayitoglu, & Kush, 2017). Students experience less cognitive load in a simple programming language like Scratch where complicated syntax synonymous with conventional languages such as Swift, Java, and C++ are removed from the equation and the programmer's focus lies on creative expression, logical arrangement of the code as well as the outcome (Lye & Koh, 2014). Scratch can be utilized in a variety of classroom content areas such as math, science, language arts, social studies and so on.

A key objective of the course is to help pre-service teachers build CT skills and pedagogies relevant to elementary and middle school settings. An important dimension along which learning occurs rests on the integration of new information with existing prior knowledge of learners (Dunlosky, Rawson, Marsh, Nathan & Willingham, 2013). It is, however, not uncommon to observe that pre-service teachers often have considerably limited understandings related to CT and programming, albeit they regularly interact with technology in their daily lives. Through games, puzzles, and personally relevant narratives, the coding activities in Hour of Code and Scratch programming environment allow pre-service teachers to experience active, engaged, and meaningful interactions with CT concepts and practices despite their limited prior knowledge.

Table 1. Description of the Educational Technology Course (Note: No classes are held during the field experience component of the course. Further, the first and last week of the semester serve as an introduction and conclusion to the course respectively).
<table>
<thead>
<tr>
<th>Technology</th>
<th>Activity</th>
<th>CT Supported Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive Whiteboards (2 weeks)</td>
<td>Identify two interactive whiteboard resources that support key CT skills: <em>Modeling</em> (e.g., a resource that can be used to represent a phenomenon such as prey and predator relationship); <em>Sequencing</em> (a resource that could be used to sequence events); <em>Data</em> (e.g., a resource that could be used to represent data such as a graph); and <em>Sorting</em> (e.g., a resource that could be used to organize information)</td>
<td>Algorithmic Thinking, Abstraction, Data representation, Automation</td>
</tr>
<tr>
<td>Internet Research (1 week)</td>
<td>Introduction to Internet Research including use of keywords and operators Evaluation of Online Content</td>
<td>Problem Decomposition, Data Abstraction Automation</td>
</tr>
</tbody>
</table>
| Programming Hour of Code Scratch (3 weeks) | *CS unplugged activity*: activity done without computers to introduce the concept of algorithms and programming.  
*Hour of Code*: Completion of a Grades 2-8 activity  
*Introduction to Scratch Programming*: Scratch is an object oriented programming language, which is used to help participants create computational products.  
Review lessons that support the use of Scratch: *ScratchED*  
Design of a lesson plan in a content area that involves Scratch Programming  
Reflection on the role of programming in disciplinary instruction | Algorithmic Thinking, Problem Decomposition, Abstraction, Automation, Simulation |
| Concept Mapping Tools (2 weeks) | Design of a learning activity that uses concept mapping in a content area to decompose and solve a math problem, model a physical phenomenon (e.g., life cycle of a butterfly), or plan essay execution. | Problem Decomposition, Algorithmic Thinking, Modeling, Abstraction |
| Collaboration Tools (2 weeks) | Select and read an article on multiple approaches to developing CT: board games, robotics, programming. Use a collaboration tool (e.g., Glogster, Voicethread, Storybird) to represent your understanding of the reading to your peers. | Problem Decomposition, Algorithmic Thinking, Abstraction Automation |

**Methods**

**Participants**

Participants included 65 pre-service teachers (N=65) enrolled in two sections of the course during one-semester. All were females and all were traditional undergraduate students in their early 20s. Both sections were taught by the same instructor. Prior to their enrollment in the course all participants completed an introductory 1-credit educational technology course in their freshman year focusing on professional tools that can support their own learning and their future teaching (e.g., authoring, presentation tools, etc.).
Data Sources

Both quantitative and qualitative data were collected. Quantitative data focusing on participants’ attitudes toward computing and their understanding of CT were collected through a pre-and post-survey. All participants (N=65) completed the survey electronically during the first and last day of the course. The survey has been developed and tested by Yadav et al. (2014) and was slightly adapted for our sample. The survey used two open-ended questions: What do you think the term computational thinking mean? and How can technologies be used to support the development of students’ CT skills? It also used 25 Likert-type items to assess student understanding and attitudes in six categories: definition (e.g., CT is understanding how computers work), comfort (e.g., I can learn to understand CT concepts), interest (e.g., I think CS is interesting), use in the classroom (e.g., CT can be integrated in the classroom), career/future use (e.g., I expect that learning computing skills will help me to achieve my career goals), and knowledge and beliefs (e.g., I can use existing lesson plans that take advantage of CT tools and approaches in my classroom).

Although the survey instrument was found to be reliable by earlier studies, we also assessed the reliability for our sample. The Cronbach alpha of a scale should be greater than 0.70 for items to be used together as a scale (Nunnally, 1978). Results of our analyses of Likert-scale responses revealed that the instrument as a whole achieved alpha levels exceeding 0.70 indicating that the survey was reliable.

To examine pre-service teachers’ understanding and use of CT in the classroom we also collected qualitative data from a random sample of 18 participants (N=18), including reflections on their experience with Hour of Code and lesson plans incorporating programming. Specifically, pre-service teachers engaged with the Hour of Code programming environment by following given instructions and interacting with any one of the available courses and materials. They then provided open-ended responses reflecting on their experience following given prompts. These prompts focused on: (a) Attitudes toward the Hour of Code (e.g., What did you like/did not like about the Code.org course you completed?) and (b) Justified recommendations for improvement (e.g., What, if any, suggestions do you have for improving the Code.org course and what is your rationale?)

In addition to the Hour of Code reflections, pre-service teachers developed lesson plans that incorporated Scratch programming within a curricular content area. To accomplish this goal, they first examined user-created projects available on the Scratch community that fit their curricular goals. Subsequently, they explored lesson plans through the ScratchEd community, an online publicly available forum where educators exchange resources, pose questions, and share experiences in order to broaden the integration of Scratch into core curricular contexts. Finally, they developed their own lesson plans by following a series of prompts divided in two categories: (a) Planning: Consider the pedagogical decisions you’ll need to make to develop this lesson idea. How will you introduce Scratch to your students? What ways will you assess their knowledge of the concept? and Reflection: How can programming be used to help your students achieve the learning goal? How will the lesson support the development of students’ CT skills? What was your experience with Scratch?

Data Analysis

Survey data were analyzed using both quantitative and qualitative methodologies. Quantitative analyses included descriptive statistics, t-tests and reliability analyses. Likert-scale items were initially scored and subsequently exported into SPSS where means and standard deviations were calculated for each CT construct and for the instrument as a whole. To test for the significance of the gain score (post measure-pre measure), a repeated measures t-test was conducted on each of the scales. Open-ended responses were analyzed qualitative using the constant comparative method (Miles & Huberman, 1994). This approach helped identify common themes that cut across participants’ open-ended responses.

Findings

Attitudes toward CT

Scores on each of the scales associated with each CT construct and the instrument as a whole were computed for each participant at the beginning/end of the course. To test for the significance of the gain score, a repeated measures t-test was conducted on each of the scales (see Table 2). Results indicated significant gains (p < 0.05) on the
instrument as a whole, but not in all scales. For instance, interest and perceived career usefulness did not demonstrate improvements. Positive results were noted for definition, comfort, use in the classroom, and knowledge/beliefs. Effect sizes ranged from small (comfort) to medium (classroom) to large (definition and knowledge and beliefs).

Table 2. Results from CT Knowledge and Attitude Pre/Post Dependent (paired) t-test

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Number of Items</th>
<th>Mean for Pre Survey</th>
<th>Mean for Post Survey</th>
<th>Mean Difference</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>p Significance (Two-Tailed)</th>
<th>Effect Size (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>4</td>
<td>2.80</td>
<td>3.05</td>
<td>0.25</td>
<td>0.41</td>
<td>4.98</td>
<td>64</td>
<td>.000**</td>
<td>0.74</td>
</tr>
<tr>
<td>Comfort</td>
<td>6</td>
<td>3.18</td>
<td>3.25</td>
<td>0.07</td>
<td>0.42</td>
<td>1.43</td>
<td>64</td>
<td>.158</td>
<td>0.20</td>
</tr>
<tr>
<td>Interest</td>
<td>4</td>
<td>2.63</td>
<td>2.63</td>
<td>0.00</td>
<td>0.53</td>
<td>0.06</td>
<td>64</td>
<td>.953</td>
<td>0.00</td>
</tr>
<tr>
<td>Classroom</td>
<td>2</td>
<td>3.18</td>
<td>3.37</td>
<td>0.19</td>
<td>0.56</td>
<td>2.75</td>
<td>64</td>
<td>.008**</td>
<td>0.48</td>
</tr>
<tr>
<td>Career</td>
<td>5</td>
<td>3.18</td>
<td>3.17</td>
<td>-0.01</td>
<td>0.50</td>
<td>-0.15</td>
<td>64</td>
<td>.881</td>
<td>-0.02</td>
</tr>
<tr>
<td>Knowledge and Belief</td>
<td>5</td>
<td>3.04</td>
<td>3.38</td>
<td>0.34</td>
<td>0.49</td>
<td>5.56</td>
<td>64</td>
<td>.000**</td>
<td>0.82</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>3.01</td>
<td>3.14</td>
<td>0.13</td>
<td>0.29</td>
<td>3.69</td>
<td>64</td>
<td>.000**</td>
<td>0.65</td>
</tr>
</tbody>
</table>

*p<.05, **p<.01 and Effect size < 0.3 is small, 0.3–0.5 is medium, and >0.5 is large (Cohen, 1988).
(N=65; Strongly Agree=4, Agree=3, Disagree=2, Strongly Disagree=1)

**Representation of CT in Participants’ Reflection of Hour of Code**

Examination of open-ended reflections on Hour of Code indicated several computational concepts and practices that can support the development of CT skills and knowledge, such as (a) moving the zombie in a logical sequence to reach the sunflower (algorithmic thinking); (b) running two sets of coding components simultaneously to move the bee and collect nectar upon reaching a flower (parallelism); (c) using ‘sides’ variable to draw a geometric pattern instead of manually setting length values (data); (d) triggering the execution of program events through the ‘Run’ button (events); and (e) using the repeat function to run the same set of code multiple times and make the angry bird reach the pig (loops). For the computational practices, the majority of participants reported how the visualization output of the programming codes motivated them to engage in problem-solving processes. Moreover, participants were incremental and iterative while creating coding units within Hour of Code. This finding aligns with previous research studies that noted how participants were observed to prefer “stepwise refinement approach which gave them the opportunity to immediately execute their commands and receive feedback” (Fessakis Gouli, & Mavroudi, 2013, p.94).

The relatable visual content including characters and narratives from popular culture, games, and films made the programming experience enjoyable while instilling motivation and interest. Specifically, participants were able to establish a personal connection with the programming environment that mirrored elements present in their surroundings which is regarded as a crucial computational perspective (Lye & Koh, 2014). Therefore, results show that interaction with programming languages had visible effects in terms of pre-service teachers’ conception of CT concepts, practices and perspectives.
Representation of CT in Participants’ Lesson Plans

Participants explored the Scratch programming environment and the Scratch user community to identify potential user-created artifacts aligned with respective content areas and curricular goals. Subsequently, participants described authentic lesson plan ideas of their own that utilized Scratch to address identified learning goals within a content area of their choice (e.g., science, mathematics, social studies and English).

The 18 lesson plans analyzed illustrated that participants targeted core CT concepts including problem decomposition, algorithmic thinking, data, simulation, automation and to some extent, abstraction. Table 3 illustrates that most pre-service teachers identified problem decomposition and algorithmic thinking as most representative computation skills that aligned with their curricular objectives.

Table 3. Description of Lesson Plans Created by Participants

<table>
<thead>
<tr>
<th>Technology</th>
<th>Scratch programming language</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content Focus</strong></td>
<td><strong>Number</strong></td>
</tr>
<tr>
<td>Social Studies</td>
<td>3</td>
</tr>
<tr>
<td>English</td>
<td>2</td>
</tr>
<tr>
<td>Science</td>
<td>2</td>
</tr>
<tr>
<td>Math</td>
<td>11</td>
</tr>
<tr>
<td><strong>CT Skills Supported</strong></td>
<td><strong>Number</strong></td>
</tr>
<tr>
<td>Algorithmic Thinking</td>
<td>8</td>
</tr>
<tr>
<td>Problem Decomposition</td>
<td>6</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>4</td>
</tr>
<tr>
<td>Abstraction</td>
<td>2</td>
</tr>
<tr>
<td>Simulation</td>
<td>3</td>
</tr>
<tr>
<td>Parallelization</td>
<td>-</td>
</tr>
<tr>
<td>Automation</td>
<td>2</td>
</tr>
</tbody>
</table>

An examination of participants’ generated Scratch lessons suggested a variety of ideas on integrating programming technology with content coupled with appropriate pedagogical strategies including: (a) historical timelines in social studies to sequence and visualize information (algorithmic thinking); (b) visualization of fractions for comparison with a benchmark fraction (data representation and problem decomposition); (c) sorting of clothing items that are suitable for appropriate weather conditions (data); (d) visual and interactive mapping of the water cycle in science (See Figure 1) (abstraction and simulation); (e) modeling of the solar system (simulation); and (f) development of a calculator to perform mathematical operations (automation).

Figure 1. Simulation of the water cycle in Scratch used as example
A large number of participants identified problem decomposition and algorithmic thinking as the most representative CT skills aligned with their curricular objectives. Specifically, they had described how programming through Scratch can potentially advance the development of discipline-related objectives while advancing students’ CT skills. Moreover, they selected sound pedagogical strategies to accompany these skills that involved learner-centered instructional methods, formative assessments, collaboration and inquiry-based learning approaches. In summary, analysis of Scratch lesson plans indicated that pre-service teachers acquired an understanding of coordinating their pedagogical and content knowledge with technology (i.e., programming tools) to support student learning.

Results, however, also suggest that pre-service teachers require more substantial exposure to CT and programming. Despite a largely positive outcome, participants had difficulties recognizing and labeling CT concepts and practices (e.g., automation, abstraction, simulation) even when those were apparent. Specifically, parallelization was not manifested in any of the lesson plans. Analysis further revealed that participants’ struggled with understanding the affordances and applicability of Scratch in disciplinary instruction. A number of students focused on the role of technology to problem-solve broadly without a specific focus in their lesson plans. Some had mistakenly thought of Scratch as a game-building, entertainment platform only. Overall, the students demonstrated moderate grasp on the role and utility of Scratch in supporting CT knowledge and skills within specific curricular content.

Participants’ Perceptions on Scratch

In terms of participants’ perceptions of Scratch and its potential applicability in classroom settings, responses were largely positive. Specifically, the majority of the participants reported that absence of prior programming experience was not an inhibitor and noted that the user-friendly interface of Scratch helped them create computational artifacts more easily than anticipated. Moreover, they all appreciated the wide accessibility of Scratch through a web browser eliminating the need to download software. Scratch allowed participants to create user accounts through which classroom projects could be saved for later access and evaluation. Participants further noted how the Scratch environment enabled them to find and integrate resources suitable to multiple content areas and grade levels. Likewise, the ScratchEd community enabled pre-service teachers to access lesson planning materials, pedagogical strategies, and critical implementation information. This abundance of user created projects, guidelines, discussions, and examples of Scratch integration available on the Internet was noted as a strength.

Despite overall positive perceptions, one of the participants rejected the idea of infusing Scratch programming into future lessons, stating the complexity involved in programming, and difficulty in learning the functionalities of the tool. A similar thought was echoed by another participant who was eager to incorporate Scratch into her future classroom instruction but expressed concerns related to time constraints, particularly the time it takes to create computational artifacts in Scratch. The participant, however, was more inclined to customize existing user-created projects to adapt to curricular needs. Interestingly enough, most of the participants showed high confidence in terms of engaging with programming activities to create authentic artifacts in Scratch.

Conclusion

For pre-service teachers to successfully integrate CT in school curricula, they must develop a sound understanding of CT concepts, practices and perspectives. In this work, we examined the ways in which visual-based programming environments, such as the Hour of Code and Scratch, contribute to the conceptualization of CT among pre-service teachers and the ways in which hypothetical lesson plans help pre-service envision the integration of programming into their future classrooms. Findings indicated that pre-service teachers took interest in Scratch and the Hour of Code materials. Even though Scratch contains multiple components that may appear intimidating to beginners, responses indicated motivation and interest for further engagement with Scratch and its potential to enhance the learning of their future students.

Findings from the analysis of lesson plans indicated that awareness and knowledge of CT concepts and skills represented in Scratch programming design varied among participants. A number of participants provided sound explanations of supported CT skills and knowledge in their chosen Scratch lesson plans that were also well aligned
with their content area. Others, however, perceived CT as basic technological support for problem-solving. These latter lessons did not demonstrate understanding of how to combine programming with the instructional design that can best support CT skills among prospective learners within the context of disciplinary instruction. Problem decomposition and algorithmic thinking were the most highlighted computational skills. In many instances, participants failed to recognize other crucial CT concepts represented in their lesson plans such as abstraction, simulation, data analysis and representation, and automation. This outcome may be attributed to the short duration of the programming unit and the duration of the course as a whole. Thus, future work may examine how more substantial experience with programming influence pre-service teachers’ knowledge and practice.

As noted, the lesson plans participants developed were hypothetical. In other words, they were not carried out in authentic classrooms. Thus, there is no indication that pre-service teachers will be able to implement CT-enhanced instructional designs in their future classrooms. Further, the data utilized in this work is primarily self-reported and did not include authentic computational artifacts. Nonetheless, the findings of this work compel us to consider how close interaction with programming tools may help pre-service teachers overcome their initial fear of CT related tools, and programming in particular, enhance their confidence in integrating CT-based programming concepts in respective content specializations, and finally, empower them to attain learning goals that extend beyond conventional curricular objectives. Future work, however, would benefit from collecting and analyzing classroom-based computational products from pre-service teachers to gauge their fluency, comfort, and expertise in the domain of programming and CT more broadly.

References


Pre-Service Teachers’ Exploration of Professional Role Identities for Teaching with Games

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Abstract: This mixed-methods study reports preliminary findings from Games, Science, and Identity Change- a year-long professional development (PD) undertaken to develop pre-service teachers’ (a) knowledge and skills to facilitate identity exploration through game-based learning (GBL); and (b) professional identities as teachers who adopt GBL as an instructional approach in the future. The study was undertaken as part of an ongoing NSF CAREER (DRL1350707) project awarded to develop and test processes to support identity exploration through GBL. Projective Reflection (PR) served as the theoretical model to frame learning as identity exploration and change in digital worlds. The Game Network Analysis (GaNA) framework was employed to define the knowledge and skills essential for educators to employ GBL. The paper illustrates the eight-professional development (PD) sessions offered once a month from October 2016-May 2017. The paper showcases the change in participants’ knowledge of game-based and professional identities as teachers who would adopt GBL to facilitate identity exploration in their future practice. The paper advances research on teacher education in GBL by focusing on facilitating the acquisition of the essential skills teachers need to adopt GBL and by motivating teachers’ actions to adopt the instructional approach.

Introduction

It is widely agreed upon that transformative teaching within ever increasing technological classrooms require the integration of content, pedagogy, and technology skills (Mishra & Koehler, 2006). However, despite the theoretical promise of GBL reported in several recent meta-analyses (e.g. Clark et al., 2016), pre-service and in-service teachers are deprived of professional development opportunities that can empower them to systematically adopt GBL in their practice in formal and informal settings (Ruggerio, 2013; Takeuchi & Vaala, 2014). In this paper, we argue that teachers not only need to acquire competence in employing GBL, but they also need to engage in opportunities to explore their professional identities as teachers who are motivated to teach with complex environments such as games.

Teachers, Games, and Identity

Several studies in recent years have illustrated the extent to which teachers can play an instrumental role in engaging students in academic domains using GBL. For example, Jaipal and Figg (2009) demonstrated how teachers needed to design supplemental activities to address the inaccuracies in the embedded content in a science game. Watson and colleagues (2011) demonstrated teachers’ adeptness in identifying and leveraging teachable moments to support students understanding of concepts in a history unit. Silseth (2012) demonstrated a dynamic teacher-student interaction and its impact on student’s learning trajectory. Eastwood and Sadler (2013) showcased how teachers needed to modify a game-based biology curriculum to meet the needs of different groups of students. The deep-dive approaches described in the studies established the fact that teachers’ presence is integral to GBL implementation in classrooms. However, in order to make GBL accessible to more teachers, researchers need to cast a wider net for explicating the process of teaching with games and by including examinations of practices involved before, during, and after game-based interventions (Kangas et al., 2016; Shah, 2015).

It is not surprising that teacher education in GBL has made marginal progress because few frameworks exist that define teachers’ knowledge of GBL and which can be used to scale teacher preparation endeavors in in-service and pre-service settings (Shah & Foster, 2015). Some scholars have identified teacher roles in classrooms (i.e.
instructor, playmaker, guide, and evaluator) (Hanghøj & Brund, 2011). Other scholars have developed typologies that can help teachers’ identity and to a certain extent their content and pedagogical characteristics (Wu, 2015). However, in the absence of generalizable frameworks, a majority of teachers may continue to adopt GBL via trial and error methods (Kenny & Gunter, 2011) and even large-scale projects will be at the risk of losing the interest of participating teachers (Caldwell et al., 2017). Furthermore, teachers’ competence in designing and facilitating GBL experiences will be incomplete if their preparation does not support teacher’s understanding of the nature of learning games can afford and what their roles may be in facilitating nuanced ways of learning with games (Foster & Shah, 2016a).

Even as research in the field attempts to address the need for a unifying understanding of which skills may be beneficial for teachers and how that can be translated into designing professional development opportunities for pre- and in-service teachers, there is a growing recognition that skill alone is insufficient for teachers to successfully teach with games (Shah, 2015). Teachers’ intention to uses games and their ability to see themselves in the role of a professional who is able to facilitate learning with these complex technologies is equally important (Chee et al., 2015; Sanchez-Mena et al., 2017).

Research on teacher learning and identity is prevalent (Borko & Putnam, 1996; Putnam & Borko, 2000), exists in the context of technology integration, and somewhat nascent in the context of GBL. For instance, Phillips (2016) examined the connection between an in-service teachers’ professional identity and a community of practice and its impact on the enactment of teachers’ Technological Pedagogical Content Knowledge (TPACK) over an eight-month period. Zibit and Gibson (2005) have used simSchool, a web-based simulation game that tracks, logs, and supports the accumulation of a teacher’s experience in analyzing student differences, adapting instruction to individual learner needs, gathering data about the impacts of instruction, and seeing the results of their teaching. Researchers such as Kaplan and Garner (2016) have developed teacher professional identity models that examine identity in four areas—self-perceptions, perceived purpose, action possibilities, and personal epistemologies as they are situated within individual characteristics, culture, and social context. We argue that focusing on identity change as part of teacher education in GBL learning is important as it can serve as a means to assess the impact of professional development experiences on teachers’ motivation to adopt GBL. This is especially vital in teacher education opportunities at the pre-service level where teachers tend to develop long term habits that influence their teaching identities (Koehler & Mishra, 2005).

In this study, we explored the application of Game Network Analysis (GaNA) and Projective Reflection to facilitate teachers’ knowledge of GBL as it relates to designing and implementing game-based curricula that focus on learning as identity exploration in a year-long PD. We also explored the impact of the PD on the evolution of teachers’ identity as professionals who perceive themselves as adopters of GBL.

Theoretical Frameworks

Game Network Analysis (GaNA) was developed as a methodological process for designing and implementing GBL experiences (Shah & Foster, 2015). It includes a focus on the pedagogy and content of games as well as the process for employing GBL in classrooms in formal and informal settings (Foster, 2012). GaNA comprises of an analytical lens for game analysis and selection by helping teachers approach the game as a curriculum with constraints and affordances for technology, pedagogy, and content. It includes Play Curricular activity Reflection Discussion (PCaRD) model that aids teachers in (a) the systematic incorporation of games in classrooms in order to flexibly accommodate challenges inherent in a typical school structure; (b) the design of learning environments where student engagement, teacher intervention, curricular inquiry are in synergy; and (c) overcoming limitations of the games being used (Foster & Shah, 2015b). GaNA facilitates teachers in designing opportunities for inquiry, communication, construction, and expression to foster transformative learning experiences anchored in the game (Foster & Shah, 2015a). The decisions teachers make during game analysis and game integration are guided by ecological conditions impacting the successful use of GBL experiences. These conditions include social dynamics, organizational and technological infrastructure, and pedagogical culture of the context in which GBL is to be introduced (See Figure 1).

Previous applications of GaNA have focused on developing teachers’ competence in analyzing games, integrating them and considering the ecological conditions as necessary skills in adopting GBL, a theoretical model that helped teachers focus on “what kind of learning” was missing (Shah & Foster, 2014; 2015). Thus, in this study, Projective Reflection (Foster, 2014) was used in conjunction with GaNA to not only facilitate participating pre-service teachers to develop the knowledge and skills essential for adopting GBL but also be able facilitate learning as identity change using games and immersive environments.
Projective Reflection offers one conceptual tool for understanding the way learners engage in self-transformation, or identity change in immersive interactive environments such as games and virtual worlds. This model integrates a focus on content and on the self through a view of learning as inextricably tied to the self (Foster, 2014). Projective Reflection informs the process of identity exploration as it is measured at repeated points over the course of students’ learning experiences, thereby tracking learning as identity change across the four constructs (knowledge, interest and valuing, regulated actions, and self-perception and self-definition), and mapped along six questions: a) what the learner knows – current knowledge, b) what the learner cares about – self and interest/valuing, c) what/who the learner expects to be throughout the virtual experience and their long term-future self, d) what the learner wants to be – possible self, e) how the learner thinks – self and interest, and f) how the learner sees him/herself – self-perception and self-definition (Shah, Foster & Barany, 2017). These questions are used during measurements of a learner’s initial current self, the exploration of possible selves (measured repeatedly over time), and a learner’s new self (at a desired specific end point).

Projective Reflection can serve as an analytical lens to design curricula or retroactively examine identity exploration in completed play experiences. The PCaRD model (See Foster & Shah, 2015b for more information) can be used to enact the Projective Reflection process in the game through Play, and outside the game through Curricular activities, including opportunities for Reflection and Discussion, that ultimately provide students with opportunities to intentionally construct knowledge, cultivate interest and valuing for the academic domain, develop competence with the learning content and context, and explore possible selves in relation to the academic domain. Weaving GaNA and PR together to design a PD allows teachers to understand the extent to which an existing game allows opportunities for identity exploration and change (game analysis), and to design opportunities that afford identity exploration and incrementally track identity change in learners (game integration) while being cognizant of the conditions that may impact these analytical and pedagogical decisions.

![Figure 1. The Game Network Analysis](image)

**Methodology**

This investigation is situated in an a larger ongoing 5-year National Science Foundation project that aims to develop and test a process of supporting learning as intentional identity exploration and change for students using immersive learning environments to learn science, and provide implications for designing and teaching in technological environments for learning as identity change (Foster, 2014). For this study, we used a concurrent mixed-methods research approach (Tashakkori & Teddie, 2003) to examine the impact of a year-long PD course (2016-2017) on pre-service Science teachers’(a) knowledge and skills to facilitate identity change through GBL; and (b) professional identities as teachers who adopt GBL as an instructional approach in the future. A mixed-method approach was adopted as the researchers quantitatively assessed knowledge gains and changes in motivation to use GBL in the future, and interpretively explored the process of learning about GBL and seeing oneself in the role of a teacher who facilitates GBL. Since this is an on-going study, this paper addresses the following research question, “To what extent do participating pre-service teachers’ experience change in knowledge of GBL and “To what extent do participating pre-service teachers’ experience change in their identification with a role of a teacher who adopts GBL in his/her practice?”
Participants and Settings

The study was conducted in a private university in a large Northeastern city in United States of America. Participants were solicited from a relatively new program within the university that offers Science, Technology, Engineering, and Mathematics (STEM) majors the opportunity to receive secondary teaching certification alongside their degree and co-op experience in Math, Biology, Chemistry, Physics, or General Science. Participants could select one of the two options as part of the PD: (a) monthly sessions only from October 2016-May 2017; (b) monthly sessions in conjunction with opportunities to co-teach a GBL for identity change course on environmental science and urban planning for high school students at a local science museum from November 2016-March 2017. Participants were given a stipend based on the nature of opportunities in which they engaged.

Three pre-service teachers initially enrolled in the PD and consented to participate in the research study. Two participants continued the professional development for the entire duration. Participant one (Min Lu, pseudonym) was a female undergraduate student of biomedical engineering and earning a teaching certification for elementary science education. Min Lu participated in the monthly sessions only. Participant two (Patrick), a male, was an undergraduate student of architectural engineering and earning a teacher certification for secondary science education. Patrick participated in the monthly sessions and the classroom experience.

Data Sources

Qualitative data for answering the research question was collected using a 7-item DSMRI trigger activity (Kaplan & Garner, 2016) that required participants to reflect on their ontological epistemological beliefs, action possibilities, purpose and goals, and self-perception and definitions in their role as a teacher who adopts GBL in his/her practice. Example of items included- "What must happen for someone in your role to be successful?", "What central personal characteristic of yours most influences how you are in your role?" Participants completed this form at the start of each session thus triggering the professional role identity that was of significance to the study during the session and making reflection on the role an intentional and a continuous process. Quantitative data was collected using the pre-post Teachers’ Knowledge of Game-Based Learning (TKGBL) survey to assess change in participants’ knowledge of GBL through subscales for game analysis (TPACK), game integration (PCaRD), and ecological conditions (CITE) that affect the use of technology in education (see Shah, 2015 for more information on TKGBL).

Data Analysis

This paper answers the research questions using findings obtained from the DSMRI activity and TKGBL survey. Qualitative data obtained for the questions on participants’ professional identity of a teacher who adopts GBL in his/her future practice were analyzed using the following guidelines suggested by Kaplan and Garner (2016). The authors read through the written responses and identified the various role-identities expressed within (e.g. teacher, teacher who adopts GBL, teacher who integrates technology). An analysis for each role was conducted separately, starting with the role that was the focus of this research study- a teacher who adopts GBL in his/her practice. For each role, themes, sub-roles, sub-contexts were identified. Statements were coded in relation to this role according to the four components in the DSMRI and the alignment/misalignment of the components were identified. Thereafter, an analytical summary of each role-identity that included its content (that is, the beliefs held, the goals pursued, self-perceptions and self-definitions that were expressed, and actions, and strategies noted), its structure (that is, the alignment and misalignment within and between components; the sophistication of the alignment and its process (that is, indications of change, reflexivity, questions) indicating the span of the role-identity across sub-roles and sub-contexts. Finally, an analytical summary of the integration or the lack-there-of of the various role-identities through the narrative were written.

A matched-paired t-test was used to assess change in participants’ self-reported knowledge of GBL on the TKGBL Survey. The significance level for all tests was set at p < .05. Cronbach’s alpha obtained from a split-half reliability analysis indicated that the TKGBL survey, which included the three subscales of game analysis (TPACK), game integration (PCaRD), and ecological conditions (CITE), had good to excellent reliability (see Shah, 2015).

Professional Development Overview

One postdoctoral scholar with expertise in developing and assessing teachers’ knowledge of GBL designed the Games Science and Identity Change PD with guidance from the Principal Investigator. The researcher led each session (once a month for five hours each) with support from at least one doctoral student and an undergraduate student who led some activities and served as participant observers respectively. Activities in each session were designed for
participants to experience play, curricular activities, discussion, and reflection (Foster & Shah, 2015b) to meet the objectives for the day. The first two sessions were mandatory for the participating teachers and focused on establishing a foundation for facilitating learning as identity change through GBL theoretical, pedagogical, and analytical frameworks such as Game Network Analysis (GaNA) and Projective Reflection. Participants explored Philadelphia Land Science, a game that was designed to facilitate the exploration of the roles of an urban planner and environmental scientist (Foster & Shah, 2016a). The game was also chosen for exploration since Philadelphia Land Science was being implemented concurrently in the museum setting. Participants were informed at the outset that the sessions thereafter would be designed based on their interests and needs in order to make the PD meaningful for them and their areas of concentration.

Results

Tables 1 and 2 present change in the two participants’ knowledge of GBL as assessed through the TKGBL survey. Next, an emerging profile of Patrick’s identification with the role of a future teacher who incorporates GBL in his practice is presented. Patrick’s profile is created based on his responses from session 1 (October 2016) to session 8 (May 2017). For each session, his role identification was documented in terms of his ontological and epistemological beliefs, self-perception and self-definition, purpose and goals, and action possibilities. Finally, for each session, whether Patrick perceived a coherence in his role identification along the four constructs was documented.

Table 1. Descriptive statistics for Teachers Knowledge of Game-Based Learning Survey

<table>
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<th>Means</th>
<th>S.D.</th>
<th>Std. Err Mean</th>
<th>N</th>
</tr>
</thead>
<tbody>
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<td>1.39</td>
<td>2</td>
</tr>
<tr>
<td>Post-TPACK</td>
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<td>0.26</td>
<td>2</td>
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<tr>
<td>Pre-PCaRD</td>
<td>29.57</td>
<td>5.00</td>
<td>3.53</td>
<td>2</td>
</tr>
<tr>
<td>Post-PCaRD</td>
<td>37.92</td>
<td>1.17</td>
<td>0.83</td>
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</tr>
<tr>
<td>Pre-CITE</td>
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<tr>
<td>Post-CITE</td>
<td>8.83</td>
<td>0.70</td>
<td>0.50</td>
<td>2</td>
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</table>

Table 2. Paired t-Tests Analysis of The Teachers’ Knowledge of Game-Based Learning

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>t</th>
<th>p</th>
<th>d</th>
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<tr>
<td>Pre-Post Game Analysis Knowledge (TPACK)</td>
<td>1</td>
<td>-4.09</td>
<td>0.00</td>
<td>-3.25*</td>
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<tr>
<td>Pre-Post Game Integration Knowledge (PCaRD)</td>
<td>1</td>
<td>-1.92</td>
<td>0.00</td>
<td>-2.30**</td>
</tr>
<tr>
<td>Pre-Post Ecological Conditions Awareness and Skills (CITE)</td>
<td>11</td>
<td>-4.20</td>
<td>0.00</td>
<td>-5.87**</td>
</tr>
</tbody>
</table>

Note: P<.01, R² = .73*, .57**, .90***

Change in Patrick’s Ontological and Epistemological Beliefs

Patrick began the PD by believing that in order for him to be successful in his role of a teacher who incorporates GBL in the future, his practice had to be student-centric; that is, “the students coming out of the classroom having learned something or taken something away from it.” His focus on the students remained constant as a measure of his success in the role as he believed in the importance of monitoring students’ progress continually and providing them with opportunities to grow via reflection. As the sessions progressed, Patrick stated that he as a teacher needed to be ‘present’ during game-based lessons in order to give feedback to students as engaged in game play and be available to support them as they investigated aspects of a game that interest them and made connections with the necessary content. He added that as a teacher he needed to be proactive and research different pedagogical approaches in order to choose the most effective one for the lesson. Additionally, he expressed he needed to be “intimately familiar with the game in order to provide the best learning opportunities for the students.” Patrick completed the PD
that in order to be successful in his role as a teacher who adopt GBL, he needed “to have both a theoretical and practice knowledge base/experiences”

Change in Patrick’s Self-Perception and Self-Definition

At the start of the PD, Patrick perceived himself as competitive and outgoing and as a result believed he could “get students to be excited about what they are doing.” He claimed to love technology and believed that this personal characteristic would be useful in a future where the world will continue to experience more technological advancements. For three consecutive sessions, Patrick indicated that his willingness to engage in self-reflective practices in addition to characteristics such as leadership and patience would greatly influence how Patrick would perform in the role of a teacher who teaches with games. During these sessions he added the following, which appeared as manifestation of his willingness to engage in self-reflection for the betterment of his practice. For instance, Patrick claimed he desired to seek out new resources, pedagogical approaches, and “do research” in preparation for teaching. In another session, Patrick believed he was keen on adapting his practice to best suit the needs of his students. Closer to the end of the PD, Patrick saw himself as a teacher who persisted when it came to trying new techniques or pedagogical methods, was willing to refine the ideas, and even discontinue them if they are unsuccessful. Towards the end of the PD, Patrick saw himself as “someone who is invested in their own growth and williness to be reflective.”

Change in Patrick’s Purpose and Goals

In terms of his major goal(s) in his role as a future teacher who is likely to adopt GBL, Patrick began the PD wanted to acquire an understanding of what GBL can help students with. As he continued to engage in the foundational sessions, Patrick expressed he wanted to use GBL in conjunction with other learning practices claiming that “most learning theories are successful in conjunction with each other, so this will be amazing addition.” His focus on students emerged even in his purpose and goals as Patrick claimed he wanted “To make sure that the games I choose have purpose and can actually help the students learn, as opposed to using GBL for the sake of GBL.” Patrick sustained his focus on students as he expressed that as a teacher his goals were for students to see purpose in what they were doing and for both groups to see measurable growth in learning. Towards the conclusion of the PD, Patrick believed his major goal as a future teacher who would adopt GBL, his major goal was to implement GBL to complement inquiry and ensure success for his students.

Change in Patrick’s Action Possibilities

In the beginning, Patrick was not sure what his one major behavior would be in role of a future teacher who incorporates GBL in his practice. In the following sessions, even though Patrick pinned down on his primary focus as a teacher (i.e. students) to articulate his action possibilities, for several sessions, what he articulated were goals. For example, he wanted to ensure that students were allowed explore “as freely as possible, while providing a safe environment for the discussion of ideas.” He envisioned being there for his students to encourage them to think critically, to provide feedback to the students “early and often”, and to engage in self-evaluation of his practices in order to maximize student growth. Towards the conclusion of the PD, he began articulating ways of achieving these goals. For instance, in the penultimate session, Patrick stated he would design a structure for his by designing student guides, rubric, forms of evaluation which students could use as they progress through a GBL unit. In the final session Patrick further explored behaviors that he would like to undertake to pursue his goals. Patrick said, he would like to be a teacher “who keeps good sets of tried and tested lessons, and is willing/interested in sharing them with others.”

Coherence in Patrick’s Role Identification

In the beginning, Patrick did not think his articulation was coherent or made sense to him. At the most, Patrick gleaned that he wanted to learn more about the benefit of GBL for student learning. Gradually he began piecing his articulation together and identifying what was emerging. Towards the end of the foundational sessions, it was clear to Patrick that he liked seeing students succeed and he wanted to use GBL in conjunction with other instructional approaches. He sustained his interest in supporting student learning and in reflecting on his articulations to begin identifying strategies or action possibilities to achieve his proposed goals. Patrick also gathered insights from his experience co-teaching a GBL course with the researchers. He believed that managing a GBL lesson/classroom was different than what he had worked on in his past. In addition, he believed he was developing confidence in
implementing a pre-existing GBL plan and be able to achieve student growth. However, he was still not confident designing a game-based curriculum.

Even when his articulations did not explicitly state the actions he would undertake, Patrick was able to draw possibilities through insights from reading his articulations. For instance, he proposed that in order to support students, he would encourage students’ discussion of in-game choices and work with them on projects as they progressed through a game. He continued making connections between his goals and actions throughout the PD. For instance, towards the end, he that in order to create student guides Patrick needed to rely on his knowledge of the game. Similarly, Patrick compared of teaching with games to teaching in general. Specifically, Patrick concluded that teaching with games is a process that can involve nurturing the willingness to try new things. In order to ensure success it is important that teachers maintain a balance between time and commitment to adopt instructional approaches like GBL.

Conclusion and Implications

This paper reported preliminary findings from Games Science and Identity, a year-long PD offered to pre-service STEM teachers as part of an on-going NSF CAREER study that aims to advance learning processes in games that can lead to the exploration and commitment to identities in a particular domain. The objective of the study reported in this paper was two-fold (a) to facilitate participants to acquire the knowledge and skills teachers need to design and lead a GBL experience; (b) to promote participants’ exploration of professional identities as teachers who would teach with games in the future.

The design of the PD was informed by Game Network Analysis and Projective Reflection frameworks. GaNA guided the methodological skills teachers need to be exposed to and cultivate in order to identify games for specific learning goals, design curricula around the game, and integrate them in their contexts of practice (Shah & Foster, 2015). Scholars have urged researchers to expand pedagogical considerations of teaching with games to showcase the entire spectrum of activities teachers need to engage in in order to successfully teach with games (Kangas et al., 2016). PR led the participating teachers to understand how games can afford learning as identity exploration and their skills of game analysis and integration can be leveraged to support nuanced ways of learning with games. While there is evidence from classroom studies to illuminate that teachers can be adept at facilitating students’ engagement in academic domains through games (Silseth, 2012; Watson et al., 2011), there is a dearth of studies that have illustrated how teachers can be trained for transformative teaching with games.

Results indicated a significant difference in pre-service teachers’ knowledge of game analysis, game integration, and ecological conditions. The Games Science and Identity PD had a strong effect size on all the three knowledge areas, the highest being for participants’ awareness of and skills to address ecological conditions that impact the success of GBL. This finding is important for researchers and teacher educators interested in GBL because it brings to the fore that teachers need to be supported to make decisions about game analysis and integration are impacted by the context in which GBL is to be introduced (Shah & Foster, 2014). As is argued by Mishra and Koehler (2006), context impacts the choice of technology and how the technology is implemented to achieve specific learning goals. One participant named Patrick (pseudonym) completed the PD sessions in conjunction with classroom experience. As illustrated in the evolution of his professional identity, Patrick believed in a student-centric approach to teaching with games. This impacted the nature of personal characteristics he identified, the goals he proposed to pursue, and the actions that might be favorable for him to support the students he would work with. Long-term examinations of change in teachers’ professional identities are important as they make the connections between teachers past and current knowledge transparent and also provide a window to teachers’ future enactments (Philips, 2016). In future reports from this study, findings obtained from multiple data sources will be triangulated to generate a more comprehensive picture of Patrick and Min Lu’s professional identities. Future analyses will also focus on identifying similarities and differences in the two participants’ articulations, and examining the impact of classroom experience on participants’ professional identities.

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Examining a “Five Community Typology” to Support Designing for Community Participation in PK-12 Practice. Does “It” Belong?

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Abstract: The calls to reimagine citizenship largely ignore the ill-defined and changing nature of community participation. Little guidance is provided in the literature to rethink curriculum related to engaging learners in community participation. Informed by community types used by community managers, a blended course was designed to support teachers’ designing for community participation. This study examined 27 practicing teachers’ perspectives about the efficacy of a five community typology to inform their learning and designing. A selected threaded discussion, synthesis reflections, and design documents were qualitatively analyzed. Overall, findings indicated the five community typology enlightened notions about the importance of community participation, brought definition to the concept, and provided a number of affordances to support designing for community participation. Teachers and teacher educators are encouraged look beyond their field and community of practice for inspirations to solve problems of practice.

Introduction

A curricular challenge today calls upon teachers to reimagine citizenship to reflect global forces and the prevalence of digital spaces. While the changing nature of citizenship “is not captured in existing curricula or taught consistently with any depth” (Partnership for 21st Century Skills, 2013, n.p.), the same might be said regarding the changing nature of community and community participation. The Partnership for 21st Century Skills (P21) (2013) advocates that educators promote community engagement and involvement across local, online, national, and global levels. The International Society for Technology in Education (ISTE) Standards for Students (2017) provides standards for citizenship in local, global, and digital communities. However, these organizational resources present community in ways that assume policymakers, education leaders, teachers, and students hold a common definition of community. Little definition or specifics are provided related to community participation and the exact nature of 21st century skills (Dede, 2010). Furthermore, the current literature on PK-12 teachers and teacher education largely ignores the depth and breadth of community participation. Given a lack of definition and research, how can teachers effectively address the changing nature of community and community participation with depth and consistency in their practice?

In an effort to answer this question as a teacher educator, the researcher stepped outside the field of education and into other fields such as sociology to review literature related to community participation. Particularly informative was the literature from business and marketing fields where the concept of community participation is viewed from a practitioner’s perspective with purpose and focus. Insights related to the literature including a five community typology used in business were translated into an advanced graduate course to support teachers’ ability to design for community participation. This study examined practicing teachers’ perspectives about the efficacy of a five community typology to inform their designing for community participation.

Community and Participation

Community is a familiar and ubiquitous word, yet elusive in meaning. Literature spanning decades is replete with debates over the definition of community (e.g., Clark, 1973; Hillery, 1955; West & Williams, 2017). Hillery (1955) identified 94 definitions of community and found three important common elements among them: area, common ties, and social interactions. Traditional conceptions have long associated community with geographical spaces or localities such as neighborhoods or towns (Kear, 2011). Modern notions of community describe geographically dispersed and multicultural members who gain a sense of identity and belonging through common interests (Pawar & Cox, 2004). The modern definition speaks to the global aspect of community and also signals the emergence of the Internet and the vast array of easily accessible Web 2.0 and social media tools that facilitate communication and interactions between members separated by time and distance. These communication technologies
have opened a debate about whether or not community can be created in these online spaces (e.g., Rheingold, 2012; Turkel, 2011). Wellman (2001) defined community as “…networks of interpersonal ties that provide sociability, support, information, a sense of belonging, and social identity…” (p. 228), offering the possibility that community can exist in both face to face and online spaces. At the heart of community definitions is interaction. “It is not merely the group that generates community, but the interactions within it” (Bacon, 2012, p. 5). Through these interactions members to take part or share with others in some kind of activity, a process known as participation (Wenger, 1998).

Wenger (1998) defined participation as a complex process that “refers to taking part and also to the relations with others that reflect this process” (p. 55). When coupled in context with community, participation is the active process by which members in a community contribute to their own and the community’s development (Oakley & Marsden, 1987). Larsen, Sewpaul, and Hole (2014) described participation as “a means to make one’s voice and opinions heard; …a means for a community or group to reach their objectives” (p. 7). Wenger (1998) clarified three points about participation and community: (1) participation does not mean collaboration; (2) participation in communities shapes our experience as well as the community; and (3) participation is a component of identity and “not something we turn on and off” (p. 57). Sharing purpose, values, and practices as part of a community situate the concept of community participation in learning contexts (Kear, 2011).

Community and Participation in Education

Community in schools is typically focused on community as a concept that “lends a social dimension to learning” (Kear, 2011, p. 4). Students learn in a community rather than also learning about the nature of community. While this kind of experience is essential and provides substantial learning benefits (West & Williams, 2017), participation in a learning community alone falls short of developing “a wide range of knowledge, 21st century skills and experiences for effective and productive participation in the democratic process, community life, education and workplaces” (P21, 2013, n.p.). In upper grade levels, attention is focused on teaching digital citizenship (Hollandsworth, Donovan, & Welch, 2017), but often separate from the context of community participation. James pointed to the need for “attention to how one’s online tweets, photos, and comments can be read by (and influence) a larger community or public than intended” (as cited in Hollandsworth et al., 2017). Research indicates a need for a more direct effort toward developing and practicing the attributes and skills needed for community participation. These include tolerance, respect, online social skills, and appropriate use for social media for all PK-12 stakeholders (Jones & Mitchell, 2016). Service learning is a curriculum-based experience that engages students in “a process of reflective education in which [they] learn civic or social responsibility through a scholarship of community engagement that embodies the principle of reciprocity” (Caspersz, Olaru, & Smith, 2012, p.14). Service learning is limited to participation for social change within a community and therefore, does not address the possibility that other kinds of community might exist.

When the nature of community is addressed in schools, it is typically in primary classrooms with a focus on traditional definitions of community- groups of people in geographical localities such as neighborhoods and towns. A search using the keyword “community” on teacherspayteachers.com, the popular online marketplace for original educational resources, elicited 8449 lesson plans. A sampling of the top 52 best sellers revealed lessons for teaching community defined by geographical spaces or lessons on citizenship without a community connection. These lessons tend to leave the message that once completed, community should be learned. In other words, lessons on community are one-offs. Stewart (2013) argued, “Creating community is not a lesson, it’s a way of life. Building a sense of caring for each other doesn’t happen by reading one book about friendship. Building a sense of belonging doesn’t happen by playing one game” (n.p.).

Teaching for community participation lacks attention to modern and holistic perspectives as well as situating learning in experiences that prepare students for real world community participation. Furthermore, the last call for a focus on community education came 66 years ago when Benjamin envisioned teacher education as a “general core of preparation for teaching through study of communities, learners, and schools in a variety of cases” (as cited in Olsen, 1951), a time when community was popularly defined and classified by geographical spaces. Aside from integrating the concept of community of practice and professional learning communities to support the development of teachers, little has been done in teacher education to shift mindsets from traditional to modern concepts of community types.

Community Types

Although definitions and perspectives of community vary, there are distinctions that can be identified to better understand what it means to belong to a particular community. Parse (1999) noted, “Community, however broad, wide, and deep, is incarnated with unique patterns by which it can be recognized” (p. 120). Identifying
distinctions and unique patterns in community is not new as education has long used distinctions of urban, suburban, and rural to describe community. Popular classifications, for example, present community in terms of relationships or cause. Tonnies (1957) delineated community of learners as community of kinship (relationships among people that create belongingness), community of place (relationships among people forged by a common habitat or locale for sustained periods), and community of mind (relationships among people formed by common goals, shared values, and shared concepts of thinking and doing). Wellman (1988) categorized community by its changing nature: solitary (preindustrial), neighborhoods (industrial), and personal networks (postindustrial) (Ohler, 2010). The ISTE (2017) standards present levels of community: local, global, and digital. These classifications are “difficult to describe in terms of specifics” (Ohler, 2010, p. 40) and do not represent the full range of communities (Millington, 2012). Millington (2012) presented five community types applied to building, growing and managing a company’s or brand’s online communities. Classified by common purpose and interest that unites the community and focuses participation, this classification provides definitions, unique characteristics of participation, and representative examples from the real world. Table 1 presents an overview of the five community types.

Table 1
An Overview of Millington’s (2012) Five Community Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Community</th>
<th>Goal(s)</th>
<th>Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest</td>
<td>People who share a specific interest or passion</td>
<td>Promote interest</td>
<td>Discuss views, history</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enjoyment</td>
<td>related to the topic</td>
</tr>
<tr>
<td>Action</td>
<td>People who share a common area of discontent</td>
<td>Change</td>
<td>Establish and highlight goals; advocate</td>
</tr>
<tr>
<td>Place</td>
<td>People brought together by geographic boundaries</td>
<td>Improve locality</td>
<td>Discuss events, local needs; share advice about the area</td>
</tr>
<tr>
<td>Practice</td>
<td>People in the same profession, craft, sport, or business</td>
<td>Improve practice</td>
<td>Share strategies, best practices, advice</td>
</tr>
<tr>
<td>Circumstance</td>
<td>People brought together by external events/situations</td>
<td>Cope</td>
<td>Share stories, coping strategies; provide support</td>
</tr>
</tbody>
</table>

Although intended to analyze participation in online communities from a marketing perspective, this classification is flexible in that relationships and interactions span both physical and digital spaces, providing a realistic perspective of how human beings interact in today’s world. Its use in the field to support the work of community managers provides insights about participation characteristics and behaviors as well as the technologies used to facilitate interactions and engagement. Examples of established communities within each type can be seen functioning in everyday life around the globe. These examples situate community participation in authentic contexts and adds concreteness to the notion of belonging. Millington (2012) advanced the understanding of community participation by adding purpose and focus to membership and interactions.

Applying this marketing perspective to education revealed key connections to inform innovative practice that has the potential to bring teaching and learning about community participation into the new century. A strategy that incorporates the five community types and associated goals and interactions would situate learning in an authentic context, respect multiple perspectives and diversity, provide purpose and meaning to community membership, engage learners in action, offer opportunities to explore the affordances of digital technologies in a risk-free environment, and make visible the processes associated with community participation. With these possibilities in mind, the researcher designed a graduate course structured by a five community typology experience to support PK-12 teachers’ designing and teaching for community participation.

A Course Structured by a Five Community Typology

In the absence of any text or formal resources to inform how to teach and design for community participation, the researcher designed a five community typology experience that situated PK-12 teacher-learners’ learning in the context of community membership across Millington’s (2012) five community types. In addition to scaffolding participation in these communities, the 10 week, three-credit hour graduate course addressed learning theories relevant to community participation, online learning, definitions of community and participation, digital citizenship, and the affordance of Web 2.0 tools and social media for facilitating communications and interactions in communities. Multimedia and web-based resources, case studies, examples, articles, and activities addressing each community type served as course content. A variety of Web 2.0 tools, social media technologies, and software were selected to present
content, to support project work, and to facilitate teacher-learners’ interactions. These included blogs, wikis, podcasts, Audacity, YouTube videos, Powtoons, Pinterest, Twitter, Facebook, and web-based games.

The course was delivered as a blended experience with three official face to face class meetings and asynchronous online activities delivered through a learning management system. Weekly activities designed for each topic provided opportunities for teacher-learners to explore examples, analyze community interactions in case studies, share personal and classroom experiences in group discussions, and synthesize/apply knowledge through individual and group projects. A final challenge tasked teacher-learners to design five lesson ideas addressing each of the five community types to support teaching and learning about community participation in their own classrooms. “Community” size varied depending on the activity: small (2), medium (5-6), large (13-14).

To develop understanding of each community type, teacher-learners were situated as members of a community of action, a community of interest, a community of place, and a community of practice. Due to the sensitive and personal topics inherent in a community of circumstance, membership and participation were addressed through case-studies, current examples, and discussions to negotiate meaning and connections to practice. For a community of action, medium-sized groups were tasked to identify and research a common area of discontent and collaboratively design a data-based rationale and action plan. A web-based, interactive template was provided to scaffold consensus building and action planning. For a community of interest, medium-sized groups were tasked to find a common interest and create a private community Pinterest board with annotated pins to share interest perspectives. For a community of place, small groups researched and created an episode for a podcast series called Monument Moment [city] Edition that highlighted a promoted a particular city attraction.

While the above activities were completed over one or two weeks, the activities situating teacher-learners in a community of practice took place over the duration of the course to highlight the importance of community sustainability and maintenance. For a community of practice, each teacher-learner was assigned a special topic related to digital learning trends/initiatives as well as a companion trade book. Care was taken to match special topics with teacher-learners’ practice and context to ensure a realistic community of practice experience (e.g., a technology resource teacher with a grant for 3D printers was assigned the topic Makerspaces paired with Nussbaum’s Creative Intelligence). Teacher-learners were tasked to share insights connecting their assigned topic and book, current research, challenges and benefits, and best practices through an ongoing blog assignment. Teacher-learners participated in blog commenting activities to support this community of practice. Additionally, in medium-size groups, teacher-learners collaborated in a wiki to develop their group’s version of an electronic book dedicated to all things related to community participation. Templates and participation requirements were provided to support the project. Each community type and digital citizenship were represented with a wiki page to be populated with subtopics addressing group-created definitions, characteristics of participation, implications for education, benefits and challenges, ideas for PK-12 practice, and links to examples and resources. The course, implemented as EDIT 784: Designing for Community Participation, was designed to visibly connect citizenship, community participation, and digital technologies that support interactions within course concepts.

Education research, teacher education, and PK-12 teacher practice largely ignore the ill-defined and changing nature of community participation. Perhaps the use of a five community typology might inform educators’ ability to rethink curriculum related to engaging learners in community participation. Does “it” belong in teacher education practice, and more important, does “it” belong in PK-12 teacher practice? This study, the first phase of a design research process to understand a problem of practice (Hathaway & Norton, 2018) was guided by two research questions:

1. What were PK-12 teachers’ perspectives related to their learning about community participation in a course structured by a five community typology?
2. What were PK-12 teachers’ perspectives related to the efficacy of using a five community typology to support their practice of designing for community participation?

Methods
Participants

EDIT 784 is part of a 30 hour advanced graduate cohort program that emphasizes designing for digital learning in schools and the fourth course in the program sequence. The course was implemented and offered in Summer 2016 and again in Summer 2017. The researcher was the designer of and instructor in the course. No substantial revisions were made between implementations. Therefore, course implementations were identical. Thirteen
teacher-learners were enrolled in and completed the course in Summer 2016. Fourteen teacher-learners were enrolled in and completed the course in Summer 2017. These twenty-seven teacher-learners served as the study participants. There were 21 female (78%) and 6 male (22%) participants. Years of teaching experience among the participants ranged from 2 to 27 years (44% = 2-5 years; 41% = 6-10 years; 15% = 11+ years). Participants’ teaching context represented a variety of grade-levels in PK-12 settings (3% = pre-school/kindergarten; 67% = elementary; 15% = middle school; 15% = high school). Sixty percent of the participants were identified as general education and content area teachers. Forty percent of the participants held specialist positions such as music, band, technical education, library media, special education, deaf and hard of hearing, and instructional technology resource teacher.

Data Sources and Data Collection

In each of the two course implementations, a whole class discussion thread with the prompt “Why 5 types?” was posted in week 9. This prompt presented alternative community classifications from the literature and current practice. Participants were asked to comment on the usefulness of each for designing and teaching community participation in their practice. As a final course product, participants submitted a design document narrative that described their design process for creating 5 lesson ideas for community participation. Finally, course participants submitted a course synthesis reflection addressing their course experience and implications for practice. The discussion thread replies, design documents, and synthesis reflection served as data sources. Electronic files of discussion thread replies, synthesis reflections, and design documents from both course implementations were extracted from the learning management system and printed at the end of the Summer 2017 semester.

Data Analysis

Since data sources were narrative in form, the researcher selected a qualitative approach to data analysis. Qualitative analysis procedures emphasize the views of the participants and interpret the subject of study from their perspective. Specifically, Values Coding, an appropriate coding method for studies that explore participants’ experiences and perspectives and particularly applicable to participant-generated materials (Saldaña, 2016), was used to analyze data. Value codes were constructed during the coding process. Value codes from each data source were summarized and examined across data sources. All codes were organized into categories and examined to identify themes. Certain codes were transformed into quantitative representations to highlight endorsement or rejection of a particular course experience or concept. In addition, lesson ideas within the design document narratives were examined for corroboration. Selected quotations that reflected participants’ voices and represented common perspectives were extracted.

Findings

Three themes emerged to inform the efficacy of the five community typology. The theme, Enlightenment and Shifting Conceptions, represented a developing awareness and a changing mindset about community. More than half of the participants (52%) had “never thought…” there were different types of community, or that “within those types there were such distinct differences,” or even “what it meant to be a member of a community before this class.” Traditional conceptions of community bounded by geographical spaces (urban/suburban/rural) were easily dismissed once participants realized alternatives as represented by “I truly had no idea that there were so many forms of communities. I simply thought of rural, urban, and suburban when it came to … community.” By the end of the course, a debate emerged about the completeness of the five community typology. “I was thinking earlier if there’s anything that does NOT fit into one of these 5 types” is representative of the discussion. This evocative question ignited a flurry of conversation and questions about possibility additions. While not resolved, global and digital communities continued to be mentioned as possible additions.

The course experience also highlighted community as a key component in developing future-ready students. On participants’ minds were students as they wondered, “How do my students think about community?” A revelation was that community needed to be taught. “I was … encouraging community involvement. Now, I comprehend that it is necessary to directly teach … about the various communities and encourage active participation.” Since a classroom
is a community, “the types of communities can easily be leveraged in the classroom.” A participant (fifth grade advanced academic resource teacher) best summarized participants’ realizations about teaching about community:

Community has always been the mysterious part … How do you teach being a member of a community? It is a bit clearer to me now that the way forward is just to give students lots of different experiences working in different communities. Students don’t necessarily need to be burdened with the names of all the communities…. What’s important is they learn to participate in communities and work together towards a shared goal. This might be the most important lesson they learn in school as it prepares them not just for a future career, but as citizens of a multitude of different communities.

Another theme focused on the Affordances of the Five Community Typology. Two subthemes emerged from this theme that highlights what the five community typology has to offer. The first related to affordances that benefit teachers’ development of learning opportunities. A five community typology brings “authenticity,” the opportunity to teach digital citizenship in the context of a real-like community, and “possibilities” as “many lessons can be designed as a result of viewing the content within the 5 types of community.” However, the typology also provides necessary boundaries as “Community is such a broad context that it requires some form of scaffold/structure to organize it in a way that’s meaningful for students.” “[H]aving these types of communities to design for gives us concrete constraints to design around or for.”

A second subtheme related to affordances of the five community typology relative to other conceptions of community. Participants described it as “more meaningful,” and “applicable.” One participant (4th grade teacher) compared alternatives, “The five types of community … have been more effective to me than Tonnies or ISTE definitions. I find the five areas … more descriptive and facilitate matching activities easier.” Participants found the five community typology over other classifications, “concrete,” and “useful,” as also represented by one participant’s (elementary special educator specialist) comment, “Understanding of the 5 types allows for better use in the classroom.” “Definition” was commonly referenced throughout participants’ synthesis reflections and participants’ appreciated the concreteness of the typology that other classifications lack. In the debate over “Why 5 Types?” in the Week 9 discussion board, a participant (elementary band teacher) shared:

I very much appreciated having the 5 types. Someone asked me what my favorite movie was last week…I don’t deal with broad questions or topics well, so this really helped me take it piece by piece. Once I figured out what the differences between community types were, I was able to give a better definition of community as a whole.

This statement also introduces evidence to the third theme that emerged from data analyses, Knowledge in Action, captures participants’ ability to articulate clear definitions related to aspects of community. The five community typology experience provided participants with a framework for distinguishing types of communities as well as defining each. Acceptance of this framework was evident in the Week 9 debate over the addition of other types of communities. When global community type was considered for addition, a participant (middle school German language teacher), posed, “If we were to establish ‘global community’ as a new community type, what ways could people participate in said community? How would we define it to stand apart from the other 5 types?” Discussion indicated that any proposed type would need to be defined along the same criteria used for the five community typology. Participants adopted a language for talking about community, using words such as “purpose,” “focus,” “characteristic behaviors.”

All participants (100%) clearly defined each community type in their discussion thread replies, in their synthesis reflections, and in their design document. This is not a surprise as there were several opportunities for participants to develop their definitions through their discussions and submitted products including the group wiki on Community. Lesson designs were examined to determine if definitions translated to learning opportunities for classroom practice.

All participants’ (100%) design documents and lesson ideas incorporated one or more digital citizenship elements. As participants’ reflections indicated, the typology offered opportunities to meet digital citizenship standards. Regarding community types, only one participant (4%) did not sufficiently design lesson ideas for any of the five community types, although the associated design document indicated accurate definitions of each type. Ninety-six percent of participants were able to design lesson ideas that would engage learners as participants in communities of action, practice, interest, and place and situate that learning in content goals. Of those 96%, only two participants (8%) developed lesson ideas that situated learners in a community of circumstance AND content goals. Each did so through role-playing (e.g., characters, such as Native Americans in Colonial Virginia, brought together
by external factors through no fault of their own). The remaining lesson ideas situated learners as support for members in a community of circumstance. This was not a surprise because participants were not situated in a community of circumstance during the course, indicating the importance of situating learners in the community experience to foster deeper understanding.

Finally, all of the design documents and associated lesson ideas (100%) indicated a variety of appropriately chosen digital technologies to support participation and interactions within the community types. Most participants used the technologies modeled in the course to support similar interactions (e.g., participants designed their own version of a podcast series to situate learners in a community of place). Participants wrote that using tools to support interactions in the five community typology led to a better understanding of those tools, in particular, social media tools. “We need to use different technologies to create and build communities … to give students the chance to learn both the knowledge and skills … to become productive members of society.”

Discussion

This study explored the efficacy of the five community typology to support PK-12 teachers’ ability to design for community participation. Overall, study findings indicated the five community typology supported teachers’ learning and designing. It brought an awareness about community not previously considered in their teaching practice. It opened their eyes to the importance of engaging PK-12 students in community participation. The idea of global or digital spaces were not new to teachers. However, as debated in the literature, not all were convinced these are community spaces. The five community typology was applicable regardless of the environment. Overall, the typology supported teachers’ design practice, aligned with content and student-centered approaches, and provided definition and structure to the concept of community participation. This study suggests the five community typology belongs in teacher education practice and likely in the practice of PK-12 teachers.

It is worth noting as a possible limitation that the course designer, instructor, and researcher were all the same person. To bring diversity and multiple perspectives to the design and instructional processes, notions of community and participation from other fields as well as a typology used in business and marketing were included. Although solo coders can benefit from member checking (Saldaña, 2016), participants were not available to the researcher during the study. The researcher did use multiple data sources for corroboration.

For future research, the impact of other design decisions such as activities that situate teacher-learners in each of the five community types should be explored. In addition, examination of teacher-learners’ lesson idea implementations would provide an understanding about the impacts of the course and the five community typology in PK-12 classrooms where it matters most.

The findings of this study have implications for teacher education. PK-12 teachers in this study indicated that prior to their course experience, they had not been prepared to teach about community and community participation in ways that prepare future-ready students. Teacher educators must find ways to support PK-12 teachers’ efforts to modernize practice with regard to teaching about community participation and its relationship to citizenship. The ill-defined nature of community is a double edged-sword. On the one hand, its abundant use without any contextual definition might relegate it to buzzword or cliché status. On the other hand, addressing the ill-defined and ill-structured concept of community presents opportunities for educators to engage learners in activities that promote multiple perspectives, debate, and the process of moving from the intangible to the tangible. This study indicates the need for concrete, meaningful, and authentic teaching approaches that bring definition and purpose to the concept of community. However, approaches to designing for and teaching about community participation are absent from the education literature. Perhaps an important lesson derived from this study is that seeking ideas and models in other fields, in other communities of practice, can inform and offer solutions to educational problems of practice.

References


Art Ed Maker PD Experience: Impacts of an Immersive Professional Development For “Making” STEM Connections In K-12 Art Classrooms

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Abstract: This mixed methods study examined the impact of an eight-month Art Ed Maker PD experience focused on STEM-infused “maker” activities using New Media Arts, specifically looking at the ways in which participants made connections between visual arts practices and STEM practices, and self-efficacy toward integrating STEM-infused "maker" activities into their visual arts curricula using New Media Arts. Using a concurrent embedded mixed methods design, data included quantitative pre-/post-test and ethnographic techniques including field notes, focus group, interview, observation, and personal communications. Participants reported that they developed technical confidence, were able to see multidisciplinary connections between New Media Arts, visual arts, and STEM, and had a willingness to collaborate with STEM teachers in order to impact student learning.

“Art, like engineering, is concerned with finding answers to problems and seeking visual solutions using the design process.”  
(Bequette & Bequette, 2012, p. 44)

Introduction

At the intersection of entrepreneurship and STEM, makerspaces are informal spaces where “makers” can create personally meaningful artifacts by experimenting with various digital and non-digital tools, such as 3D additive manufacturing, 2D subtractive manufacturing, textiles, and electrical circuits (Kurti, Kurti, & Fleming, 2014). Universities, K-12 schools, and public libraries now recognize makerspaces as an effective way to facilitate multidisciplinary learning, including novel explorations of STEM concepts (Clapp, Ross, Ryan, & Tishman, 2017; Halverson & Sheridan, 2014). Makerspaces are the natural evolution of the contemporary art classroom (Robbins & Smith, 2016; Wilkinson, & Petrich, 2013); however, the problem is that many art teachers do not feel confident in the fundamental elements of New Media Arts tools and STEM content that these “maker” activities utilize (Bequette & Bequette, 2012). Professional development that strategically scaffolds these “maker” activities allows art teachers to continue to spark student creativity and self-expression while providing unique opportunities for students to apply STEM content and skills (Fontichiaro, 2014).

The purpose of this mixed methods project was to examine the impact of an eight-month Art Ed Maker PD experience focused on STEM-infused “maker” activities using New Media Arts. The intended outcome of the project was that upon engaging in the Art Ed Maker PD, participants would have increased confidence in integrating STEM-infused “maker” activities and New Media Arts technologies into their K-12 visual arts curricula. The following research questions guided this mixed-methods study:

1. In what ways do participants make connections between visual arts practices and STEM practices?
2. What is the impact of the Art Ed Maker PD experience on participants’ self-efficacy toward integrating science, technology, engineering, and mathematics into their visual arts curricula using New Media Arts?

Theoretical Background

Like many “maker” experiences and environments, the Art Ed Maker PD experience included activities that were guided by the constructionist belief that hands-on design activities support “learning by doing” and encourage
learners to actively build upon existing knowledge (Papert, 1991, p. 10). Constructionism builds upon familiar Piagetian-based theories (Blikstein, 2013; Halverson & Sheridan, 2014; Martinez & Stager, 2013; Vossoughi & Bevan, 2014), such as the social-constructivist belief that learning is enhanced through social interaction (Vygotsky, 1978) and the belief that being reflective and “wide awake” as one engages in self-discovery is critically important in order to make sense of one’s own learning (Greene, 1995). Socio-cultural influences on attitudes, motivation, and self-efficacy beliefs (Bandura, 1997) are also important considerations for understanding impacts of these types of learning experiences and being able to recognize one’s own views allow behavioral changes to take place. Maker experiences encourage a variety of learning outcomes, including an empowering sense of agency (Clapp, Ross, Ryan, & Tishman, 2017) and encourage a reconceptualization of failure as an integral part of developing resilience and creativity (Smith, 2015; Smith & Henriksen, 2016; Brahms, 2014; Sheridan et al., 2014).

**Teachers’ Perceptions of Formally Integrating Making into the Classroom**

Makerspaces are the natural evolution of the contemporary art classroom (Robbins & Smith, 2016; Wilkinson, & Petrich, 2013); however, confidence in the fundamental elements, tools, and STEM content that these “maker” activities often utilize varies (Bequette & Bequette, 2012). In fact, this apprehension and lack of confidence is common for pre-service and in-service teachers in other content areas as well. Recent studies show teachers have many misconceptions about integrating “making,” including being able to authentically connect to learning objectives & access necessary tools they perceive are required (Cohen, Jones, & Smith, 2018). Though they have positive beliefs toward the engaging nature of “maker” activities, teachers perceive many external constraints and barriers that they feel are beyond their control (Jones, Smith, & Cohen, 2017). Scaffolding “maker” professional development opportunities can help teachers establish a sense of community (Cohen, Huprich, Jones, & Smith, 2017), which can positively impact their self-efficacy and confidence, suggesting they will be more likely to integrate multidisciplinary making in the future. Teachers are guided by their self-efficacy beliefs in instruction and the capability to bring about positive student change (Bandura, 2006).

**New Media Arts as a Boundary Object Between Visual Arts and STEM**

With a focus on scientific systems and ecologies of knowledge, Star & Griesemer (1989) originally defined boundary objects as “scientific objects which both inhabit several intersecting social worlds...and satisfy the informational needs of each of them” (p. 393). Bowker, Timmermans, Clarke and Balka (2016) elaborate that boundary objects are “representational forms—things or theories—that can be shared between different communities, with each holding its own understanding of the representation” (p. 52). Essentially, boundary objects are phenomena represented and/or understood in different ways by different participants (i.e., participants who have varied experiences, varied perspectives, and associate the objects with varied meanings). It is through this lens that we look at New Media Arts as a boundary object that exists within the aesthetic domain of visual arts and the technical domain of STEM. The National Coalition for Core Arts Standards (NCCAS) provides the following definition, which highlights this intersection:

*Media Arts is a unique medium of artistic expression that can amplify and integrate the four traditional art forms by incorporating the technological advances of the contemporary world with emerging skill sets available to students and teachers. Media arts students cultivate both artistic abilities and a technological aptitude. The media artist utilizes a fundamental understanding of the mediums of analog and digital media to integrate digital technologies with traditional forms of artistic expression.*

Bequette and Bequette (2012) point out that, “crossing boundaries between arts and science is predicated on the perception that these areas can meld fluidly together, and that a synergistic relationship may result” (p. 40). Bolin and Hoskins (2015) assert that this predication is dependent upon individual visual arts teachers’ values and beliefs that inform their professional practice. Some value multidisciplinary synergy, while others do not. Regardless of their values and beliefs, in order to engage art teachers in this STEM-infused approach to art making it is critically important to ensure that “the arts are seen as an end goal, not just an entryway to presumably more important STEM topics, thoughtfully developed STEAM curricula can truly engage sustained cross-disciplinary student learning in PK-12 settings and informal education” (Bequette & Bequette, 2012, p 43). It is here that one can see how New Media Arts can effectively cross those boundaries and there are numerous artistic techniques that can be used to exemplify these multidisciplinary intersections, such as CAD modeling, digital fabrication, electronics.
Methodology

This eight-month exploratory study used a concurrent embedded mixed methods design (Creswell & Plano Clark, 2011) that included the use of quantitative data (i.e., pre-/post-test) and Fetterman’s (2010) ethnographic techniques (i.e., field notes, focus group, interview, observation, personal communications). This mixed methods design allowed for more thorough examination of the eight-month Art Ed Maker PD’s impact on self-regulatory factors that influenced participants’ attitudes toward integrating STEM-infused “maker” activities using New Media Arts. Using convenience sampling, participants were 16 voluntary local area art teachers.

Data Collection

Quantitative data collection was focused on a modified version of T-STEM Survey (Friday Institute for Educational Innovation, 2012), which for our purposes we titled, The New Media Arts Self-Efficacy Survey. The T-STEM survey is available in a variety of forms for different disciplines with each measuring changes in educators’ confidence and efficacy toward STEM as well as their attitudes toward 21st century learning and teacher leadership. The survey uses a 5-point Likert scale to collect perceptive data (what respondents think or feel) from teachers regarding their teaching confidence and efficacy and attitudes, and frequency data regarding the use specific instructional practices and technology in the classroom. There are seven constructs, which the survey developers indicated can be used collectively or separately. The version administered for the Art Ed Maker PD used a total of 16 items consisting of a variation of Personal Teaching Efficacy Beliefs (construct 1; reliability = .905) and STEM Instruction (construct 4; reliability = .95). In order to document changes over time, the instrument was administered three times. The first administration took place at the beginning of Day 1 of Art Ed Maker Camp (n=16). The second administration took place at the end of Day 2 of Art Ed Maker Camp (n=14). The third and final administration took place in April 2017 (n=2).

Qualitative data included observations, focus group, and interview. Observations took place at each session throughout the eight-month project (Art Ed Maker Camp and Art Ed Maker Meetup) and included the use of The Learning Dimensions Framework (Petrich, Wilkinson, & Bevan, 2013), which includes four learning dimensions (i.e., engagement, initiative and intentionality, social scaffolding, and development of understanding) and 13 indicators that exemplify the dimensions. It was designed by the Tinkering Studio’s research team based on hundreds of hours of observing visitors’ participation and interactions within the Exploratorium Museum’s interactive activities. Though the developers state that The Learning Dimensions Framework should be used as a tool for discussion rather than rigorous schemes for coding behavior, the research team wanted to see if it could be used to observe frequencies of maker-related behaviors thereby indicate if the activities were supporting meaningful learning and self-regulatory factors. In addition, photography of participant creations and interactions, as well as researcher field notes, thick descriptions, and memos were used to record observations. A 45-minute semi-structured focus group took place at the end of the two-day Art Ed Maker Camp and included researcher field notes. Finally, 45-minute semi-structured interviews took place after the final Art Ed Maker Meetup in April to serve as a retrospective account. In addition to these more formal ethnographic techniques, communications were also used as qualitative data including emailed communications and forum discussions.

Data Analysis

The research team collected survey responses from 16 participants at the start of the camp (pre-camp), 14 participants at the end of the camp (post-camp), and two participants at the end of the eight-month project. Pre-camp data from the two participants who did not complete the post-camp survey were removed. The third administration of the survey was not included in the overall quantitative analysis because there were only two respondents; however, the raw data is included in the case study vignette (see Results and Findings).

The survey used a 5-point Likert scale, including 1=Strongly Agree, 2=Agree, 3=Neither Agree Nor Disagree, 4=Disagree, and 5=Strongly Disagree. Analysis began by computing mean responses for each question on the pre- and post-camp surveys. Change score (post-camp minus pre-camp) was then computed for each person and question using a one-sample t-test with 0 as the reference value indicating no change in response between post- and pre-camp surveys.

Qualitative data was analyzed using a variety of ethnographic techniques. The Learning Dimensions Framework (Petrich, Wilkinson, & Bevan, 2013) was used to record observational frequencies that aligned with four learning dimensions and 13 indicators. One researcher was tasked with observing and recording frequencies for each of the sessions throughout the study, which were tallied and compiled in tables. Researcher field notes, thick descriptions, and memos were compiled in word-processing software. Focus group, interviews, emailed communications, and forum discussions were similarly formatted in word-processing software. All qualitative data
was imported into NVIVO software and analyzed to triangulate. Researchers used thematic analysis based on codes that were devised from the constructs of both The New Media Arts Self-Efficacy Survey and The Learning Dimensions Framework and also recorded emergent themes that arose.

**Procedures**

The Art Ed Maker Camp Experience provided eight-months of in-depth professional development for 16 local area K-12 in-service art teachers. It consisted of three phases: 1) Art Ed Maker Camp, an intensive full day summer workshop that took place on two consecutive days in August 2016, 2) Ongoing email communication between research team and participants, and 3) Art Ed Maker Meetup, an interactive session held in April 2017.

Using the Art Education program’s contact list of local area art teachers, a solicitation email was sent to advertise for the project and request participants, which was limited to twenty due to cost and facilitation. 20 participants signed up; however, four were unable to attend the first day of activities; therefore, they were dropped from the study. The intensive two-day Art Ed Maker Camp took place in August 2016 in conjunction with the Art Education Program’s annual summer professional development series held at a large Hispanic-serving university in the Mid-South. They began by completing the first administration of The New Media Arts Self-Efficacy Survey. Then four researchers facilitated activities that were based on the first author’s existing makerspace curricula used in teacher education courses, which combined various strategies for hands-on STEM-infused art-making, including non-digital “upcycling” construction with cardboard and recyclable materials; 2D subtractive manufacturing with cardboard, fabric, paper, and vinyl; 3D CAD modeling, scanning, and 3D printing; and simple electronics creation using conductive tape, thread, LED lights, and motors. In addition to inquiries about visual arts connections to STEM concepts, facilitators encouraged participants to engage in interactive discussions about best practices, visual arts standards, access and equity, and sustainability. At the conclusion of the second day of the Art Ed Maker Camp, participants took the second administration of The New Media Arts Self-Efficacy Survey, participated in a 45-minute focus group, and received a Maker Ed Starter Kit that included a variety of materials for use in their own classrooms.

The Art Ed Maker Meetup was an interactive follow-up session scheduled face-to-face in April 2017. Prior to the meetup, emails were sent to participants to promote the meetup session and also posed questions about issues, new practices, and asked participants to share the maker experiences they’d engaged in since the initial camp in August. The face-to-face session in April 2017 was held in conjunction with a free university-sponsored EdTech conference; therefore, it allowed participants to collaboratively engage in hands-on “making” activities and discussion with other local area pre-service and in-service teachers from a variety of disciplines and contexts. Participants were asked to complete a third administration of The New Media Arts Self-Efficacy Survey and two participants were chosen to participate in a 45-minute interview.

**Results and Findings**

Results and findings are presented in three sections. First, the quantitative results of the first (pre-camp) and second (post-camp) administration of The New Media Arts Self-Efficacy Survey are presented. Second, the key findings from the focus group are presented. Lastly, quantitative and qualitative data are merged to form a case study vignette that illustrates the personalized experience of one participant who completed each phase of the entire eight-month professional development program.

**Results from the New Media Arts Self-Efficacy Survey**

There were three administrations of The New Media Arts Self-Efficacy Survey (pre-camp, post-camp, meetup); however, only two participants completed the third administration after the meetup and those scores are not included in the results here. Table 1 shows the mean ratings averaged across all participant responses to each of the 16 survey items on both the pre- and post-tests, the mean change in participant’s response scores, and the t-test for the change scores with the associated p-values. This survey uses a Likert scale (ranging from 1 = strongly agree to 5 = strongly disagree) with lower responses indicating that participants more strongly agreed with the item and higher responses indicating that participants more strongly disagreed with the item.

There were changes in ratings for two of the items that are significant at the traditional alpha of 0.05: Item 2 ($t[13] = -1.79, p = 0.048, d = 0.48$) and Item 5 ($t[13] = -4.84, p = 0.0002, d = 1.29$). The change in ratings for Item 2 (I know the necessary steps to teach new media effectively) indicates that participants felt more knowledgeable about the steps required to teach New Media Arts after the two-day camp than before; with is a medium effect size. The change in ratings for Item 5, which was negatively worded (I wonder if I have the necessary skills to teach New Media Arts), indicates that participants felt less confident about actually teaching New Media Arts after completion of the
camp; with is a large effect size. Because of the 16 comparisons conducted, a Bonferroni correction was applied, which changed the critical alpha from 0.05 to 0.003. This conservative correction means that only the change in ratings for Item 5 can be considered statistically significant. Implications of this change are discussed in the Discussion section below.

Table 1. Mean Scores and Change Scores for Pre-Camp and Post-Camp Administrations of The New Media Arts Self-Efficacy Survey

<table>
<thead>
<tr>
<th>Item</th>
<th>Pre-Camp Mean</th>
<th>Post-Camp Mean</th>
<th>Post-Pre Change Score Mean</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I am continually improving my new media teaching practice.</td>
<td>1.86</td>
<td>1.86</td>
<td>0.00</td>
<td>0.00</td>
<td>0.50</td>
</tr>
<tr>
<td>2. I know necessary steps to teach new media effectively.</td>
<td>2.43</td>
<td>2.23</td>
<td>-0.36</td>
<td>-1.79</td>
<td>0.048</td>
</tr>
<tr>
<td>3. I am confident that I can explain to students why new media experiments work.</td>
<td>2.21</td>
<td>2.29</td>
<td>0.07</td>
<td>0.29</td>
<td>0.612</td>
</tr>
<tr>
<td>4. I am confident that I can teach new media effectively.</td>
<td>2.07</td>
<td>2.36</td>
<td>0.36</td>
<td>0.36</td>
<td>0.291</td>
</tr>
<tr>
<td>5. I wonder if I have the necessary skills to teach new media.*</td>
<td>3.36</td>
<td>2.71</td>
<td>-0.64</td>
<td>-4.84</td>
<td>0.00</td>
</tr>
<tr>
<td>6. It is important for students to develop problem-solving strategies through</td>
<td>1.07</td>
<td>1.23</td>
<td>0.17</td>
<td>0.56</td>
<td>0.709</td>
</tr>
<tr>
<td>7. It is important for students to work in small groups.</td>
<td>1.43</td>
<td>1.50</td>
<td>0.07</td>
<td>0.56</td>
<td>0.709</td>
</tr>
<tr>
<td>8. It is important for students to make predictions that can be tested.</td>
<td>1.36</td>
<td>1.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.50</td>
</tr>
<tr>
<td>9. It is important for students to make careful observations or measurements.</td>
<td>1.36</td>
<td>1.23</td>
<td>-0.13</td>
<td>-1.38</td>
<td>0.095</td>
</tr>
<tr>
<td>10. It is important for students to use tools to gather data (e.g. calculators, computers, scales, rules, compasses, etc.).</td>
<td>1.38</td>
<td>1.46</td>
<td>0.07</td>
<td>0.43</td>
<td>0.664</td>
</tr>
<tr>
<td>11. It is important for students to recognize patterns in data and the world around them.</td>
<td>1.29</td>
<td>1.38</td>
<td>0.00</td>
<td>0.00</td>
<td>0.50</td>
</tr>
<tr>
<td>12. It is important for students to create reasonable explanations of results of an experiment or investigation.</td>
<td>1.38</td>
<td>1.29</td>
<td>0.00</td>
<td>0.00</td>
<td>0.50</td>
</tr>
<tr>
<td>13. It is important for students to engage in content-driven dialogue.</td>
<td>1.21</td>
<td>1.36</td>
<td>0.14</td>
<td>1.00</td>
<td>0.832</td>
</tr>
<tr>
<td>14. It is important for students to reason abstractly.</td>
<td>1.21</td>
<td>1.23</td>
<td>-0.07</td>
<td>-0.56</td>
<td>0.291</td>
</tr>
<tr>
<td>15. It is important for students to reason quantitatively.</td>
<td>1.29</td>
<td>1.29</td>
<td>0.00</td>
<td>0.00</td>
<td>0.50</td>
</tr>
<tr>
<td>16. It is important for students to critique the reasoning of others.</td>
<td>1.21</td>
<td>1.21</td>
<td>0.00</td>
<td>0.00</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Note: The New Media Arts Self-Efficacy Survey used Likert-scale where lower numbers indicate stronger agreement. * indicates the question was negatively worded.

Findings From Focus Group

The semi-structured focus group was conducted at the conclusion of day two of the Maker Camp. Facilitators asked participants to discuss the ways in which the two-day camp impacted the way they thought about their teaching practice, their visual arts content, and their willingness to bring STEM disciplines into their visual arts classroom. Thematic analysis revealed that participants had positive reactions to the immersive two-day camp, including recognition that they had developed technical confidence, were able to see multidisciplinary connections, and had a willingness to collaborate with STEM teachers in order to impact student learning.

Developing technical confidence. Most of the participants indicated that they were engaging with unfamiliar tools and techniques, which they shared was both interesting and daunting at the same time. However, there were 30 instances where participants expressed they were thinking about teaching practices in new ways, which they agreed was rooted in the intrinsic desire to develop technical confidence. Participant 1 shared that the two-day camp “helped me to experience what kids go through as they struggle through a new process.” Many agreed with smiles and laughs...
as they were reminded that being a learner can be difficult at times. Because of this, the group jointly acknowledged that technical confidence can take time and practice in order to develop, which Participant 4 shared “I am more open to allowing time for exploration and tinkering in the art class instead of always expecting a product.” Participant 2 agreed that “having more time [to practice] in more technical areas allowed it to set in and [took] the intimidation out of it.” Through this ability to be immersed for two days, participants made several comments about how they felt ready to integrate it into lessons, such as, “I have expanded my knowledge in the area of digital media and electronics. That gain will transfer to my lesson planning” (Participant 9).

**Seeing multidisciplinary connections.** Thinking about visual arts content in relation to STEM can be a challenge at times, especially for those who might feel unconfident in their understanding of STEM or feel annoyed by what they view as “acronym clichés like STEM, STEAM, STREAM” (Participant 7). There were 18 instances where participants mentioned a positive reaction to or newfound realization of the connections between visual arts and STEM concepts, including Participant 12’s admittance that the immersive experience had “totally taken me by surprise...I normally would not touch these topics and projects.” Participant 10 verbalized that the experience brought greater awareness to the importance of global vocabulary” or the intersectionality of vocabulary and concepts among these multidisciplinary contexts. In agreement, several participants acknowledged that paying more attention to design process allowed them to see the integration of many STEM concepts embedded within the process as opposed to just looking for multidisciplinary concepts that were visible in the end product (Participant 4, Participant 9, Participant 10, and Participant 15). Seeing the breadth of STEM concepts within the visual arts content Participant 7 shared, “I have a broader content than I realized.” Participant 4 elaborated, “I am thinking more about how art is a natural partner to math and science, instead of completely separate. Art lends itself to scientific process!” Similarly, Participant 15 shared, “I’ve always linked art with science and math interdisciplinary concepts but these STEM-infused art activities with open-ended results are genius.” Participant 1 admitted that the immersive experience “makes me value the STEAM approach and see how to make the technology much more strongly connected to artistic expression and aesthetics.” This acknowledgement that one could embrace of multidisciplinary STEM connections while also prioritizing the "A" for visual arts was a grand revelation for the participants.

**Collaborating to impact student learning.** Inspiration was a major theme for the focus group resulting in 15 instances. This was expressed both in a general sense of being inspired to integrate what they had learned during the two-day camp and being inspired to reach out to their STEM colleagues at work. Armed with awareness of and an understanding of a “global vocabulary” (Participant 10) made participants feel they could “collaborate with STEM teachers” (Participant 5) and approach STEM colleagues for assistance. This willingness to bring STEM disciplines into the visual arts room was agreed upon by all participants, which Participant 6 said she wanted to “incorporate STEAM throughout the school.” Participant 3 elaborated, “I feel like I am very willing to incorporate other disciplines into my art lessons, but this PD has shown me many ways I can help my other classroom teachers incorporate art, creativity, and innovation into their areas too.” Laughing, Participant 4 shared, “I’m so excited to integrate STEAM activities into my art studio! I’ve already contacted my FLI (Facilitator of learning and Innovation) today about incorporating STEAM challenge boxes into my free-time activities!”

**Case Study Vignettes**

One participant was chosen to highlight as a case study vignette. He participated in each phase of the eight-month project including, attending the two-day camp, continuing involvement through email correspondence between face-to-face sessions, attending the Meetup session, completing the survey a third time, and participating in the retrospective interview at the conclusion of the project in April 2017. Findings from face-to-face observations using *The Learning Dimensions Framework* (TLDF) and retrospective interview are woven in with the aforementioned data results for the case study below.

**Charlie (Participant 9).** Charlie (pseudonym) had been teaching middle school art in a large urban area for 13 years. His pre-camp survey score average (1.6875) showed that he already valued STEM-infused practices and New Media Arts techniques going into the two-day Maker Camp. He was consistently observed demonstrating the four learning dimensions associated with maker-related behaviors, such as engagement, initiative and intentionality, social scaffolding, and development of understanding. For example, he frequently tinkered and played with his materials in order to develop unique strategies for creation (TLDF: initiative and intentionality). Always willing to share his creations and talk about his design process (see Figure 1), Charlie displayed many positive emotions and motivational behaviors (TLDF: engagement). He also actively described things he was noticing during his experimental process and would talk to others around him about process and problem-solving (TLDF: social scaffolding). Throughout the two-day camp Charlie excelled at verbalizing connections between visual arts, New Media Arts, and STEM, often posing questions about how he might adjust his pedagogy to enhance student learning with the activities (TLDF: understanding). His post-camp survey score average (1.5) showed a slight positive increase after the two-day camp.
Charlie frequently emailed the research team photos between the face-to-face sessions to share New Media Arts projects that he and his middle school students were completing in his visual arts classroom. Figure 2 shows an example that accompanied an email in which Charlie reported that he "researched ways of teaching practical circuitry" and how he used "old ties to create circuit bracelets" (email, November 2016). Figure 2 also shows an example of his students' work, which he said involved "transforming their own kirigami paper sculptures into wooden stabiles inspired by Alexander Calder. These will go on display at the McNay's Spotlight Exhibition in May." (email, March 2017).

Figure 1. Charlie's demonstration of New Media Art processes during the two-day camp. Left: Visual literacy activity combining images and text using Silhouette Studio and Silhouette Cameo. Right: Artbot activity creating a moving mark-making machine using 3-volt battery, DC motor, tape, drawing tools, and paper.

Figure 2. New Media artifacts created by Charlie's middle school students. Left: Student-created circuit bracelet made with menswear tie, conductive thread, LED lights, and snap. Right: Student-created sculpture made with laser-cut plywood and acrylic paint.
Charlie's 3rd survey response showed an increase in self-efficacy with an ending survey score average of 1.25, which was a .25 change from the 2nd survey response. In the retrospective interview, Charlie thoughtfully spoke of his confidence in and willingness to embrace new strategies, "I'm trying to develop lessons that aren't experimental only. I want students to be able to combine traditional art making knowledge and skills with the emerging possibilities of new media." Despite Charlie's consistent demonstration of maker-related behaviors and high self-efficacy scores, he said in the interview that "time is my adversary and my self-confidence is always wavering."

**Discussion**

**Connections between visual arts practices and STEM practices.** Bequette and Bequette (2012) state that "examining how artists mix art, science, technology, and math in imaginative artworks can blur boundaries between art, design, and STEM disciplines" (p 43). Visual arts teacher, by nature, already see connections in their content, context, and practice. That said, the survey results did not show significant changes in the ways that participants reported how they valued STEM practices and they didn't quantify a change in value in relation to their view of visual arts, New Media Arts, and STEM practices. This result could occur for several reasons. First and foremost, many of the responses were already strong (average = 1.38, 1.21) before the camp started so a ceiling effect may be responsible for the small gains observed for this aspect of the survey data. Also, the 5-point Likert scale may be too small to identify small changes in confidence. Additionally, there were only 16 participants; therefore, participant sampling was a limitation. The intent of this exploratory study was not to have as many participants as possible, rather the intent was to have a small group to explore over the course of the year. Despite the lack of tangible survey results, the focus group participants made many statements about newfound realizations and multidisciplinary connections between visual arts, New Media Arts, and STEM concepts and practices.

**Self-efficacy toward integrating STEM-infused New Media Arts into visual arts curricula.** Only one survey item was significant in which participants reported a slightly decreased confidence in teaching New Media Arts after the completion of the two-day camp. By itself, this appears to be contrary to the research hypothesis; however, when coupled with the qualitative data it becomes apparent that this particular self-efficacy construct (perceptions of one's ability to teach New Media Arts) is constantly wavering. Despite reporting on the post-camp survey that they had slightly lowered perceptions of their technical competence, participants discussed in the focus group that they had developed technical confidence, which they described as being the most important step toward attempting STEM-infused "maker" activity integration. Conversations that arose during the focus group illustrated that participants were constantly questioning themselves and their ability to teach New Media Arts in a meaningful way. This was interpreted during the focus group as a positive reflective practice behavior as opposed to the way it was interpreted on the survey as a negative self-efficacy behavior. This suggests that participants may have reconsidered their levels of confidence on the second administration of the survey after they grappled with the difficulties of being a learner again with unfamiliar tools and processes. However, their verbalization of seeing multidisciplinary connections and increased willingness to reach out to STEM colleagues showed that participants realized these efforts would require collaboration beyond their solo abilities and efforts.

Charlie represented a model participant because he participated in each phase of the eight-month project including, attending the two-day camp, continuing involvement through email correspondence between face-to-face sessions, attending the Meetup session, completing the survey a third time, and participating in the retrospective interview at the conclusion of the project. Despite his high aptitude, positive enthusiasm, and continuously active participation, even Charlie exhibited moments of questioning his own self-efficacy (both on the survey and in the interview). This suggests that a negative view of one's self-efficacy (either qualitative or quantitative) does not necessarily represent a disconnection between visual arts, New Media Arts, and STEM practices. In essence, everyone's self-efficacy falters but what matters is how they persevere in the face of challenge.

**Conclusion**

This mixed methods project examined the impact of an eight-month Art Ed Maker PD experience focused on STEM-infused “maker” activities using New Media Arts, specifically looking at the ways in which participants made connections between visual arts practices and STEM practices, and developed self-efficacy toward integrating STEM-infused "maker" activities into their visual arts curricula using New Media Arts. Participants reported that they developed technical confidence, were able to see multidisciplinary connections between New Media Arts, visual arts, and STEM, and had a willingness to collaborate with STEM teachers in order to impact student learning. Collectively
participants viewed these concepts as key to increasing their confidence and ability to use New Media Arts to integrate STEM-infused "maker" activities into their visual arts curricula, which is in line with many theoretical studies that present the learning value of these types of "maker" experiences (Clapp, Ross, Ryan, & Tishman, 2017; Halverson & Sheridan, 2014). This study provides valuable insight into how professional development experiences can positively impact self-efficacy in order to enable art teachers (and those in other non-STEM/humanities areas) to successfully integrate the fundamental elements, tools, and STEM content that these New Media Arts “maker” activities utilize; thus, promoting broader access to quality multidisciplinary learning experiences.

**Acknowledgements**

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**References**


Teacher Experiences with Professional Development for Technology Integration at a K-12 Independent School: A Multi-Case Study

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Abstract: K-12 schools in the US have been challenged by a recent national trend for preparing students for success in the 21st century. Effective technology integration has risen to the forefront of education reform. Many schools turn to PD to train teachers for technology integration. Despite its importance, the current literature has not reached a consensus about how to best address teachers’ learning needs with PD. Independent schools are not immune to the pressure from these national trends. According to the National Association of Independent Schools (NAIS), independent schools are non-profit private schools that are self-determining in mission and program, governed by independent boards, and funded primarily through tuition, charitable contributions, and endowment income (NAIS, 2017). Although independent schools educate 10% of all students in the US, they are overlooked in the current literature. Little is known about PD at independent schools, and teachers’ experiences need to be studied in-depth to determine how to meet their learning needs. This qualitative study explored seven independent-school teachers’ experiences with PD for technology integration through the lens of diffusion theory. Data were collected through a survey of innovativeness, lesson observations, and teacher interviews. Data were analyzed using open coding and axial coding, resulting in the identification of themes for each case and across all seven cases. The findings revealed that participants had varied experiences with PD for technology based on their innovativeness. This current study extends the current literature by identifying teachers’ differing learning needs and suggests relevant considerations for improving technology integration within PD settings.

Introduction

In the public-school arena, much attention has been placed on recent initiatives that have aimed to raise standards to prepare all students for college and careers, to invest in our country’s teachers and school leaders, and to turn around the lowest-performing schools (U.S. Department of Education, 2014). These initiatives have imposed significant changes on public school teachers, especially as they learn to integrate technological innovations (Lavenia, Cohen-Vogel, & Lang, 2015). Independent-schools have not been excluded from this national trend; they are also facing similar pushes toward raising achievement, improving teaching and learning, and increasing access to innovative technologies. Like their public-school counterparts, independent-school teachers are at the center of this change process. They are being required to evolve in an era of continuous innovation, often without the support they need to learn how to implement new ideas, particularly new technologies (Hall, 2016). Ultimately, today’s experienced teachers must continue to be learners themselves in order to keep up with new requirements, new technologies, and greater expectations of themselves and their students (Tondeur, Braak, Ertmer, & Ottenbreit-Leftwich, 2017).

Purpose of the Study

The purpose of this study was to examine independent-school teachers’ experiences with PD for technology integration and the role that PD plays in teachers’ integration of technology. The diffusion of innovations theoretical framework was used to guide the research design, data analysis, and interpretation of the findings for this study.
Research Questions

This study sought to answer the following three research questions:

1. What elements of professional development for technology integration impact teachers’ implementation of technological innovations?
2. How do independent-school teachers’ beliefs about technology impact their implementation of technological innovations?
3. How does the innovativeness of independent-school teachers impact their experiences with professional development for technology integration?

Method

This study used qualitative multi-case study to understand teachers’ experiences with professional development for technology integration. Creswell (2007) stated, a case study provides a good approach when the investigator has clearly identifiable cases with boundaries and seeks to provide an in-depth understanding of the cases. This current study focused on an extensive exploration of teachers’ professional development experiences and beliefs about technology integration through the lens of Rogers’ (2003) diffusion of innovations theory.

Study Site, Subject, and Participants

The study site was an independent K-12 school in the eastern U.S. During August of 2016, the school held a two-day technology workshop focusing on the introduction of a new learning management system (LMS), which served as the subject of the study. The workshop was structured to introduce several topics related to the LMS, provide demonstrations and examples for each topic, and allow time for teachers to explore each topic at their own pace. Forty teachers attended the workshop, representing a wide variety of grade levels and content areas. Seven teachers volunteered to participate in the study; these participants made up the representative seven cases for this current study.

Data Collection

Data were drawn from multiple sources to provide for an in-depth look at the seven cases being studied and to provide triangulation of data to ensure validity and reliability of the study (Creswell, 2007). Data were collected from an observation of the PD workshop, a participant survey about individual innovativeness, participant classroom observations, and individual participant interviews.

The survey was adapted from the Individual Innovativeness (II) measurement instrument (Hurt, Joseph, & Cook, 1977), which contains twenty statements about innovativeness and a five-point Likert scale (strongly disagree, disagree, neutral, agree, strongly agree) for respondents to select for each statement. This survey had previously been used to identify individuals’ innovation adopter categories and was evaluated psychometrically by Pallister and Foxall (1998). The survey was adapted to reflect the current study’s focus on innovation with instructional technologies, rather than general innovativeness. The participant classroom observations were scheduled between October and February of the 2016-2017 school year. The ISTE ICOT evaluation tool was used to guide the classroom observations (ISTE, 2008). After classroom observations, individual semi-structured interviews were conducted with all participants to allow for the collection of specific data while remaining flexible regarding the wording and order of questions (Merriam, 2009). Interviews were audio recorded with permission from the participants.

Data Analysis

The Individual Innovativeness measurement survey was scored according to the scoring guide provided by Hurt, Joseph, and Cook (1977). This provided an innovation adopter category for each teacher who completed the survey. Of the seven participants, there were three innovators, two early majority, one late majority, and one laggard. Data collected during each classroom observation using the ISTE ICOT evaluation tool were used to create a narrative description of each lesson that was observed. The audio recordings of individual interviews were transcribed and analyzed for each of the seven cases. On the first reading of each transcript, open coding was used to identify various aspects of the data. On the second reading of each transcript, axial coding was used to group codes into categories.
Findings

The findings of this study indicated that the participants had varied experiences with PD for technology integration and differed in their implementation of technology after attending PD based on their levels of innovativeness. The seven participants in the study represented four innovation adopter categories: innovators, early majority, late majority, and laggards (Rogers, 2003). Each category of adopters differed in their learning needs, epistemological beliefs, instructional strategies, technological skill levels, and perspectives about the benefits and drawbacks of technology.

The cross-case analysis identified three elements of PD that influenced teachers’ subsequent integration of technology: the structure of PD, the content of PD, and school support for PD. More specifically, depending on the innovativeness of individual participants, these three elements had a different manifestation in their classroom practices. The participants considered as innovators had a positive learning experience in terms of the structure and content of PD and a positive view of school support for PD, resulting in the belief that the PD was valuable to their technology integration in the classroom. The early majority also presented a positive experience with the PD structure and content, but they demonstrated a measured response to their PD experiences and cautious implementation of technologies within their classrooms. The participants who were considered late majority and laggard groups found the content of the PD to be beneficial, but they expressed the structure did not meet their instructional needs. Additionally, these participants generally had a negative view of school support and school priorities. This resulted in a less-positive view of the effectiveness of PD and a conscious decision to limit the technology integrated into their classes.

The findings for the second research question identified three areas of beliefs that informed participants’ technology integration: beliefs about the nature of teaching and learning; beliefs about innovative teaching strategies; and beliefs about the benefits and drawbacks of technology. Specifically, participants’ technology integration depended on their willingness to implement innovative practices. Those participants considered innovators believed that student-centered learning environments were most beneficial for their students, and they were willing to explore innovative instructional strategies within their classrooms. Innovators incorporated technologies that supported student-centered learning in their classrooms. The participants considered early majority believed that student-centered learning activities were most effective when they were incorporated as a supplement to teacher-centered direct instruction. The early majority minded teachers were also cautious about changing their teaching practices, preferring to use technology only when there was a clear benefit to students. The participants considered late majority and laggards held teacher-centered beliefs about their classrooms, and they were unlikely to change their instructional strategies to implement innovative teaching methods. In turn, they believed technology was beneficial when it clearly enhanced their established teaching and curriculum. Overall, the findings of this study suggest that participants’ core teaching beliefs were indicators of how they chose to integrate technology into their instructional practices.

The findings for the third research question identified several factors related to innovativeness that impacted participants’ experiences with PD for technology integration: skill levels and learning preferences, teaching methods, problem solving and change strategies, and access to technology experts. Depending on participants’ innovativeness, they had different experiences during PD and after PD as they integrated technologies. Those participants labeled innovators were self-directed learners who enjoyed exploring technology and experimenting with innovative tools in their classrooms, therefore, PD for technology integration was often considered a positive experience. The participants labeled early majority had varying experiences with PD. They needed formal PD to learn how to use new technologies, and they required additional support until they mastered various technical skills. The early majority participants approached PD with caution and were deliberate in their choices about integrating technology in their classrooms. The participants within the late majority and laggard groups relied on PD to learn the basic skills needed to implement required technologies. If they were not able to access help when they needed it, they were inclined to abandon technological innovations altogether. Overall, the above findings indicated that participants differ in their experiences with PD for technology integration based on their levels of innovativeness.
Discussion

Depending on a participant’s innovativeness, a teacher had a wide range of experiences with the PD workshop and integrating the technology afterwards in the classroom. As Merriam, Caffarella, and Baumgartner (2006) suggest, all adult learners come to a learning experience with their background, their personal experiences, and their beliefs. These factors for adult learners should be considered when planning and implementing professional development for in-service teachers.

The current study concurs that teachers have different learning needs based on their innovativeness. For example, the early majority experiences initial frustration or skepticism when they encounter technological innovations, but with support from others and enough time, they can make good decisions as they move through the adoption process (Crompton & Keane, 2012; Yuksel, 2015). During professional development, the early majority should be afforded the time and support they require to make decisions about integrating technologies. Similarly, the group of late majority and laggards are impacted by their beliefs about the value of technology in education. The current literature indicates that these teachers often remain skeptical about innovative technologies and are reluctant to put forth the time and energy it takes to learn to integrate a new technological tool (Crompton & Keane, 2012). When the late majority and laggards are offered individualized support, as they implement innovative technologies in their classrooms, they may have a more positive experience with professional development about technology.

Based on the results from this current study, previous research, and knowledge about adult education the following four suggestions for making improvements to the structure of professional development to meet the needs of innovation adopter categories are listed below:

- Observations of colleagues integrating technologies within their classrooms
- Collaboration with a more-innovative colleague to design a lesson using a specific technological tool
- Participation with direct support from a technology department member to co-teach a class that incorporates a new technological tool
- Participation in an online professional learning community that regularly meets and provides PD content as well as technical and pedagogical support to teachers

Additionally, integrating activities similar to these four suggested above would benefit members of the early majority, late majority, and laggard innovation adopter groups by providing the continuous support needed while learning to integrate educational technologies. These non-innovation teachers may be better equipped to grow in their technology integration with consistent, sustained support by colleagues and school-based technology experts, in conjunction with access to long-term professional learning experiences.

Conclusions

The overall findings of this study indicate how independent-school teachers’ experiences with PD for technology integration and subsequent implementation of technology differed depending on their established beliefs about innovativeness. In addressing these differences, it is paramount to consider how PD for both independent and public school teachers include technology integration that should be designed to align with each teacher’s level of innovativeness. Specifically, the structure and content of PD should address the varying learning needs of the teacher situated within the innovation adopter categories. As the previous literature and this current study suggest, professional development for technology integration should be a continuous process with well-planned follow-up and support, which play a crucial role in the continued growth of teachers’ technology integration (Camburn, 2010; Cole, Simkins, & Penuel, 2002; Ertmer & Ottenbreit-Leftwich, 2010; Glazer, Hannafin, & Song, 2005; Keller, Bonk, & Hew, 2005; Kopcha, 2012; Lawless & Pellegrino, 2007; Mouza, 2009; Pourreau, Shields, & Wright, 2012; Slabine, 2011; Sugar & Wilson, 2005). The design of professional development, teacher beliefs, and teacher innovativeness are core elements that interact with each other to influence teacher learning as related to instructional practices. Specifically, the interaction among design, PD, and innovation are part and parcel to the process of planning and implementing professional development for technology integration.
References


Evaluating University Facilitators’ Perceptions of Video as an Observational Tool

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Abstract: This paper is a report on the findings to evaluate university facilitators’ (UFs) perceptions of the use of video recordings as a means of teacher observation. The UFs who participated in this qualitative study used an asynchronous video observation tool, in addition to face-to-face observations, to observe teacher candidates during their internship. Results show that UFs perceive both benefits and challenges regarding the use of video as a tool for teacher observation, but see the most benefit in a combination of the two practices. UFs also remarked on the need to be purposeful about the format they use to implement video as an observational tool based on their own time-management needs. Implications for the field of teacher education and a call for additional research are discussed.

Introduction

For over thirty years, teacher observations have acted as a central feature in evaluating teachers and improving their practice (Krummel Reinking, 2015). Research has found that teacher observations can have positive impacts on both teacher performance and student achievement (Shaha, Glassett, & Copas, 2015). Effective teacher observations can encourage teachers to reflect upon and improve their practice, which in turn, can lead to a positive impact on student achievement.

Currently, the most common teacher observation model involves face-to-face observations. In the face-to-face model, a supervisor visits a classroom and observes the teacher at work while taking notes for later discussion. Shortly after the lesson, the supervisor and the teacher typically sit down for a post observation conference (POC), to discuss the lesson. This face-to-face observation model has been shown to be effective, but it is not without its challenges.

Research indicates that some of the major limitations to face-to-face teacher observations include: that they are time consuming for the supervisor, can be disruptive to the classroom environment, limiting in the number of classroom observers that can be present at any one time, and that they often involve extensive transportation costs (Heafner, Petty, & Hartshorne, 2011). Another limitation to the face-to-face observation model involves the POC. In the current model, the POC tends to be dominated by supervisor feedback and this pattern can result in the teacher becoming defensive and even resistant to supervisor feedback (Baecher, McCormack, & Shiao-Chuan Kung, 2014). This pattern of interaction can occur especially if the teacher and supervisor have differing perceptions and remembrances of a specific event and may result in decreasing the effectiveness of a teacher's self-reflection process (Baecher, et al.).

Although face to face teacher observations have been the staple in teacher evaluation for the past three decades (Krummel Reinking, 2015), more and more school systems appear to be incorporating video technology in their teacher evaluation process (Cuthrell, Steadman, Stapleton, & Hodge, 2016). In fact, the practice of video observation has become so popular that resources are being developed to aid schools in incorporating video
technology. One such resource, “The Video Observation Toolkit” was developed by the Harvard University Center for Education Policy Research as part of their Best Foot Forward (BFF) project. Their toolkit is designed to assist schools in integrating video observation technology for the purposes of teacher development (Shafer, 2015). The current popularity of video observation may be due to the wealth of research which suggests that incorporating video into the observation process may benefit the current teacher observation model (Colasante, 2011; Sonmez, D., & Hakverdi-Can, M. 2012; Shewell, 2014; Heafner, et al., 2011).

Benefits of Video Observation

Research indicates that incorporating video into the observation process may benefit the face-to-face observation model (Colasante, 2011; Sonmez, & Hakverdi-Can, 2012; Shewell, 2014; Heafner, et al., 2011). Studies indicate teachers were able to recognize the benefit of watching themselves in action through a video observation (Colasante; Sonmez & Hakyrdi-Can). After using video in observations, teachers highly recommended using video observation to improve teacher practices (Sonmez, & Hakverdi-Can). By viewing recorded video of their lesson, teachers commented on the benefits of being able to observe their teaching practices in “real time” (Sonmez, & Hakverdi-Can). Supervisors who used video observation generally reported that video-based evidence allowed teachers to have increased awareness of their own instructional behaviors that they might not have been cognizant of without the use of video (Shewell).

Research findings indicate that both synchronous and asynchronous use of video can improve the process of teacher self-reflection and evaluation (Marsh & Mitchell, 2014). Synchronous use of video implies that the supervisor and the teacher will view the video together, while asynchronous use of video implies that the supervisor and teacher view the video separately. Studies involving synchronous use of video suggest that when a teacher reviews video of their lesson with a supervisor, the typical POC dominated by supervisor feedback has the potential to be interrupted (Baecher et al., 2014). Moreover, post observation conferences can benefit from the use of video as videos can act as an undisputed and unbiased record of classroom interactions and can be more impactful and reliable in discussion than teacher memory alone (Sonmez & Hakverdi-Can, 2012). Studies reveal that the video documentation effectively presents classroom situations that might be difficult to explain verbally (Marsh & Mitchell).

Asynchronous use of video is also viewed as an effective instrument due to the notion that it allows teachers to review and reflect upon their own practice, and that of others, in a more convenient setting (Marsh & Mitchell, 2014). Further benefits of using video observation include improving teacher candidates’ ability to identify specific details in their teaching practices (Sonmez & Hakverdi-Can, 2012). Using recorded video has also been found to increase a teacher’s observation and evaluation skills (Sonmez & Hakverdi-Can). Supervisors who were involved with video observation studies noted the added value of video observations minimizing the disruption to the classroom environment and the decreased time and expenses associated with traveling to schools for teacher observations (Heafner, et al., 2011). A recent study at the Center for Educational Research Policy at Harvard University supports these findings for asynchronous video as an observational tool. Kane, Gehlbach, Greenberg, Quinn, and Thal (2015) reported that video can increase objective feedback to teachers, as well as allow administrators time to complete teacher observations on a more flexible schedule.

Improving Video Observation with Additional Technology

Research findings indicate that the benefits of video observation can be enhanced with the incorporation of additional technologies. One way to successfully enhance video observation is to focus the video usage through the editing and sharing of specific video segments (Shewell, 2014). Coupling video observation with annotation tools such as: the Media Annotation Tool (MAT) or DataCapture has been found to improve the quality of reflection and self-evaluation of teaching practice (Colasante, 2011; Shewell). Media annotation tools effectively categorize and catalogue specific portions of video to simplify the viewing process.

Limits of Video Observation

A large body of evidence indicates that video observation can effectively support teacher development, but it is not a panacea. Although studies have suggested several benefits to using video observation, research has revealed several limitations of video observation as well. Video observation is currently not seen as an effective replacement for face-to-face observations and supervisors admit that observing a lesson through video alone does limit their ability to experience a teacher in action (Baecher, et al., 2014). Research reveals that video observations made some teachers uncomfortable, which at times made it difficult for supervisors to provide effective feedback (Colasante, 2011;
Moreover, supervisors viewing the lesson on video reported feeling disconnected to the classroom experience at times (Baecher, et al.). Logistical challenges such as poor audio and video signals and inability of video to capture certain aspects of a lesson, like small-group work, also had the potential to negatively impact the video recording as well (Heafner, et al., 2011; Kane et al., 2015).

Furthermore, research findings indicate that simply using video during the teacher observation process does not necessarily guarantee teacher improvement. Video observation has been shown to generate deep, powerful reflection, but only through the interaction and discussion generated between viewers of the video (Marsh & Mitchell, 2014). Research identifies that the work that is conducted after the video observation is just as important as the video observation itself (Baecher, et al., 2014). A growing body of evidence points to the importance of quality discussion and reflection between the learners and their supervisors after being stimulated and informed by video viewing sessions (Marsh & Mitchell). When a study compared face-to-face observation with video observation, the researchers concluded that both models had benefits and limitations and that currently they are not effective substitutes for one another (Heafner, et al., 2011).

The Study

This study examined the perceptions of university facilitators (UFs) towards the use of video as a tool to observe teacher candidates during their internship semester. We looked specifically at the following research questions:

1. What do UFs perceive as the benefits and challenges of using video as an observational tool?
2. How has the use and availability of video impacted the practice of UFs as teacher educators?

Participants

UFs are responsible for supervising teacher candidates while they are completing their internship in a school placement. UFs can be either full-time or part-time faculty and observe teachers in various school settings. Seven UFs participated in this study. Six of the UFs were supervising Elementary (Pre K-6) teacher candidates and one was supervising Secondary teacher candidates (Gr. 6-12). Five of the UFs were full-time faculty. Two of the UFs were part-time faculty whose sole responsibility was supervising teacher candidates during their internship.

- Katherine is a full-time faculty supervising Elementary teacher candidates at two school sites. She has been a UF for over 10 years, and is supervising 10 teacher candidates.
- Caroline is a full-time faculty supervising Elementary teacher candidates. She has been a UF for two years and is currently supervising six teacher candidates.
- Martin is a full-time faculty supervising Elementary teacher candidates. He has been a UF for 12 years and is currently supervising six teacher candidates.
- Mary is a part-time faculty supervising Elementary teacher candidates. She has been a UF for two and a half years and is currently supervising five teacher candidates.
- Beth is a part-time faculty supervising Secondary teacher candidates. She has been a UF for one year and is currently supervising four teacher candidates.
- Louise is a full-time faculty supervising Elementary teacher candidates at two schools. She has been a UF for 17 years and is currently supervising 11 teacher candidates.
- Jessica is a full-time faculty supervising Elementary teacher candidates at two schools. She has been a UF for four years and is currently supervising three teacher candidates.

Video Observation Tool

All participants in this study used Edthena (https://www.edthena.com/) as the tool for uploading and sharing of videos. Edthena is a commercial product that enables teacher candidates to upload videos to a secure server. The UFs in this study used Edthena as an asynchronous observation tool, since they and their teacher candidates would each watch and comment on the videos at different times. This tool provides the teacher candidate with the ability to watch, reflect, and post comments on their uploaded videos. The UF can post comments on a candidate's videos, as well as anyone else that candidate chooses to invite (such as a classmate or their mentor teacher). Figure 1 shows the
Edthena tool. UFs can ask questions, make suggestions, comment on strengths, or add notes. The colored bands show where and what type of comments were made. Private comments that can only be seen by the candidate can be made by clicking on the third icon on the right side of the video.

Figure 1. Screenshot of Video in Edthena

UF Observation and Conference Methods

The UFs who participated in this study each used a combination of video and face-to-face observations when working with their teacher candidates. All UFs visited their candidates face-to-face at least once per week at the school site during each candidate’s internship semester and conducted informal observations. Six formal observations per intern were conducted each semester, the mentor teacher conducts four of these and the other two are conducted by the UF. A rubric is used during the formal observations. All of the UFs engaged in POCs immediately after face-to-face observations whenever possible.

In terms of videos, UFs had their candidates upload videos for the two formal observation lessons they had observed face-to-face, as well as two lessons in which they were not physically present. For those lessons in which the UF was not present, the teacher candidates were able to choose which lessons to upload. Once videos are uploaded, teacher candidates review their own videos and add comments. Afterwards, UFs log on to Edthena, comment on the videos, and provide candidates with an opportunity to answer or address those comments via the online platform.

Data Collection

Data was collected through separate, semi-structured interviews with each university facilitator. UFs answered a series of questions related to their time as a facilitator, how they used video as an observational tool, and how they combined the use of video with face-to-face observations. UFs also commented on what they perceived to be the benefits and challenges of using video as an observational tool. Interviews lasted approximately 30-45 minutes.

Data Analysis

Interview data was analyzed using an emic, or insider approach to analysis. In an emic approach, the perspectives and the words of the participant are the starting point for analysis (Lett, 1990). According to Lett, “Emic
constructs are accounts, descriptions, and analyses expressed in terms of the conceptual schemes and categories regarded as meaningful and appropriate by the native members of the culture whose beliefs and behaviors are being studied” (p. 130). In this approach, themes or unexpected findings emerge from the words of the participants.

The first two researchers coded the interviews separately. The researchers met and discussed the various identified themes. Thirteen themes emerged from the data, based on ideas and concepts that repeated themselves across all seven participants. Table 1 contains the codes that emerged and the number of times each appears in the interview transcripts.

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<th>Martin</th>
<th>Mary</th>
<th>Beth</th>
<th>Louise</th>
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**Table 1.** Data Analysis Themes

The researchers then discussed what was important about each theme and how each related to the research questions. Similar themes were collapsed into six major categories: reflection, review, teacher candidate focus, time intensity, face-to-face vs. video observations, and purposeful implementation. The benefits and challenges of using video as an observational tool are reflected in each of these major themes.

**Results**

The six categories that emerged during data analysis all represent areas where UFs see benefits and challenges to the use of video as an observational tool.

**Reflection**

UFs found video as an observational tool to be beneficial in helping themselves and their teacher candidates achieve a deep and critical level of reflection. UFs noted that video allowed them and their candidates to focus on specific aspects of a lesson, ask more directed questions, and follow good research-based reflective practices. Caroline commented that as a facilitator, she does not always know what questions to ask candidates to think about at the time of a face-to-face observation. Using video she finds that, “there’s more time for me to reflect on what’s going on with
the use of Edthena, as opposed to having to wait and see...how to respond in the minute.” (Caroline, personal communication). Louise noted that the built-in lag time of video distances candidates from the lesson on which they are reflecting and allows them to focus on what they are interested in developing in their teaching practice. “I refrain from commenting first. And that’s because I want them to drive the reflection….I want the agency to be with them” (Louise, personal communication). Jessica encourages her teacher candidates to use different types of reflection when viewing their uploaded video clips. “Once they post the video, I ask them to comment first….they should go through and use the, you know, the three forms of reflection, critical, technical, and practical” (Jessica, personal communication).

UFs attributed this rich reflection during observation to the lag time that exists between when a video is filmed and when it is viewed, and the ability of UFs and candidates to pinpoint and comment on critical incidents during a lesson. These perceptions are consistent with current research findings that it is not the act of watching a recorded lesson itself that causes deeper reflection, but the discussions and interactions that video enables UFs and teacher candidates to have after the observation takes place (Marsh & Mitchell, 2014). The program in use in this study coupled the viewing of videos with an annotation tool for comment, further aiding in reflection (Colasante, 2011; Shewell, 2014). Katherine noted that the, “[video] just lets them drive the reflection a bit more than just me sitting and talking with them” (Katherine, personal communication). Mary finds that when her teacher candidates reflect with video, “there’s a different dynamic in the conversation. It’s, she says something, I comment, or I bring something else in and she comments, but there’s not a back and forth that’s natural” (Mary, personal communication). Other than the communication flow noted by Mary, there were no other drawbacks or challenges noted by participants for the use of video in the category of reflection.

Review

Similar to the reflection category, UFs found the ability to review lessons via video very beneficial, with no noted drawbacks. Katherine found not having to rely solely on her memory to be a “definite benefit”, and enabled her to better highlight both what candidates do well in a particular lesson and where they need improvement (Katherine, personal communication). Similarly, Martin commented that the ability to review a video enables him to catch critical incidents in a particular lesson that he can then discuss later when he debriefs with each candidate. “With the video it’s right there, like, that’s the timestamp” (Martin, personal communication). Mary found the review feature of a video helpful because it allowed her to see many more lessons than she would if she were not using any kind of video. “Edthena gives me a better eye into what [teacher candidates are] doing and how they’re doing it” (Mary, personal communication). Finally, Beth noted, “the opportunity to look at the video carefully, slowly, and multiple times gives me the confidence that I have done the right thing or I’ve made the right observation” (Beth, personal communication).

UFs found value, and describe their teacher candidates as finding value, in the ability to go back and review the precise events that happened during a lesson under observation. This is consistent with current research showing the benefits of video as recording an unbiased record of events (Sonmez & Hakverdi-Can, 2012). Katherine discussed the benefits her teacher candidates seem to find in the ability to review their lessons. “I think once interns, our students, get used to [video] by internship a number of them really invest and believe, okay this helps me professionally. I want to go back and see what I’m doing, I learn a lot from this” (Katherine, personal communication). Louise found that, “Edthena allows the teacher candidate to hear their own words. And I think that’s different than my telling them what they said” (Louise, personal communication). Jessica found a similar benefit in a teacher candidate’s ability to observe themselves teach and the language they used. “I do think there’s like the benefit of going back and picking up on….where there’s teacher language or behavior” (Jessica, personal communication).

Teacher Candidate Focus

Research shows teacher candidates can focus on their own instructional behaviors better when watching themselves on a video than they can via memory alone (Shewell, 2014). A common statement from UFs in this study was that teacher candidates tend to focus on those aspects of a lesson they feel went poorly, rather than those that went well. Facilitators felt that video allows candidates to focus on their strengths as well as those areas of their teaching they wish to improve. Katherine stated that the use of video “opens up for [teacher candidates] lots of things that they couldn’t see in the moment of the lesson” (Katherine, personal communication). Caroline noted that teacher candidates can be overly critical of themselves, and the use of video helps them refocus and reflect on what was positive in a given lesson. “So not only does it give them the chance to say, “okay, well it wasn’t as bad as I thought it was.” Or, “oh I really need to work on this.” But then they get the chance to reflect on it” (Caroline, personal communication). Louise felt that video helped teacher candidates develop a positive mindset by switching their focus to what they are
interested in developing in their own pedagogy. “There’s a tendency for them to pick apart what they’re doing poorly….so Edthena allows us to switch that a little and really, it’s that positive mindset piece” (Louise, personal communication). In this way, UFs in this study perceived the impact of video on teacher candidate focus to be a benefit. Video allowed teacher candidates to look at the whole picture of a lesson, instead of honing in on just elements they viewed as negative.

Two UFs also commented on the fact that video helps teacher candidates focus on what they feel is important in a lesson, and not worry about the presence of an observer in the room. Mary found a tendency for teacher candidates to focus on critical incidents when they comment on their own lessons. “The teacher candidate is not going to be commenting on, um, you know, the best practices in a good lesson from start to finish. She’s going to be commenting on more things that struck her as the lesson was going on, or as she reviewed the lesson” (Mary, personal communication). Beth found that “the video screen is still up and….they’re not worried about what I’m gonna see. Um, they’re just doing their job” (Beth, personal communication). For Beth, being videotaped did not seem to provide the same level of distraction for her teacher candidates as her own presence in the room during an observation.

**Time Intensity**

UFs perceived both benefits and drawbacks when it came to time intensity and video observations. One of the benefits came from times when UFs watched videos of lessons they had also observed face-to-face. Louise uses notes from her in-person observation to hone in on particular moments of a lesson on which she wants to comment, so she does not need to re-watch entire lessons. “I know where in the lesson I want to comment….I don’t have to watch a 45 minute lesson again….which would be exceedingly time intensive” (Louise, personal communication). This was important for Louise because she noted it cut down the time she needed to spend watching certain videos.

A drawback to the use of video as an observational tool was due to the overall time needed to review and comment on lessons for candidates. Katherine remarked that, “to watch even a 10 minute clip can take a half an hour to code” (Katherine, personal communication). Martin also noted it is easy to become overwhelmed with the amount of time it takes to review and comment on video observations. “Because [videos] can pile up quickly, and they take a long time” (Martin, personal communication). Research demonstrates that time intensity is typically viewed as a benefit when it comes to the use of video observations, because it decreases the time UFs spend traveling from one school site to another (Heafner, et al., 2011), as well as allowing UFs and teacher candidates to watch videos in a convenient setting and time (Marsh & Mitchell, 2014). The UFs who commented on the time intensity of watching and commenting on videos were all full-time faculty, indicating concerns about time-intensity differed between full-time and part-time faculty.

**Face-to-face vs. Video Observations**

The contrast of face-to face and video observations offered a variety of perceived benefits and drawbacks. University facilitators found that both video recordings and face-to-face observations are limited in what they can capture. In terms of benefit, Caroline contrasted the amount of time she spends taking notes between video and face-to-face observations. Caroline finds that face-to-face observations require her to take copious notes to try to capture every detail of the lesson. Video allows her to take keynotes because she knows the details of the lesson are being recorded (Caroline, personal communication). Beth commented that when teacher candidates were able to choose the lessons they upload for viewing, they are more confident and more engaged in the process of reflection on their practice (Beth, personal communication).

In terms of drawbacks, the nature of the video recording itself represented a challenge for some UFs. Katherine found that there are often technical limitations when watching taped lessons. “I mean, there are technical things. Like sometimes it’s really hard on a video to capture everything that’s going on. You can’t see documents, you might miss a student interaction” (Katherine, personal communication). Mary found that technical issues, like low volume and bad camera angle, are a limitation of using just video observation alone (Mary, personal communication). The concern over technical issues both in the recording itself and what the recording can capture reflect current research on the drawbacks of video observation (Heafner, et al., 2011).

When asked which they preferred, video or face-to-face observations, several UFs stated they preferred a combination of the two, and would be reluctant to give up one or the other type of observation. For Caroline, being physically present in the room for some observations is very important. “I wouldn’t want to not be there for formal observations because I think there’s some limitation to what [video] offers” (Caroline, personal communication). Louise also discussed the benefits of a combination of both video and face-to-face. “[I prefer] the combination [of video and face-to-face observation] because of the power it brings to critical reflection” (Louise, personal communication).
communication). Lastly Jessica also described the combination of the two observation methods as being very important to her as a facilitator. “So I prefer honestly like, the combo...I think it’s actually the hybrid between the two is what is actually needed” (Jessica, personal communication).

**Purposeful Implementation**

UFs who were full-time faculty and had been working with video for a number of years noted the ways they thought purposefully about how to use it for observations. Several UFs commented on the need to develop systematic techniques for reviewing video-recorded lessons. “I think something we’re still trying to figure out is how to maximize the tool” (Katherine, personal communication). Martin and Katherine specifically group teacher candidates into rotating pairs to view and comment on each other’s videos. Each week one candidate in a working pair will upload a 5-10 minute video, and the next week their partner will comment on that video. Previously Martin had all his candidates record and upload a video each week, but he found that it was easy to become overwhelmed with the amount of time it takes to review and comment on video observations. “One thing I’ve learned in the three or four years of using Edthena uh, is to be very thoughtful about how you use it” (Martin, personal communication). Caroline perceived that her candidates needed additional guidance when reflecting on their videos. In response, she strategically developed a guide for her students that works in conjunction with a specific practitioner text on teacher education. She felt that having a framework for video reflection was beneficial and created richer reflection for her teacher candidates. “Yeah the biggest challenge I think is how do you design it so it’s purposeful?....In terms of you know, knowing what to do that works and is valued by everyone?” (Caroline, personal communication). Martin, Katherine, and Caroline all expressed a desire to continue to refine how they use video as an observational tool in their practice as UFs.

**Discussion**

Research has shown that the use of video can help teacher candidates develop a deeper understanding of their teaching practice (Marsh & Mitchell, 2014). The UFs in this study expressed concern for how to best use video to improve teacher candidates’ teaching practice. Although many have been using video as an observational tool for several years, they are still struggling with how to integrate video observations with in-person observations. Several issues have emerged from this study.

First, is video a viable replacement for face-to-face observations? For many online teacher certificate programs, video observations are a common way for assessing teacher candidates. However, the UFs in this study favored a combination of video and in-person observations. They felt both were needed to ensure an accurate assessment of the teacher candidates, as the benefits of one observation type mitigate the drawbacks of the other. The finding that each observation method is incomplete in and of itself is consistent with current research that video is not an effective substitute for face-to-face observations or vice versa (Heafner, et al., 2011). Although six formal, face-to-face observations were conducted each semester, the mentor teacher conducted four of these. For online programs, in-person observations could be conducted by local school personals. More research is needed to determine the most advantageous balance between video and in-person observations.

The discussion by full-time UFs about the need for a systematic approach to how video is used as an observational tool indicates that simply having candidates use the technology for video observations is not enough to generate benefits. The perception of full-time UFs in this study is that the approach to using video as an observational tool must be purposeful and systematic to glean full benefits of the tool. Teacher candidates need to be taught how to view the videos and reflect on their teaching practice. Therefore, multiple opportunities to teach lessons and reflect on the videos need to be built into the teacher education program.

**Conclusion**

The use of video as an observation tool for teacher candidates is an area in need of further study. As technology improves, university facilitators will have more options for how to incorporate video into their observations that facilitate reflection and learning on the part of teacher candidates. The difference between video as an observational tool and traditional face-to-face observations seems similar to the difference of fishing with a line as opposed to fishing with a net: it comes down to what one is fishing for and how much one wants to catch. None of
the UFs who participated in this study preferred the sole use of video instead of face-to-face observations, but each discussed the benefits of combining video and face-to-face observations. Given the number of UFs who had to develop their own processes and methods for implementing video, it would be beneficial to examine the different ways video and face-to-face observations can be combined so that these two means of collecting data on teacher candidate performance can inform each other.

References


High School Teachers’ Self-Assessment of Their TPACK after Graduate Coursework: A Mixed Methods Evaluation

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Abstract: This paper describes a study of high school teachers’ Technological, Pedagogical and Content Knowledge (TPACK) following coursework in educational technology and project-based learning. The coursework was part of a novel pathway of a Master’s program in Curriculum and Instruction to prepare teachers to set academic learning in the context of real-world situations relevant to the workplace. Eighteen teachers completed the instructional activities, and complete data sets and informed consent were obtained from fifteen. The study used a quantitative method, a survey of TPACK (at the beginning and end of instruction) together with a qualitative method, a Graphical Analysis of TPACK Instrument (at the end of instruction). The TPACK survey showed statistically significant changes in most subscales, including large effect sizes on scales related to Technological Pedagogical Knowledge and TPACK. The complementary GATI instrument provided self-reflections extending the surveys. A comparison of the two methodologies illuminates strengths and limitations of each.

Introduction

Efforts to develop programs to prepare teachers to use technology in their teaching lead also to questions how to assess those efforts, as well as to questions regarding the strengths and limitations of particular methodologies available. A prevalent construct for assessing teachers’ knowledge for integrating educational technologies is Technological Pedagogical and Content Knowledge (TPACK; Koehler & Mishra, 2008, 2009; Koehler, Shin, & Mishra, 2011; Herring, Koehler, & Mishra, 2016). This study uses TPACK as a framework to assess teachers’ learning in a course in a graduate program. We first review the context of the study, and then describe research questions and methods used for assessing teachers’ TPACK.

The study is set in the context of a teacher education program in the area of Linked Learning, an emerging area for teacher preparation. Linked Learning is an approach to education designed to help students see connections between their academic learning and real-world contexts. Linked Learning is an overall framework based on combining rigorous academics, technical training, work-based learning, and comprehensive support services (Linked Learning Alliance, n. d.; Warner et al., 2016). A pedagogical method that aligns well with goals of Linked Learning is project-based learning (PBL). PBL can provide authentic contexts with real-world and cognitively complex problems, help students link current and new knowledge, and provide a motivating social context (Blumenfeld et al., 1991). Further, educational technologies align well with PBL: They can be used as a tool for analyzing problems, constructing artifacts, and sharing artifacts (Blumenfeld et al., 1991). Educational technologies can also support Linked Learning goals of providing technical education relevant to careers. Although PBL, supported with educational technologies, is a natural fit for Linked Learning, the latter is broader than PBL. Linked Learning includes explicit goals and programs for supporting work-based learning, together with extensive support services, including counseling. Also, although the major components of Linked Learning are not new, the concept of Linked Learning is to bundle these components. Research on Linked Learning has shown that this combination has beneficial outcomes for students, including increasing high school graduation rates (Warner et al., 2016).

Linked Learning programs are available in 100 school districts in California and expanding outside the state to districts in Texas, Michigan, Massachusetts, and Canada (“Where Linked Learning is Happening”, n.d.). This process of adoption, in turn, creates a need for teacher preparation programs to develop the skills teachers need to be engaged in Linked Learning programs. To address this need, a new pathway in a Master’s program in Curriculum and Instruction was developed at a university in California. The pathway integrates Linked Learning ideas throughout the program, and it includes a 3-unit course in educational technology taken concurrently with a 3-unit course in curriculum and instruction introducing project-based learning. This study focuses in particular on teachers’ learning in the educational technology course, taken concurrently with the course on PBL.
The framework for the study is based on TPACK, which is an extension of the concept of pedagogical and content knowledge (Gudmundsdottir & Shulman, 1987) that adds the domain of technology (Fig. 1, below). A core construct of the framework is knowledge that combines three major domains: technology, pedagogy, and content. The TPACK framework has seven factors consisting of the various possible combinations of these domains of knowledge. Three factors correspond to knowledge of one of the three major domains: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). Three further factors correspond to knowledge that combines two of the major domains, that is, Pedagogical and Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological and Pedagogical Knowledge (TPK). The seventh factor corresponds to the combination of all three of these domains, that is, Technological, Pedagogical and Content Knowledge (TPACK).

![Figure 1. The TPACK Framework.](http://tpack.org) Reproduced by permission of the publisher, © 2012 by tpack.org

A variety of methods for assessing teachers’ TPACK are in use, including quantitative methods, particularly closed ended surveys (Schmidt et al., 2009), and qualitative methods (Tondeur et al., 2012) including analyses of teacher lesson plans or classroom behaviors. A relatively new qualitative method that was proposed by Foulger (2015) is the Graphical Analysis of TPACK Instrument (GATI). In the GATI method, teachers choose circles of different sizes to represent their knowledge of TK, CK, and PK. They then create diagrams in which they position circles to represent their knowledge and use the diagrams as a springboard for reflecting about their knowledge. Teachers can use this method to provide self-reflections about past, present, or desired future knowledge. As it fosters metacognitive reflection, GATI is also proposed as a tool for teacher professional development (Foulger, 2015; Krauskopf, Foulger, & Williams, 2018). Analyses using the GATI method have been reported regarding teachers in the US (Foulger, 2015; Adams & Bernal, 2016) and in a study using German teachers (Krauskopf, Foulger, & Williams, 2018).

In TPACK research, it can be useful to use not just a single method to assess teachers’ knowledge, but to use multiple methods. The use of multiple methods helps triangulate phenomenon being observed. It also helps highlight strengths and limitations of the different methods. The present study uses two different methods for assessing teachers’ self-assessments of their knowledge of TPACK. One is a quantitative method, based on a closed-ended TPACK survey. The other is a qualitative method, using GATI. The study investigates the following research questions:

1. As measured by surveys at the beginning and end of the course, are there statistically significant changes in teachers’ TPACK?
2. As measured by the end-of-course GATI process, what are teachers’ self-reflections about changes in their TPACK?
3. How do the findings using TPACK survey and GATI methods compare?

**Design of the Educational Technology Course**

As mentioned previously, the educational technology course was part of a novel pathway of a Master’s program in Curriculum and Instruction. This pathway aimed to support teachers in using project-based learning strategies to help them set their own students’ academic learning in the context of real-world situations relevant to the
workplace. As part of the pathway, teachers took the educational technology course concurrently with a course in curriculum and instruction that emphasized project based learning. The educational technology course also introduced applications of technology to PBL, and in this way, connected to that course.

The content of the educational technology course included material on using technologies in PBL. Teachers were shown videos about prominent high schools that used educational technologies in project-based learning, including Hi Tech High (Chula Vista, California) and Manor New Tech High (Manor, Texas). The course included material on various “literacies,” including information, media, digital, and visual literacies, that are part of 21st Century Skills (Partnership for 21st Century Skills, 2007; Pearlman, 2010). The course also introduced material related to integrating technology into teaching, including the Substitution Augmentation Modification Redefinition (SAMR) framework (Puente, 2006) and TPACK (Koehler & Mishra, 2009). In one assignment, teachers learned specific technological skills in small groups, and then conducted workshops for the other teachers about those skills. The topics included Google tools (e.g. Google Hangouts, Sheets, and Docs), web authoring and wiki tools, tools for online assessments, and audio editing tools for podcasting. In their presentations, teachers discussed both hands-on skills and educational applications. In a further assignment, teachers planned how they will use new technologies in their teaching, implemented their plans in their own classrooms, and evaluated the process. Some of the elements of the course, including teachers teaching technologies to one another and assignments in which teachers applied technologies to their own teaching, were used successfully in prior work (Adams, 2005). The course also included self-reflection activities, at the beginning and at end of the course, in which teachers assessed their TPACK and considered their goals for learning. These assessments are discussed further in the next section. The course used a hybrid format combining face-to-face and online meetings that include discussions of readings in small group activities. Online activities included interactions using Google Hangouts, text-based discussion boards, and Flipgrid, a kind of discussion board based on video segments (https://info.flipgrid.com/).

Methods

Participants

A total of 18 high school teachers completed the educational technology course (as well as the course taken concurrently in Curriculum and Instruction) in Spring, 2017. Of these, 17 agreed to participate in the study per an approved IRB protocol, and complete data was obtained for 15 participants. Of this group, 12 were women and 3 were men. All participants had bachelor’s degrees and teaching credentials. Their subjects taught included art, business, English, history/social science, Spanish, computer science, mathematics, and science. Their prior teaching experience averaged 8 years, and it ranged from 2 to 16 years. One of the authors was the participants’ instructor in the educational technology course, and it is possible that was an influence on the study. The coursework was offered in the second semester of a 1 ½ year program.

Methods

The present study used a mixed methods approach (Johnson & Onwuegbuzie, 2004). A TPACK survey was administered at the beginning and the end of the course. The survey used in the study was based on one by Chai, Ko, and Tsai (2010) and their survey was in turn derived from a TPACK survey by Schmidt et al (2009). Our survey followed the approach of Chai, Ko and Tsai (2010), who, citing the recommendations of Thorndike (2005) used a 7-point Likert scale (rather than a 5-point scale) to create a response tool that could allow the researcher to better discern results between choices. Responses ranged from “1” or “strongly disagree” to “7” or “strongly agree.” Also, the original survey by Schmidt et al (2009) had questions about content knowledge that referred to specific subject content areas taught by elementary teachers. Teachers in the present study were teaching a variety of subjects at the high school level. Chai et al. adapted Schmidt’s survey for use in high school subject areas by instead referring, in a general way, to two content areas. Their study was set in Singapore, and they referred to content areas as “CS1” and “CS2” — names that were used in that country in the teacher preparation curriculum. Our approach was similar to Chai et al., but instead of referring to “CS1” or “CS2” referred to teachers’ “primary content area.” For example, one of our question items read, “I can think about the subject matter like an expert who specializes in my primary content area.” For simplicity, our survey referred only to “my primary content area” and did not attempt to distinguish between knowledge of more than one content area.

Also, Chai et al. (2010) did not include items for the TPACK composite subscales TPK, PCK, and TCK, as these items were not a focus of their study. However, we did include a TPK scale with four items that were a focus of the course content, to assess learning in this area. These new questions were aligned with technologies introduced in the course and set in the context of applications of those technologies to teaching. Researchers have pointed out it can
be difficult to discriminate between the boundaries of the overlapping areas of TPACK (Graham, 2011). To simplify the survey, we did not add TPK or PCK to the survey by Chai et al. The original survey by Chai et al. had 18 items. We dropped three of their survey items, in particular if they referred to a second domain of knowledge. As mentioned previously, we added four items, related to TPK. Thus, after dropping three items and adding four, our survey had a total of 19 items. Each subscale had 3 to 5 items, whose values were averaged to determine the overall value for that subscale. The full survey is presented in Appendix 1.

As a way of reflecting on their TPACK, teachers created GATI diagrams at the beginning and end of the course. At the beginning of the course, teachers were asked to create diagrams reflecting their current knowledge. They were given sets of circles to represent their knowledge of Technology, Pedagogy, and Content. Lastly, teachers wrote written commentary reflecting on their diagrams and knowledge. At the end of the course, the process was similar, except the teachers were asked to create diagrams regarding three points in time: the beginning of the course, the end of the course, and their goal for one year after the course. Teachers wrote written reflections regarding why they made their diagrams the way they did. In the present study, only their end-of-course diagrams, in which they assessed their learning in the course, were analyzed. Directions for the GATI process are shown in Appendix 2 and were adapted from Foulger (2015).

Analysis

For the first research question, to check for statistically significant changes in teachers’ responses to survey questions at the beginning and the end of the course, paired t-tests were conducted. To check for effect sizes, Cohen’s $d$ was computed for these items and characterized with the convention small $\geq 0.20$, medium $\geq 0.50$, large $\geq 0.80$ (Cohen, 1992). For the second research question, one of the authors reviewed the GATI self-reflections, coding whether a change in knowledge on a TPACK subscale was identified. In addition, comments were coded that referred to ways of overlapping the circles. In Figure 1, the intersection of a Technology circle and a Pedagogy circle refers to Technological Pedagogical Knowledge (TPK). If, in a GATI diagram, a participant referred to the overlap of a Technology circle and a Pedagogy circle as referring to something that is consistent with TPK, this would be considered a comment “typical” of the TPACK framework. On the other hand, if a participant referred to placing a “content” circle on top of a “technology” circle because content was more important than technology, that was coded as a comment atypical of the TPACK framework. The comment would be coded as atypical of TPACK because the normative TPACK theory does not ascribe meanings to circles in this way.

For the third research question, the number of participants showing an increase on knowledge on a subscale was identified using both survey and GATI methods. Using surveys, participants’ mean responses on TPACK subscales were compared using data from the beginning and end of the course. If mean responses on a subscale were higher for a participant at the end of the course, that was coded as an increase of knowledge for that subscale. An analysis of self-reflections using the GATI method was likewise conducted to identify the self-reflections that referred to an increase in a subscale of TPACK. If a self-reflection explicitly referred to an increase of knowledge on a TPACK subscale, that was coded as an increase. For example, if a self-reflection stated, “my technology knowledge has definitely grown,” that was coded as an increase in technological knowledge. Also, a separate analysis was conducted for increases in the size or overlap of circles in a TPACK diagram. A larger circle for technology, pedagogy, or content was coded as evidence of an increase in knowledge of that domain. Also, an increase in the overlap of the technology and pedagogy circles was an indicator of perceived increase of TPK, and an increase in the overlap of all three circles was an indicator of perceived increase in TPACK.

Results

Question 1. As measured by surveys at the beginning and end of the course, are there statistically significant changes in teachers’ TPACK?

As discussed previously, the TPACK survey was based on one used by Chai et al. (2010), except that one new scale for TPK was added with questions aligned with content in the course. Table 1 presents an overview of the survey findings. There were statistically significant changes for all subscales except for TK. At the beginning of the course, the highest mean responses were in the areas of PK and CK, which had mean responses of 5.7 and 5.8, respectively. On the other hand, the lowest responses were in TK, TPK, and TPACK, which had mean responses of 4.7, 4.1, and 4.8, respectively. Comparing scores at the beginning and end of the course, the TPK and TPACK scales increased with large effect sizes ($d = 1.63$ and 0.93, respectively), while the TK scale did not increase significantly and had a small effect size ($d = 0.29$). The scales for Content Knowledge and Pedagogical Knowledge increased with medium effect sizes ($d = 0.44$ and 0.74, respectively).
Table 1: Changes in TPACK Survey Results Before and after Course
(1 = Strongly Disagree, and 7 = Strongly Agree)

<table>
<thead>
<tr>
<th>Knowledge Type</th>
<th>Pre</th>
<th>Post</th>
<th>Change (Post-Pre)</th>
<th>t</th>
<th>p</th>
<th>Cohen's d</th>
<th>Cohen's d size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological Knowledge (TK)</td>
<td>4.7</td>
<td>5.0</td>
<td>0.3</td>
<td>1.42</td>
<td>0.18</td>
<td>0.29</td>
<td>small</td>
</tr>
<tr>
<td>Technological Pedagogical Knowledge (TPK)</td>
<td>4.1</td>
<td>6.2</td>
<td>2.2</td>
<td>7.26</td>
<td>0.00</td>
<td>1.63</td>
<td>large</td>
</tr>
<tr>
<td>Content Knowledge (CK)</td>
<td>5.8</td>
<td>6.1</td>
<td>0.3</td>
<td>2.23</td>
<td>0.04</td>
<td>0.44</td>
<td>medium</td>
</tr>
<tr>
<td>Pedagogical Knowledge (PK)</td>
<td>5.7</td>
<td>6.2</td>
<td>0.5</td>
<td>2.77</td>
<td>0.02</td>
<td>0.74</td>
<td>medium</td>
</tr>
<tr>
<td>Technological, Pedagogical, and Content Knowledge (TPACK)</td>
<td>4.8</td>
<td>5.8</td>
<td>1.0</td>
<td>3.16</td>
<td>0.01</td>
<td>0.93</td>
<td>large</td>
</tr>
</tbody>
</table>

Question 2. As measured by the end-of-course GATI process, what are teachers’ self-reflections about changes in their knowledge of TPACK?

Figure 2 gives an example of a participant’s GATI diagram.

Figure 2. Example of a Teacher’s GATI Diagram

A common theme in teachers’ self-reflections about GATI diagrams is that at the beginning of their course the knowledge of technology was not as substantial as their knowledge of content or pedagogy, but that the educational technology course helped their knowledge of technology to increase. A teacher reflection following this pattern is listed below and linked to the “beginning of course” and “end of course” diagrams.

The only way they differ is the amount of technology I have learned. I had no clue there were options (Wix, Padlet, Flipgrid, Canva, etc.) that would all help my students be more creative and allow us to collaborate more efficiently.

Other written reflections also reflected this pattern:

For the first diagram, I chose fairly large circles for pedagogy and content because I was confident I knew the material and how to teach it. I felt strong in my abilities as a teacher to effectively teach my content. As for technology, I chose a smaller circle because I knew the basics of technology but not as much as I should know in a classroom setting.

For the second diagram, I chose all large circles, but they are not the largest circles in the pile. I feel that now, I feel more confident with technology in the classroom than I was at the beginning of the semester.

Teachers’ self-reflections also referred to an increase in their overall TPACK:

Overall, my main difference between the beginning of the course and now is that I’ve seen more connections to content and pedagogy. I've seen how technology (like PollEverywhere, Flipgrid, etc.) can be used to build content knowledge and in conjunction with pedagogy in my class.
In addition, teachers’ self-reflections identified ideas that informed their creation of GATI diagrams. These ideas concerned both the size of the circles and their positioning. First, one idea mentioned was to refrain from selecting the largest possible circle for a diagram, due to the possibility that there is still room for growth in knowledge: “I did not choose the largest circles because I feel that even as I am now, there is always room to improve an educate myself more on my content.” Also, although in most cases teachers used larger circles to indicate more knowledge, in one case, after learning more about technology, a teacher deliberately chose a smaller circle. This is because after learning more, the teacher realized that there was still more to learn: “The circles are smaller on #2 because I realized I can learn way more…. this whole program made me realize that I can learn waaaaaayyyy more.”

In addition to these ideas that informed the size of the circles chosen, teachers’ self-reflections also indicate considerations for deciding how to overlap the circles. Altogether, there were 15 instances of comments about overlapping circles, of which 11 instances were coded as “typical” of TPACK and 4 instances were coded as “atypical.” The ideas coded as “typical” were those that align with ideas represented by normative TPACK diagrams. For example, as noted previously, teachers used overlapping circles to indicate knowledge cutting across different domains, such as three overlapping circles to refer to knowledge combining technology, pedagogy, and content, or TPACK. On the other hand, in some cases teachers used overlapping circles to indicate other meanings—meanings that while reasonable and interesting are not typically intended by TPACK diagrams. For example, one teacher positioned a pedagogy circle behind a content circle to indicate that pedagogy was a “vehicle” for teaching content: “In the first diagram, pedagogy (Linked Learning) is behind content, demonstrating how the approach is the vehicle in teaching the content.”

3. How do the findings using TPACK survey and GATI methods compare?

Table 2 compares the number of participants showing an increase in knowledge using the GATI and TPACK methods. The first two columns pertain to the GATI analysis, and show (a) the number of participants making physical diagrams that indicated an increase in knowledge (as evidenced by an increase in the size of a circle or the overlap of circles), (b) the number of participants giving written reflections that showed an increase in knowledge. For the domains TK, TPK, CK, and PK, the number of diagrams showing an increase in knowledge ranged from 5 to 9, while the number of reflections showing an increase in knowledge ranged from 13 to 15. Thus, for each of these domains, more participants were identified as having an increase of knowledge using the “written reflections” method than were by the “diagram” method. On the other hand, for the TPACK domain, the number of participants identified as having an increase in knowledge as shown by their diagram (12), was higher than the number of participants showing an explicit increase in TPACK in their written reflections (9).

<table>
<thead>
<tr>
<th>TPACK Area</th>
<th>A. GATI Diagrams</th>
<th>B. GATI Written Reflections</th>
<th>C. TPACK Surveys</th>
<th>Difference (C – B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TK</td>
<td>9</td>
<td>15</td>
<td>10</td>
<td>-5</td>
</tr>
<tr>
<td>TPK</td>
<td>5</td>
<td>14</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>CK</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>PK</td>
<td>8</td>
<td>13</td>
<td>12</td>
<td>-1</td>
</tr>
<tr>
<td>TPACK</td>
<td>12</td>
<td>9</td>
<td>12</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2: Comparison of Number of Participants Showing and Increase in Knowledge Using TPACK Survey and GATI Methods

The latter two columns of Table 2 compare the number of participants showing an increase of knowledge using the GATI written reflections with the number of participants showing an increase in knowledge based on TPACK surveys. In the last column of the table, the TPACK domain that had the largest discrepancy between the two methods was technological knowledge (TK). In GATI reflections, all 15 participants referred to an increase in technological knowledge, but only 10 participants showed an increase in TK in TPACK surveys, a difference of five participants. As noted previously, the questions on the TK scale, like all other scales except for the TPK scale, were based on the survey by Chai et al. (2010) and were not based specifically on content of the course being investigated. The domain with the second largest discrepancy was that of TPACK. In this area, 9 participants referred to an increase in TPACK in their GATI written reflections, but 12 participants showed an increase in knowledge on TPACK surveys.
and in their GATI diagrams. In the other domains (TPK, CK, and PK), the number of participants showing an increase in knowledge differed was within one person in either direction.

**Conclusion and Implications**

Using a TPACK survey based on one published by Chai et al. (2010), this study found evidence of statistically significant increases in teachers’ knowledge in four of the five TPACK scales assessed, but not TK. Also, GATI self-reflections showed increases in knowledge for most teachers in all areas of this TPACK survey. Further, the TPK scale we created to align with course objectives also showed statistically significant increases. These findings are a promising indicator of teachers’ learning. The large effect sizes seen in the TPACK and TPK scales (0.93 and 1.63) are encouraging. The effect size for the TPACK scale is in line with some other studies of professional development for in-service teachers. For example, a study of a professional development program for in-service teachers involving a much more extensive intervention—nine courses concerning educational technology—resulted in an effect size of 0.75 (Lehiste, 2015). Also, a professional development program with eight days of instruction plus further activities in which teachers began integrating technologies into their classroom resulted in effect size for TPACK of 0.84 (Graham et al., 2009). Identifying the reasons for the increase in TPACK in the professional development program is beyond the scope of the present study, but a topic for subsequent research. We conjecture that part of the reason for the effect size in our program was that teachers were engaged with applying new ways of using technologies learned in the course into their own teaching.

That said, further questions remain regarding how specific course activities may have fostered these changes. In a subsequent phase of this work, we are addressing this question using other data sources, including interviews with teachers. Also, although the TPACK survey method is quantitative and the GATI method is qualitative in nature, both measures address teachers’ self-perceptions of their knowledge. Self-reports may not necessarily be indicative of teachers’ classroom behaviors, which could be investigated by including a measure of teachers’ lesson planning (Kopcha, Ottenbreit-Leftwich, Jung, & Baser, 2014). A subsequent stage of this research will analyze teachers’ use of technology in their lesson plans. As noted previously, GATI serves not only as an assessment purpose, but also an instructional purpose. The GATI process gives teachers a framework and process for explicitly reflecting on their knowledge. Thus, it is possible that the GATI process influenced teachers’ learning, by highlighting and prompting reflection about TPACK and its components. The potential impact of GATI on instruction could also be systematically investigated in future research.

Although there was not a significant increase on the TK scale, the GATI method did show evidence of an increase in TK. It seems likely that teachers’ TK increased, even if this was not identified by the survey method. Teachers’ GATI self-reflections explicitly referred to their view that their knowledge of technology increased. Also, both GATI and survey methods show an increase in TPACK. In addition, the survey scale we created for TPK shows and increase. TK is an important component of TPACK, and technologies are constantly changing. It is possible that the TK scale would have shown a statistically significant change with a larger sample size, but larger sample sizes are not always practical. In a factor analysis of the components of TPACK, Archambault & Barnett (2010) found that of the various domains of TPACK, the only domain that could be clearly separated out was Technological Knowledge. Our findings underscore that TPACK surveys with general items about TK may miss pertinent technological knowledge. These findings highlight the need to consider the alignment between question items about technological knowledge and the instructional situation being investigated.

Our approach of including GATI self-reflections in addition to a traditional, closed-form TPACK survey allowed us to compare results from these measures. The results from the GATI self-reflections tend to corroborate the overall findings from the survey results. The GATI method is relatively new, and our study highlights some considerations about it as an instrument for assessing TPACK. Because it is more open-ended, it is not prone to the kind of effects that occurred with the TK scale, in which the general TK items were less sensitive to the specific technology taught in the course. Using GATI, we considered explicit written reflections about a change in in area of TPACK to be direct evidence of their perceptions. A limitation of this approach is that teachers may overlook making an explicit reflection, even if their knowledge increased. For example, while the same number of teachers, 12, showed evidence of an increase in TPACK based on their TPACK surveys and their GATI diagrams, only 9 teachers explicitly referred to the change in TPACK in their written reflections. A possible refinement of the instructions used in the GATI method would be to explicitly prompt teachers to address changes in TPACK.

GATI addresses teachers’ overall impressions of their knowledge in various domains of TPACK. That said, the process of creating GATI diagrams with circles also allows the possibility of self-reflections that extend beyond meanings represented by normative TPACK diagrams. The normative TPACK diagram illustrates how different
domains of knowledge may interrelate, but the circles corresponding to the different domains do not move. In GATI, teachers move and position the circles and ascribe meeting to their decisions. What is perhaps more important than the actual diagrams teachers make is the self-reflections that teachers produce in the process of creating the diagrams. Our directions for creating the GATI diagrams did not explicitly discourage teachers from coming up with “creative” interpretations regarding the positioning of their circles for different knowledge domains. Researchers using GATI methods could elect to be more prescriptive or not, depending on their methodological goals.

Although TPACK studies have been done in a variety of settings, the present study is unique in that it is in the context of coursework that is part of a graduate program for teachers in Linked Learning. This context is noteworthy because there is a need for teacher preparation in this area, and educational technology aligns and supports overall goals of Linked Learning including fostering project-based learning and career technical education.

One limitation of the research is that the study did not include a control group. It is possible that there would be some effects from the TPACK survey results that are due to taking it twice, rather than to instructional activities. This is ameliorated to some degree by the use of multiple methods. Overall, results from the TPACK and GATI methods tended to corroborate one another. Also, there were statistically significant changes and moderate to large effect sizes in some areas of the TPACK survey. Altogether, this study contributes evidence that the instructional programs investigated led to increases in teachers’ TPACK and the components of TPACK it investigated. From a methodological standpoint, the study highlights that general TPACK survey questions about Technological Knowledge can miss knowledge of technology gained by participants. The study also illuminates benefits and characteristics of the GATI methodology.

References


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**Appendix 1: TPACK Survey Items**

Derived from a survey published by Chai, Ko, & Tsai (2010), who adapted them from Schmidt et al (2009).

**Technological Knowledge (TK)**
I know how to solve my own technical problems.

I can learn technology easily.

I have the technical skills I need to use technology.

I am able to use website editors to create and/or modify web pages.

**Content Knowledge (CK)**
I can think about the subject matter like an expert who specializes in my primary content area.

I have various ways and strategies of developing my understanding of my primary content area.

I have sufficient knowledge about my primary content area.

**Pedagogical Knowledge (PK)**
I can adapt my teaching style to different learners.

I can adapt my teaching based upon what students currently understand or do not understand.
I can use a wide range of teaching approaches in a classroom setting (collaborative learning, direct instruction, inquiry learning, problem/project based learning etc.).
I know how to assess student performance in a classroom.
I know how to organize and maintain classroom management.

**Technological, Pedagogical, and Content Knowledge (TPACK)**
I can teach lessons that appropriately combine my primary subject area, technologies and teaching approaches.
I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom.
I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn.

**New Items**

**Technological Pedagogical Knowledge (TPK)**
I can use Google tools (such as Google Docs, Sheets, or Forms) to support my teaching.
I can create web pages or wikis to support my teaching.
I can use web-based surveys to support my teaching.
I can use audio tools or podcasting to support my teaching.

**Appendix 2: GATI Self-Reflection Activity**
Adapted from the GATI Method Described by Foulger (2015)

In this activity, you will make and discuss 3 diagrams of your Technological, Pedagogical and Content Knowledge, for 3 points in time:
1. At the beginning of this course
2. At the end of this course (today)
3. Your goal for your knowledge one year from today.
   Please use the materials provided in class by the instructor. If you miss class, please see the instructor.

**Steps**
1. Please start with making a diagram of your knowledge at the beginning of the course. However, please do not check the diagram you made at the beginning of the course.
2. Each packet has circles of different sizes corresponding to knowledge of technology, pedagogy, and content. For each of the three sets of circles, choose one to represent your knowledge in this area compared to other teachers. Choose a larger circle to represent relatively more knowledge and a smaller circle to represent relatively less knowledge.
3. Position the circles in relation to one another to make a diagram of your technological, pedagogical and content knowledge. To represent knowledge that combines different categories, please position the circles to overlap. To represent a greater amount of knowledge that overlaps categories, make your circles overlap relatively more. It is up to you whether the circles overlap, and if so, how much to make them overlap. Use the labels in the packet to label your diagram for each of the three points of time listed above.
4. Take a photo of your diagram with a smart phone. Please take each photo such that the whole sheet of graph paper fills the photo.
5. Repeat the process to make a diagram for your knowledge today and take a photo of it.
6. Repeat the process to make a diagram for your goal for your knowledge one year from today and take a photo of it.
7. Insert all three pictures to a word processing file such as MS Word.
Transforming Teacher Preparation: Assessing Digital Learners’ Needs for Instruction in Dual Learning Environments

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Abstract: As traditional classrooms have expanded to include virtual learning environments, teachers’ acquisition of specific knowledge and skills for effective use of technology has become paramount. This research examines pre-service teachers’ needs relevant to integrating technology in an online learning environment and is a first step toward acknowledging the responsibility teacher preparation programs have in the formation of educators equipped to instruct in dual learning environments, providing opportunities to become fluent in the technological pedagogical content knowledge (TPACK) vital for online and traditional face-to-face instruction. The purpose of this study was to determine if active engagement with content of an online instruction module would affect the attitudes, knowledge and skills, and instructional centeredness of pre-service teachers towards technology integration in an online learning environment. A mixed-methods concurrent triangulation design procedure was conducted to evaluate the effect of engagement with the content of the online instruction module for all three domains. Participants made statistically significant gains upon completion of the intervention. The implementation of an intervention such as this online module supports teacher preparation programs in identifying strengths and weaknesses of their pre-service teachers, providing valuable information necessary to guide program goals and preparing for instruction in dual learning environments.

Keywords: Pre-service teacher, Teacher preparation, TPACK, Dual Learning Environments, Attitude, Knowledge and Skills, Instructional Centeredness

Introduction

This is an exciting time to be an educator. Every day we witness transformational changes in learning taking place in part by the affordances new technologies have provided in creating opportunities for learning that were never possible only a few years ago. “With greater technology access, online learning is already a daily activity in many U.S. schools” (Adams Becker et al., 2016, p.38) and hundreds of thousands of students pursue their education completely online (Gemin, Pape, Vashaw, and Watson, 2015). Innovative and global engagement, crossing geographical boundaries to gain new insight and share new knowledge with people across the globe, is redefining the traditional textbook and resources available in the classroom. However, is the current climate of preparation for educators to instruct in these new learning environments appropriate, reasonable, and justifiable?

It is widely understood that teachers tend to teach the way they were taught (Lee, 2008) and hence, we have an entire generation of new teachers who may know technology as consumers, for its social affordances, but most likely have not had the pedagogical experiences necessary to guarantee its continued effective use (Christensen and Knexek, 2017); Digital natives (Prensky, 2011) perhaps, but these neophyte educators are in desperate need of digital pedagogy and intentional experiences with technological pedagogical content knowledge (TPACK). It is conceivable that attention to curriculum design in teacher preparation programs focused on providing rich learning experiences promoting 21st century learning skills of creativity, collaboration, communication, and critical thinking (NEA; P21) and the modeling and observation of technology-rich learning environments (Kovalik, Kuo and Karpinski, 2013) would result in a positive step towards achieving our national educational goals while capitalizing on the affordances technology provides for nontraditional pedagogy.

The possibilities for meeting the needs of the 21st century digital learner have expanded beyond the traditional brick and mortar classroom to include virtual spaces, the online classroom and blended learning spaces. This research marks the beginning of a movement to acknowledge the immediate responsibility teacher educators
have for training pre-service teachers to be fluent in dual learning environments, to integrate technology effectively in both blended and online learning environments. Taking a programmatic approach to the integration of technology with specific attention to a variety of learning environments in teacher preparation may provide important gains in creating future-ready educators.

**Research Questions**

The goal of this research was to determine the effects of an online instruction module intervention on characteristics of pre-service teachers enrolled in a teacher preparation program relative to attitudes, knowledge and skills toward technology integration, and instructional centeredness in an online learning environment. The three domains, attitude, knowledge and skills, and instructional centeredness, are fundamental to the integration of technology and were observed in relation to the online learning environment. RQ1 and RQ4 were relative to the domain of Attitude, RQ2 and RQ5 were associated with the domain of Knowledge and Skills, while RQ3 and RQ6 correlated to the domain of Instructional Centeredness.

**RQ1.** In a teacher preparation program, what are the attitudes of pre-service teachers towards technology integration in an online learning environment?

**RQ2.** In a teacher preparation program, what are the knowledge and skills in technology integration of pre-service teachers in an online learning environment?

**RQ3.** In a teacher preparation program, what is the instructional focus of pre-service teachers in an online learning environment?

**RQ4.** What are the effects of an intervention on the attitudes of pre-service teachers towards technology integration in an online learning environment?

**RQ5.** What are the effects of an intervention on the knowledge and skills in technology integration of pre-service teachers in an online learning environment?

**RQ6.** What are the effects of an intervention on the instructional focus of pre-service teachers in an online learning environment?

**Literature Review**

The three domains of this research- attitudes, knowledge and skills, and instructional centeredness- are essential in the formation and development of teachers who are willing and able to serve the needs of digital learners. Traditionally, teacher preparation programs address the obvious learning space, that of the face-to-face classroom in a typical brick and mortar school. As the landscape of education changes to include virtual learning spaces, pre-service teachers need access to and experience with instructing in dual learning environments or both face-to-face and online. However, preparation for teaching in an online learning environment and the integration of technology required for this classroom space is a relatively new area of research.

In exploring the characterization of attitude, three aspects surfaced in the literature, namely readiness, habit and motivation. Attitude may be described as a readiness of the psyche to act or react in a certain way (Jung, 1921). Additionally, there exists a relationship between attitude and behavior (Eagly and Chaiken, 1998), which includes the component of habit. Finally, the motivation to respond or act in a certain way is an additional facet to the definition of attitude (Venkatesh, 2008). Factors associated with attitude included intrinsic and extrinsic barriers (Ertmer, 1999) that may act as barriers or bridges toward effective technology integration in an online learning environment. For instance, positive prior experiences in an online classroom as a student may affect the readiness and motivation to incorporate appropriate online pedagogy in instruction. Opportunities to train, practice, and rehearse through personal experience acts as a bridge to increase perceived usefulness of particular online strategies. Conversely, the absence of a positive personal experience or field experience in an online learning environment affects attitude by creating a barrier. This lack of opportunity to practice and a deprivation of familiarity with tools appropriate for this learning environment then negatively affects attitude toward integrating technology in an online classroom.

The knowledge and skills domain includes an investigation of the technological, pedagogical and content knowledge (TPACK) appropriate for the preparation of teachers to integrate effectively within these dual modes. Though research supports intentional integration of technology with its modeling and experiential opportunities in
blended and online learning environments, inadequate teacher preparation persists as researchers continue to report hesitancy and uncertainty regarding technology integration (Archambault, 2011; Gronseth, Brush, et al., 2010; Kovalik, Kuo and Karpinski, 2013) and a deficiency in the ability to create student-centered lessons (O’Connor, 2010). There is an urgent call for educators to be prepared to facilitate learning online (NEA, n.d.; Rice and Dawley, 2009; Kennedy and Archambault, 2012; Gunter and Gunter, 2014; Archambault et al., 2016).

Online learning is largely impacted by the orchestration of the instructor. The online instructor facilitates acquisition of knowledge and knowledge building within the three types of presence, Social, Cognitive, and Teaching presence in the online classroom. Effective online instructors deliberately attend to this Community of Inquiry (Garrison, Anderson, and Archer, 1999), intentionally combining these elements with web 2.0 to create a natural experience of a network environment. This framework contributes to the research for preparing teachers to instruct with the knowledge and skills necessary for an online learning environment and teacher preparation programs provide a pivotal starting point for educating technologically and pedagogically proficient teachers (Petri, Poyo, McVey, Smith, and Pratt, 2015).

The third domain of this research is Instructional Centeredness. Instructional centeredness describes the behavior of a teacher as he or she designs and executes learning experiences. It is a continuum (O’Neil and McMahon, 2005) in which a teacher may find himself fluctuating depending upon the learner, the context, the learning environment and the available technology. Dominant characteristics of student centered teaching (Weimer, 2002; 2013) are contrasted with traditional practices of teacher centered learning. Both the first and second domains disclose the struggle pre-service teachers have with a vision of instructional space and instructional pedagogy that is unfamiliar to them. If pre-service teachers are to enter the profession equipped to practice learner-centered instruction, it is important for them to experience these while they are still in a student role.

Active learning, cognitive constructivist theory and learning that is situated in the sociocultural context, are included in the online instruction module. Designing opportunities for students to cooperate and learn from each other is characteristic of the learner-centered environment supported by Piaget, Dewey, Vygotsky, and Bruner. This is not simply the utilization of group projects, but rather taking the classroom environment, be it face-to-face or online, and course components to create a synergy of ideas, motivation, engagement and the social nature of learning. Thus, this research explores both the characteristics of effective online instructors and the changing roles of effective online instructors in relation to instructional centeredness.

Methodology

Design: The goal of this research was to determine the effects of an online instruction module used as an intervention with pre-service teachers enrolled in a teacher preparation program. Concurrent triangulation design was used to simultaneously collect quantitative and qualitative data, merge the data using both quantitative and qualitative analysis methods, and interpret the results together to provide a more complete picture of the phenomenon being studied (McMillan and Schumacher, 2010). Criterion sampling was used to select participants (N=55) based on predetermined characteristics, specifically novice (freshman level) and developing (sophomore and junior level) undergraduate students in the institution’s teacher preparation program. Three groups of participants were represented: Group A (novice, mean age = 18.5), Group B (novice, mean age = 21.5), and Group C (developing, mean age = 20.8).

The researcher created an online instruction module intervention designed to provide content relevant to the planning of a lesson for an online learning experience. Participants engaged with content of the online instruction module, both synchronously and asynchronously, for four days as an alternative to attending their regular face-to-face class. This engagement was a requirement for all students enrolled in the targeted courses and had been built into the syllabus by the instructors. Content included an introduction to models of online learning, design elements for lesson planning, central concepts for effective technology integration, curriculum approaches such as Technological Pedagogical Content Knowledge (TPACK) and Substitution Augmentation Modification Redefinition (SAMR), and tools and resources for engaging active learning in an online learning environment. Additionally, the online instruction module intervention included learning experiences and tasks to be completed, which culminated in the creation of an artifact. Participants were given a choice of the modality and tool they utilized to demonstrate learning in their artifact.

Participants completed a pre- and post-survey, engaged with content in the online instruction module, utilized Discussion Boards for knowledge development, and completed tasks culminating in the creation of a lesson plan. A 3x2 ANOVA was conducted to evaluate the effect of the online instruction module on each of the three groups mean scores on the survey measuring each of the three domains- attitude, knowledge and skills, and instructional centeredness toward technology integration in an online learning environment. The dependent variable was a mean score for each participant on the group of questions pertaining to the domain being measured. The
within-subjects factor was time with two levels (pre and post intervention) and the between-subjects factor was group with three levels (group A, group B, and group C). The Time, Group, and Time X Group Interaction effect were tested using the multivariate criterion of Wilk's Lambda (λ). An additional quantitative score was obtained on artifacts completed during the online instruction module intervention.

Data Collection Methods: Two instruments were selected for measuring the effects of the intervention. To measure development of a teacher’s TPACK knowledge domains (Koehler and Mishra, 2008), a self-reporting survey, adapted to include online learning environments, A Survey of Preservice Teachers’ Knowledge of Teaching and Technology, developed by Schmidt, et al., (2009) was used. This instrument was tested for reliability and validity using expert judges and Cronbach’s alpha (.919). A performance-based rubric, the Technology Integration Matrix (TIMS) was also used to measure instructional centeredness within the created lesson plan from each participant. Qualitative data were obtained by analysis of discussion board posts. Surveys were collected through Google Forms while all other data were collected through the Blackboard learning management system.

Findings

Survey results support the hypothesis that the use of the online instruction module positively affects pre-service teachers’ attitudes, knowledge and skills, and instructional centeredness toward integration of technology in an online learning environment. A two-way within-subjects analysis of variance showed significant differences between groups A, B, and C with both the Time main effect and the Time X Group interaction effect significant for all three domains using the multivariate criterion of Wilk’s Lambda (Table 1, 2, and 3).

RQ1. In a teacher preparation program, what are the attitudes of pre-service teachers towards technology integration in an online learning environment?

RQ4. What are the effects of an intervention on the attitudes of pre-service teachers towards technology integration in an online learning environment?

Table 1
Repeated Measures ANOVA for Attitude Summary Table

<table>
<thead>
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<th>MS</th>
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</table>

Note. *p < .05
RQ2. In a teacher preparation program, what are the knowledge and skills in technology integration of pre-service teachers in an online learning environment?

RQ5. What are the effects of an intervention on the knowledge and skills in technology integration of pre-service teachers in an online learning environment?

Table 2
Repeated Measures ANOVA for Knowledge and Skills Summary Table

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Note. *p < .05

Figure 1. Line plot interaction between Time and Group within the Attitude domain
Figure 2. Line plot interaction between Time and Group within the Knowledge and Skills domain

RQ3. In a teacher preparation program, what is the instructional focus of pre-service teachers in an online learning environment?

RQ6. What are the effects of an intervention on the instructional focus of pre-service teachers in an online learning environment?

Table 3
Repeated Measures ANOVA for Instructional Centeredness Summary Table

<table>
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Note. *p < .05
It was interesting to note the demographics of the two novice groups, mainly their mean age. Group A was a typical entering freshman class with a mean age of 18.5 years. However, although Group B was a second section of the same introductory course, there were non-traditional students in this section causing an increase in mean age to 21.5 years. This was slightly higher than the developing group, Group C whose mean age was 20.8 years. The older of the novice groups had the highest means and made the largest gains while the younger of the novice groups displayed the least amount of participation. All three groups displayed low means for survey questions related to classroom management, teaching approaches and assessment in an online learning environment. In relation to the three domains this research addressed, one could hypothesize that the influence of non-traditional students may have been a factor in Group B’s significant scores both within-subjects and between groups.

The five levels of technology integration from the TIM instrument were assigned a point value (0-25) based by the researcher on the degree of integration the participant demonstrated with their lesson plan artifact. Characteristics of traditional didactic teacher centered instruction were found in the lesson plans of all three groups. These characteristics included passive reception of content, individual student use of technology, conventional knowledge building, directions given to students by the teacher, and activities that were unrelated to the world outside of the instructional setting. Mean scores were as follows: The developing group (Group C) scored the highest mean (µ = 13.94), the older novice group (Group B) scored (µ = 7.75) and the younger novice group (Group A) scored (µ = 5.47).

Discussion Boards were analyzed each day for themes related to the domains of the research. Data reflected changes in attitude toward not only technology but also the validation of online learning space as a place where learning can occur. Participants affirmed their awareness and new understanding of the Backwards Design process and the importance of aligning objectives to assessments. Connections were made between this process of designing a lesson and integrating technology to increase learning outcomes. The inclusion of the synchronous experience on Day 3 confirmed the critical nature of experiential learning in teacher preparation as much as the appropriate use of discussion boards fostered new knowledge construction through social interaction. Participants commented on new ideas gained for integrating technology in both their content area as well as in an online learning environment. The inclusion of reflection upon their own experiences with technology, specifically on the last day of the intervention, provided additional information on these pre-service teachers’ level of comfort with newer technology or technology they had not experienced in their traditional classrooms. Evidence of change in perspective, particularly in using technology for collaboration and student-centered learning was also noted. Two additional interesting observations pertained to the content videos and instructor presence. First, the videos did not include formative assessment or other data collection tool to determine the amount of participation while engaged with the content. It is possible that a correlation could be made between time spent on task with the online content and domain improvement. Recommendations to include this type of assessment in order to gather additional data would improve the intervention. Secondly, it would be interesting to measure the impact of instructor presence.
within an online learning environment. The module included only one day of instructor presence (during the synchronous session) and the researcher posits an increased presence may increase learner outcomes given the literature reviewed.

Significance of the Study

**Instructional Design:** Continued focus on the quality of educator preparation programs and the teachers produced by these programs requires a deeper understanding of the needs of students enrolled in these programs. Instructional design of quality lessons, units, and programs require time taken to gather evidence of characteristics of both the learners and the context for learning. A learner analysis includes gathering information about attitudes, knowledge and skills, learning preferences, and group characteristics. These characteristics are influential in determining the effectiveness of instructional experiences and attainment of learning goals. “They help the designer develop a motivational strategy for the instruction and will suggest various types of examples that can be used to illustrate points, ways in which instruction may (or may not) be delivered, and ways to make the practice of skills relevant for learners” (Dick, Carey & Carey, p. 94).

**Future Ready Educators:** The time it takes to use a tool such as this online instruction module is time well spent when data may be collected to inform instruction of meaningful and transferable experiences, particularly as these experiences produce highly effective, future ready educators. The introduction of online technologies in this intervention changed what was pedagogically possible, highlighting the development of new literacies including the knowledge and skills associated with this practice of online instruction. Participants were given opportunities to share ideas, stories, experiences and perspectives as they engaged in instruction specific to the online classroom. This research included the operational dimension skills such as the ability to use tools available online to operate desired functions, search for information, multitask online, and share resources and information effectively. The addition of telecollaboration was assistive in participants gaining these new literacies and confirming the effect of the intervention.

**Modeling and Experiencing:** It cannot be denied that the use of this tool yielded significant results and provided valuable information for assessing and addressing the needs of pre-service teachers in this teacher preparation program. The online intervention module incorporates cognitive and behavioral modeling of lesson design and technology integration, providing numerous and authentic experiences with technology where pre-service teachers have an opportunity to practice using a variety of digital tools for learning, assessing and managing students in an online classroom. The integration of these learning experiences through an online intervention has the potential to revolutionize teacher preparation and positively impact K-12 learners in any learning environment.

**Transforming Teacher Preparation:** The needs of digital learners must convince stakeholders in teacher preparation that traditional practices of instruction perpetuate tedious and synthetic education thus doing harm to the current generation of learners. Rather, this is a call for determined efforts toward incorporating student-centered instructional modeling of effective technology integration within a variety of online and blended learning spaces. Teacher education programs must undertake a transformation to include the preparation of pre-service teachers for dual learning environments, face-to-face as well as online in order to meet the changing needs of our K-12 digital learners. This generation of pre-service teachers is pivotal to the sustainability of effective technology integration and innovation of learning spaces, particularly as we aim to increase learner outcomes among our PK-12 students. They have an integral part to play in the transformation of education through innovation and creativity and thus will be essential components to the quality of instruction.

Limitations

As stated in the findings, the design of the online instruction module would be improved with attention to instructor presence and attention to time on task for the participants, both of which are key characteristics of effective online instruction. Inclusion of formative assessment within the content videos would provide data regarding individual participation and evidence of desired outcomes. Strength of this design is its focus on assessing and addressing the needs of the students in the teacher preparation program. Understanding the target audience is the key to designing effective instruction. The implementation of an intervention such as this online instruction module may help other teacher preparation programs identify strengths and weaknesses of their pre-service teachers in regard to their attitudes, knowledge and skills, and instructional centeredness for online learning environments. This valuable information may also provide
necessary guidance for program goals and policy change specific to the institution of higher education incorporating this intervention.

Summary

1. Intentional inclusion of instructional planning and design for virtual contexts positively affects pre-service teachers’ attitudes, knowledge and skills, and instructional centeredness for integrating technology.
2. Experience with synchronous online learning environments assists in pre-service teachers’ attitude toward the usefulness of online tools and aids in their technology skill.
3. Preparing pre-service teachers for dual learning environments promotes an awareness of diverse learners and learning environments.
4. Instructor presence and prompt feedback are essential in an online learning environment.
5. Effective use of discussion boards promotes new knowledge building within a learning community.
6. Negative attitudes towards technology have their basis in previous experiences of ineffective technology integration in traditional classrooms.
7. Pre-service teachers need experience with and modeling of student centered learning.

References


Koehler, M., & Mishra, P. (2008). What is technological pedagogical content knowledge (TPCK)? In AACTE Committee on Innovation and Technology (Eds.), Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators (pp.3-29). New York, NY: Routledge.


