Research Highlights in Technology and Teacher Education 2019

Edited by

Senior Book Editors:
David C. Gibson
Marilyn N. Ochoa

Book Editors:
Peter Albion
Leanna Archambault
Jonathan Cohen
Kevin Graziano
Mark Hofer
Elizabeth Langran
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John Lee
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SITE
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FOREWORD

It is exciting to present the 2019 edition of the Research Highlights in Technology and Teacher Education, now in its eleventh year of publication. This collection of peer-reviewed articles represents the outstanding scholarship and notable work presented during the past year at the 2019 Society for Information Technology and Teacher Education (SITE) conference. SITE is committed to advancing the creation and dissemination of knowledge about information technology and teacher education. These chapters represent the worldwide expertise and insight of teacher educators, researchers, and practitioners who are examining the contemporary, creative and innovative solutions around topics critical to our field.

This edition of the Research Highlights book includes sixteen chapters organized around eight themes: (1) Technological Pedagogical Content Knowledge (TPACK), (2) Mathematics Education, (3) Virtual Learning, Games, and Simulations, (4) Maker, (5) Citizenship Education, and (6) Teachers’ Perceptions and Experiences. Collectively, this scholarship illustrates the broad-based impact of SITE and demonstrates our commitment to disseminating research that will inform and improve the teacher education community as a whole.

Our sincere gratitude and thanks goes out to the many SITE members who are willing to put in the extra time and effort to make the Research Highlights book a reality. We are extremely grateful to the senior book editors, David Gibson and Marilyn Ochoa, who provide the necessary expertise, leadership, and guidance of these efforts from start to finish. We must acknowledge this is Marilyn’s first year serving as a book editor and we truly appreciate the seamless transition into this position. Thank you to the numerous “reviewers” who took time to review, select, and provide feedback on the chapters. Because of these efforts, we can engage in a rigorous review process that promotes and maintains the high-quality standards present within our organization. Such work continues to strengthen SITE’s outreach efforts with our global network of teacher educators and researchers.

Enjoy reading this eleventh edition of the Research Highlights in Technology and Teacher Education and remember to share it with your colleagues!

Denise A. Schmidt-Crawford
SITE President
PREFACE

Research Highlights in Technology and Teacher Education is now in its eleventh year of publication. Collections in this book series present distinguished work by leading educators and researchers in the field, illustrating the broad-based impact of SITE and commitment to disseminating research to inform and improve the teacher education community as a whole. The research highlights contemporary trends and issues, theory and practice-based models, design-based research methods, innovative ideas, and effective use of research tools and approaches in the field of information technology and teacher education. This year seventeen chapters are organized into six themes: (1) Technological Pedagogical Content Knowledge (TPACK), (2) Mathematics Education, (3) Virtual Learning, Games, and Simulations, (4) Maker, (5) Citizenship Education, and (6) Teachers’ Perceptions and Experiences.

TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK)
As with many editions before it, this edition highlights research that explores TPACK (technology, pedagogy, and content knowledge). The framework is a theoretical and practical model that has been used by educators and researchers to acknowledge the value of technology integration into educational practice. This year, three chapters are included in the section, and explore effective methods to improve technology-based teaching and learning.

In the first chapter, Ralph Saubern, Daniel Urbach, Matthew Koehler, and Michael Phillips begin this section in “A Rasch analysis of TPACK proficiency: describing what it means to have more or less TPACK.” Saubern and colleagues explore the key questions about the definition of the TPACK construct, its components and the boundaries between the TPACK components, the transformative or integrative nature of TPACK components, and the validity of TPACK measurement. Using a measurement lens to focus on the description of the TPACK construct, they studied confidence to use ICT and perceptions of usefulness to support student learning. Intended to improve the clarity of the TPACK model, the research demonstrates how and why to construct a map of what it means to have TPACK, and recommends that this research could contribute to the development of a more detailed map that includes each of seven TPACK components.

In the next chapter, “Tracking T-dimensional TPACK in Elementary Preservice and Clinical Teachers,” Robin Nelson explores the development of confidence in T-dimensions of TPACK in preservice and clinical teachers through a needs assessment. Using an adaptation of the Survey of Preservice Teachers Knowledge of Teaching and Technology developed Schmidt et al., 2009, Nelson researched how TK, TCK, TPK, and TPACK developed in preservice and clinical teachers, and also how their confidence compares to each other. The results demonstrated the variability in TPACK development between preservice and clinical teachers.

In Chapter 3, we continue to examine TPACK in Mark Hofer and Judi Harris’ “Topics & Sequences in Experienced Teachers’ Instructional Planning for Technology Integration.” The chapter describes the professional development experience of eight K-12 teachers designed to investigate the ways in which teachers plan technology-enhanced, curriculum standards-specific lessons, units, and projects. The results of the study revealed that their decision making in lesson
planning emphasized curriculum content and knowledge of students and learning activities, even when prompted with planning aids that matched recommended educational technologies.

**MATHEMATICS EDUCATION**

Mathematics education is one of the most studied areas in the field of using information technology in teacher education. Two chapters are included which explore this theme.

Michael L. Connell begins this section with “Mathematical Mediation: From Raw Experience to Spreadsheets via Data Tables.” The chapter explores design and use of frame-based data tables as a mediational tool between informal initial hands on experience and the representational forms required in order to apply more abstracted technology-based tools such as spreadsheets. These data tables prove to be an excellent device to help teacher candidates mediate initial raw experience into spreadsheets. The study suggests that data table created around a frame model should be included when designing technology enabled activities to prepare teacher candidates.

In Chapter 5, “Relationships between Mathematical Language, Representation Connections, and Learning Outcomes in Digital Games,” Patricia S. Moyer-Packenham, Kristy Litster, Allison L. Roxburgh, Joseph S. Kozlowski, and M. Jill Ashby examine children’s mathematical language and connections among representations to understand the relationship to pre-and post test changes when children played with digital math games. Through the lens of the artifact centric activity theory, Moyer-Packenham and colleagues considered children’s actions with math games on a touchscreen device. They found that children made a variety of mathematics connections among representations using language to connect images, symbols, and gestures.

**VIRTUAL LEARNING, GAMES, AND SIMULATIONS**

Several chapters discuss the virtual learning environment, which includes games and simulation and augmented reality. In these chapters, new applications, tools, and recommendations for research are examined.

In chapter 6, “Usability and Usage of a Citizen Science App by Teachers and Students,” Richard T. Bex, II, Lisa Lundgren, and Kent J. Crippen report on the design, implementation, and study of science specific mobile apps. A usability study on a new citizen science mobile app, myFOSSIL, was completed through iterative design in which ten high school students and 25- K-12 teachers rated their experience for a number of user-centered variables. The study is of interest to those who want to understand how users interact with the product to improve its capacity for achieving its design goal.

Mark Petrovich Jr., Mamta Shah, and Aroutis Foster conducted a systematic review of empirical publications on Augmented Reality (AR) implementation in informal learning settings. In their chapter, “An Expanded Systematic Review of Augmented Reality in Informal Learning,” the authors evaluated twenty-five articles published between the time period of 2010 to 2017 after several phases of data collection, coding, and analysis. The chapter provides insights into expected educational outcomes being investigated, the methodologies utilized in AR evaluation, the populations involved in AR research, and the claims surrounding AR technologies.
The next two chapters consider productive reflection (PR) as a way of conceptualizing learning as a process of identity exploration and gaining the knowledge and skills to reconstruct oneself. Both chapters describe the Philadelphia Land Science, an augmented virtual learning environment (AVLE), used to facilitate high school students’ exploration of role identities as urban planners and environmental scientists. Chapter 8, “Facilitating and Tracing Identity Change in Augmented Virtual Learning Environments,” by Hamideh Talafian, Amanda Barany, Mark Petrovich Jr., Mamta Shah, and Aroutis Foster reports on a concurrent mixed methods design to assess and visualize identity change in participants as tracing change in their knowledge, interest and valuing, self-organization and self-control, and self-perception and self-definition. The result shows significant change in interest in valuing levels and that these changes are intertwined constructs of PR.

In Chapter 9, “Tracking Identity Exploration Trajectories in Game-Based Learning,” Barany, Talafian, Petrovich Jr., Shah, and Foster further explicate this theory through design and implementation of a 9-week course that used the VLE Philadelphia Land Science and supportive classroom augmentations to promote intentional exploration of future possible selves in urban planning and environmental science. Two illustrative student cases characterized unique trajectories of identity exploration, and offer insights into the design of future augmented VLEs.

**MAKER**

The Maker movement is among the most studied areas in the field as teacher preparation programs are beginning to include aspects of making into their curricula. The two chapters in this section present research into designing courses that include aspects of making in a systematic way to improve the impact of the making movement.

In Chapter 10, “Design and Development of a Modular Maker Education Course for Diverse Education Students,” Jonathan D. Cohen, Cassandra Gaul, Julia Huprich, and Leigh Martin describe the design and development of a maker education course using design-based research. Responsive to students with diverse interests in education and consistent with the principles of making, the mastery-oriented learning environment leveraged a modular design and digital badging system. This course allowed students to focus their learning on making aspects relevant to their context, and represents the first stage of a design-based research project for designing maker education courses.

Unlike Cohen and colleagues’ course design, Ozlem Karakaya focused on designing a makerspace course module for preservice teachers in an undergraduate learning technologies minor program. In “Designing a Blended-Makerspace Course for Preservice Teachers in an Undergraduate Technology Minor Program,” the Computer Supported Collaborative Learning (CSCL) framework informed the module design. Findings show that collaboration in online platforms is important to better improve makerspace knowledge of preservice teachers. Several themes emerged from the study.

**CITIZENSHIP EDUCATION**

Chapter 12, “Bridging STEM and the Civic Mission of Social Studies: Integrating Spatial Reasoning & Computational Thinking Into Decision-Focused Secondary Social Studies
Instruction,” by Thomas Hammond and Julia Oltman recommend a new framework for bridging the divide between social studies and STEM education. This study addresses the challenges of secondary social studies education to connect the curriculum of specific disciplines with the central aim of preparing citizens. Using the Engle decision-focused approach to social studies education coupled with spatial reasoning and computational thinking STEM skills frameworks, The authors devise an integrated strategy that reaches back to core social studies principles and emerging areas of the STEM skill set.

In Chapter 13, Marie K. Heath and David Marcovitz recommend a change in how digital citizenship learning standards are taught to teachers in “Reconceptualizing Digital Citizenship Curricula: Designing a Critical and Justice-Oriented Digital Citizenship Course.” Heath and Marcovitz report on their work, which is part of a larger study, to examine the ways in which candidates and their students learn and practice digital citizenship. The work involves re-writing the learning standards, and the coursework re-design described emphasizes justice oriented digital citizenship, activism, and social change. They suggest ways to develop new models of digital citizenship in teachers, and subsequently, in their students.


TEACHERS’ PERCEPTIONS AND EXPERIENCES

The section begins with chapter 15, “Pre-service Teachers’ Technological Self-Efficacy – an Irish Perspective,” written by Alison Egan, Ann FitzGibbon, Keith Johnston and Elizabeth Oldham. Egan and colleagues report on an exploration of preservice teachers confidence with using technology on school placements. In a sequential explanatory mixed methods study, two cohorts were surveyed over a three-year period during their college preparation course. Results reveal a transfer gap between personal knowledge and confidence using technology in professional contacts, and suggest that mentoring to develop technological self-efficacy may lead to greater levels of technology integration in the classroom.

Chapter 16, “Challenges in Professional Social Media Use,” by Jeffrey P. Carpenter and Stephen Harvey reports on a study on the use of social media for professional purposes. Through semi-structured individual and focus group interviews with a sample of 48 educators who actively use social media over a period of time, the authors identified four types of challenges. the participants experienced intrapersonal, interpersonal, school community, and online educator community challenges. Implications of findings for educators, teacher educators, and education researchers are considered.

The last chapter of this edition is “Educators on the Front Page of the Internet: Teacher Learning in Four Subreddits,” a report on an exploratory study related to accessing and contributing to online
spaces as part of professional activity. K. Bret Staudt Willet and Jeffrey P. Carpenter conducted a comparative analysis of data related to one-year of activity on four education-related subreddits. Results revealed differences in terms of engagement, sentiment, and network characteristics. Reddit is considered a source for informal learning, professional development, and online mentoring for both pre-service and in-service teachers, and its diverse online spaces might meet or respond to different educator needs.

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. This collection of papers is a welcome addition to the literature in the field of information technology in teacher education.

August, 2019

Senior Book Editors
Marilyn N. Ochoa
David C. Gibson
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Melda Yildiz, Kean University, United States
Hong Zhan, Embry-Riddle Aeronautical University
A Rasch Analysis of TPACK Proficiency: Describing what it means to have more or less TPACK

Ralph Saubern
Monash University
ralph.saubern@monash.edu

Daniel Urbach
Australian Council for Educational Research
daniel.urbach@acer.org

Matthew Koehler
Michigan State University
mkoehler@msu.edu

Michael Phillips
Monash University
michael.phillips@monash.edu

Abstract: Over the last ten years, the TPACK model has had a major influence on research into technology integration in education and has been adopted for research across a wide variety of contexts. While this research has provided a valuable contribution to our understanding of professional knowledge of teachers, the TPACK construct, like the PCK construct on which it is based, remains in flux. Researchers continue to explore key questions about the definition of TPACK and its components, boundaries between the TPACK components, the transformative or integrative nature of TPACK components, and the validity of TPACK measurement. This chapter uses a measurement lens to focus on the description of the TPACK construct. It demonstrates how a 'construct map' for TPACK, which describes increasing proficiency in TPACK, can be developed using empirical data gathered from a TPACK survey tool.

Introduction

The Technological Pedagogical and Content Knowledge (TPACK) framework (Mishra & Koehler, 2006, 2007) has had a substantial influence on research investigating the integration of educational technology. At a PCK/TPACK international symposium, it was reported that there were 2658 publications that used the TPACK framework between 2007 and 2016 (Phillips, Harris, van Driel, Berry & Cooper, 2017). The contributions from this corpus of work have been many and varied, and our understanding of the development and use of TPACK in a variety of educational settings is undoubtedly richer as a result.

While these investigations have made valuable contributions to our understanding of the interplay between forms of professional knowledge in a variety of settings, elements of the TPACK framework, like the PCK framework which preceded it, remain in flux. Researchers have highlighted and investigated issues relating to defining TPACK components and the component boundaries (Angeli & Valanides, 2009; Archambault & Crippen, 2009; Archambault & Barnett, 2010; Scherer, Tondeur, & Siddiq, 2017), whether the construct is intended to be understood as integrative or transformative (Graham, 2011), the validity of TPACK measurement (Cavanagh & Koehler, 2013; Koehler, Shin, & Mishra, 2012) and the relationship between TPACK and PCK (Graham, 2011, Phillips & Harris, 2018).

This chapter aims to explore some of the questions raised in previous research about the TPACK construct through a measurement lens, using the analysis of empirical data gathered in the measurement of teachers’ TPACK to highlight and return to questions about the theoretical framing of TPACK. An analysis of data collected using an established TPACK survey tool is used to demonstrate how empirical data can be used to develop a 'construct map' for TPACK - a qualitative description of increasing proficiency in the TPACK construct.
The Technological Pedagogical and Content Knowledge (TPACK) framework

The knowledge of expert teachers has long been an area of interest for researchers (Loughran, 2010). In particular, efforts to distinguish expert teachers from content experts led to the proposition of a knowledge base for teaching (Shulman, 1986). Shulman suggested teachers draw on seven different forms of knowledge as part of the “outrageously complex” (Shulman, 1987, p. 11) task of teaching, arguing that pedagogical content knowledge (PCK) was of particular interest as this category of teacher knowledge distinguishes teachers from content experts in that it:

goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching. I still speak of content knowledge here, but of the particular form of content knowledge that embodies the aspects of content most germane to its teachability. (Shulman, 1986, p. 9)

The Technological Pedagogical and Content Knowledge (TPACK) framework builds on Shulman’s (1986) conceptualization of teachers’ professional knowledge. Mishra and Koehler (2006) added to Shulman’s PCK framework in an attempt to understand how the increasing use of digital technologies in schools might impact on the development of teachers’ professional knowledge. In doing so Mishra and Koehler (2006) expanded the PCK framework through the addition of technological knowledge (TK). Mishra and Koehler (2006) proposed that good teaching with technology involves a combination of technological, pedagogical and content knowledge, or TPACK. Mishra and Koehler (2006) represented their TPACK framework as three overlapping circles, with each circle representing a component of teachers’ professional knowledge. This framework resulted in seven potential forms of teachers’ professional knowledge with the aspirational TPACK positioned at the nexus of these circles. Bounding these different forms of knowledge is the context in which teachers acquire and exhibit their knowledge as shown in Figure 1.

Figure 1. The TPACK framework. Reproduced by permission of the publisher, © 2012 by tpack.org

The TPACK model has been used in a great variety of contexts, including international examinations of the TPACK development of pre-service teachers (for example, see: Agyei & Keengwe, 2014), distance educators (e.g Brinkley-Etzkorn, 2018) and primary teachers (Gill & Dalgarno, 2017). In Australia, a noteworthy example was a study titled Teaching Teachers for the Future (TTF) (https://www.ttf.edu.au) in which 10,443 pre-service teachers’ knowledge regarding technology integration was examined through a TPACK lens (Finger et al., 2013). The data used for the analysis in this chapter is from a small study which attempted to collect data to validate the use of the TTF TPACK Survey tool with in-service teachers and contribute to the empirical base for understanding the TPACK of in-service Australian teachers (Saubern & Southcott, 2018).
Issues in TPACK research

Despite the widespread use of the TPACK model for research, there is ongoing critique of significant elements of the framework (Graham, 2011; Angeli & Valanides, 2009; Phillips & Harris, 2018). A fundamental and key question researchers using the TPACK model have asked is whether the construct is intended to be understood as integrative or transformative. That is, whether TPACK (and the other ‘emergent’ components in the model: TPK, TCK and PCK) are distinct and new, synthesized forms of knowledge or are a mixture of aspects of the three core categories of knowledge: TK, PK and CK (Angeli & Valanides, 2009; Graham, 2011). While Mishra and Koehler’s (2006) original description of TPACK suggests a transformative interpretation, Graham (2011) cites a number of researchers who have treated TPACK as an integrative construct, including by seeking to measure TPACK by measuring TK, PK and CK (Doering, Scharber, Miller, & Veletsianos, 2009; Graham, 2011; Guzey & Roehrig, 2009; Mouza & Wong, 2009). The lack of theoretical clarity and empirical evidence on this critical aspect of the model presents significant epistemological and ontological challenges for researchers.

Closely related to this, researchers using the TPACK model have explored problems relating to defining the components of the TPACK model and component boundaries (Angeli & Valanides, 2009; Archambault & Crippen, 2009; Archambault & Barnett, 2010; Cox, 2008; Koehler et al., 2012; Scherer et al., 2017). In a review of the TPACK research literature, Cox (2008) found multiple, distinct definitions for TCK, TPK and TPACK. Scherer et al. (2017) review a number of studies which investigate the factor structure of TPACK concluding that empirical evidence of the distinction between TPACK components was “mixed” and calling for further research to clarify meaning of the components and provide empirical evidence of distinctions between them.

Underlying these concerns are critical questions about the relationship between TPACK and PCK (Graham, 2011; Phillips & Harris, 2018). Despite the extensive use of the PCK model in research and attempts to develop a ‘consensus model’ (Gess-Newsome & Carlson, 2013), Chan and Hume (2019) continue to highlight notable “debates regarding [PCK’s] nature and content [which] have arisen as researchers and educators have endeavored to use the construct in their work” (p. 5). The lack of clarity in PCK presents obvious problems for researchers seeking to work with and effectively measure the TPACK framework built upon it (Graham, 2011).

Finally, researchers have raised questions about the validity of TPACK measurement and what the analysis of validity can tell us about the construct that instruments are attempting to measure (Cavanagh & Koehler, 2013; Graham, 2011; Koehler et al., 2012). Of 303 studies measuring TPACK identified by Koehler et al (2012), the vast majority did not report on reliability or validity in the paper, with only 24 papers providing clear evidence of reliability and only 13 papers clear evidence of validity. Cavanagh and Koehler (2013) propose the use of a seven-criterion lens for evaluating the validity of TPACK measurement. The seven criteria include content evidence, or the relationship between the evidence collected and the construct the instrument is attempting to measure, and interpretability evidence, or how the meaning of scores can be understood in a qualitative sense.

Purpose

While TPACK has provided a useful and popular model for researching the skills and understandings that teachers need and use to effectively integrate technology in education, improvements in the theoretical framing of the construct will contribute to its utility and long-term viability. Graham (2011) argues that a well-developed theoretical model has “prescriptive value”, that is, it is valuable not only because it describes the phenomenon but also has the ability to describe how the phenomenon develops and what interventions can predictably influence its development. The purpose of this study was to contribute to efforts to improve the clarity of the TPACK construct by demonstrating how an analysis of empirical data can be used to describe the construct in terms of increasing proficiency. Specifically, this study explores how Rasch analysis of TPACK survey data can be used to describe and interrogate what it means to have more or less TPACK.

Method

To investigate and describe the TPACK construct, a Rasch analysis, in particular a partial credit model analysis, was undertaken on data collected as part of a recent study of the TPACK of 152 practicing teachers in Australian schools (Saubern & Southcott, 2018). The partial credit model (Masters, 1982; Wright & Masters, 1982) is an extension of the dichotomous Rasch model and is suitable for use when items have polytomous categories. Rasch analysis allows for the construction of a scale which satisfies the requirements of objective measurement. It enables independent measurement of person ability and item difficulty. It allows for estimating the extent to which a person
possesses an ability, comparing the ability of a person with the difficulty of an item. This allows us to describe a person’s ability in relation to the probability of them being able to successfully complete an easier or more difficult item.

The study used a modified version of the TTF TPACK Survey (Finger et al., 2013; Jamieson-Proctor et al., 2013) with a simplified demographics section and only the first two scales: teacher confidence to use ICT to support student learning (TPACK Confidence) and teacher perceptions of usefulness of ICT to support student learning (TPACK Usefulness) (see Appendix). The two scales that were omitted were created to explore the TCK and TPK of pre-service teachers, and so not of direct relevance to the research question. It is important to note that like many instruments intended to measure TPACK, the TTF TPACK Survey tool is a self-report measure of teachers’ confidence and perceptions of usefulness. As the survey is a self-report tool and an indirect measure of the construct, care must be taken not to overstated the generalizability of the findings in the absence of supporting evidence collected from other sources. For each of the items in the survey, respondents were asked to provide a response on a 7-point Likert scale (from 0=Not Confident/Useful to 6=Extremely Confident/Useful) or indicate that they were unable to judge. Overall, the respondents in the survey reported a high mean response on both the TPACK Confidence and TPACK Usefulness scales, confirming the relatively high levels of self-reported TPACK of pre-service and in-service teachers observed in other research (Alrwaished, Alkandari, & Alhashem, 2017; Farrell & Hamed, 2017; Finger et al., 2013; Handal, Campbell, Cavanagh, Petocz, & Kelly, 2013; Jaikaran-Doe, 2016).

Given the high mean response rates, statistically significant skewness for each scale and the small number of responses in the bottom three Likert scale categories, it was assumed that the seven original response categories in the TTF TPACK Survey (0, 1, 2, 3, 4, 5, 6) could be collapsed into four groups for the analysis, ensuring that each category had qualitative meaning and a substantial number of responses for analysis:

- Less than Moderately Confident/Useful (0, 1, 2);
- Moderately Confident/Useful (3);
- More than Moderately Confident/Useful BUT less than Extremely Confident/Useful (4, 5);
- Extremely Confident/Useful (6).

The Rasch analysis provided strong evidence for the four substantive categories described above, with discernible differences when grouping the original rating scale for each item. When the Rasch analysis was performed with more than these four categories, the strong evidence of discernible differences between categories was not found.

Person-item maps were constructed for each scale. For the sake of brevity, only the person-item map for the first scale, TPACK Confidence, is discussed in this chapter. Person-item maps show the population on the left of the scale, with each X representing one respondent, arranged along the latent variable scale according to their ability; in this case, it is the ease with which they agree with the survey statements. Respondents with more TPACK Confidence are shown higher on the scale. Item parameter boundaries for each item are arranged on the right of the scale, showing the difficulty of each item. The item parameter boundaries are category boundaries, the point on the scale at which the probability of being in one category and the next is equal. In the current analysis, three item parameter boundaries represent the boundaries of the four analyzed categories. For each item, the difficulty of the boundaries is marked as .01, .12, and .23. So for example, q1.01 is the boundary between Less than Moderately Confident and Moderately Confident for question 1 (Figure 2).

Results

Reviewing the person-item map for TPACK Confidence (Figure 3), it is clear that the great majority of respondents are located on the scale between the first and third item category boundaries of most of the items, although relatively few above the third item category boundary. In other words, the great majority of respondents were able to agree they were moderately to more than moderately confident for most items but only a relatively small group were able to agree that they were extremely confident for most items. Very few respondents agreed that they were less than moderately confident for the items.

Another observation is that while most if not all of the items were fairly easy to agree with, there were differences in the location of the item parameter boundaries for the different items and the size of the gaps between the item parameter boundaries, providing an opportunity to analyze and interpret meaning of the scale in a qualitative sense.
Figure 2. Explaining the item parameter boundaries for each item

Figure 3. TPACK Confidence Person-Item Map
Interpretation

A construct map is an application of Rasch analysis which identifies items of increasing difficulty along the scale of the latent variable or construct (Masters, Adams, & Wilson, 1999; Wilson, 2003, 2004). A qualitative analysis of the construct map informs a better understanding of what it means to be more proficient in a particular construct:

- Analysis of the hierarchical difficulty of the items - the meaning of low, average or high scores with regards to ability that accumulates - allows for inference on how the construct is structured and represented by the items (Nakano & Primi, 2014, p. 2)

Observing the order of the category boundaries of the item parameters along the scale is one way to describe what it means to have increasing proficiency in TPACK. In developing a qualitative description, a useful approach is to divide the scale into bands of arbitrary but equal length and describe each band in terms of the item parameters that fall within that band. So, for example, the TPACK Confidence scale could be divided into interval bands each of two logits in length starting at -2.0 logits (Figure 4). (Logits are a unit of measure used in Rasch analysis. Each logit is an interval length along the scale.)

Taking just a few items as examples and looking at just the top three bands, we could begin to construct a description of increasing proficiency along the scale (Figure 5). Item numbers have been included in parentheses in the descriptions for ease of reference.

Figure 4. TPACK Confidence scale bands
Teachers in Band 5 of the TPACK Confidence Scale are extremely confident that they have the knowledge, skills and abilities to support students’ use of ICT to synthesise their knowledge (6), integrate different media to create appropriate products (9) and critically evaluate their own and society’s values (20).

Teachers in Band 4 of the TPACK Confidence Scale are extremely confident that they have the knowledge, skills and abilities to support students’ use of ICT to demonstrate what they have learned (7), acquire the knowledge, skills, abilities and attitudes to deal with on-going technological change (8) and are beginning to be extremely confident they have the knowledge, skills and abilities to support students’ use of ICT to integrate different media to create appropriate products (9).

Teachers in Band 3 of the TPACK Confidence Scale are more than moderately confident that they have the knowledge, skills and abilities to support students’ use of ICT to synthesise their knowledge (6), demonstrate what they have learned (7), acquire the knowledge, skills, abilities and attitudes to deal with on-going technological change (8), integrate different media to create appropriate products (9) and critically evaluate their own and society’s values (20).

Figure 5. TPACK Confidence Band Descriptors

The development of a construct map provides an empirical description of TPACK and what it means to have more or less proficiency in TPACK. Interrogating this empirical description allows us to reflect on, interpret and develop the theoretical framing of the construct in a fine-grained way. For example, item 17 (use of ICT to critically evaluate their own and society’s values) is not only the most difficult item to agree with extremely, but also has a very large gap between category boundaries q17.12 and q17.23. Item 12 (use of ICT to develop understanding of the world) is easier to agree with extremely but also has a large gap between category boundaries q12.12 and q12.23. Why would this be? Why do teachers need substantially more confidence in these areas than others to move from one category to another? At the other end of the scale, item 7 (use of ICT to demonstrate what they have learned) is very easy to agree with moderately but takes surprisingly large amount of additional confidence to become easy to agree with extremely. Does this fit with our theoretical understanding of the construct? What does it look like in practice? Finally, there are some interesting differences in items covering similar areas. For example, does it make sense that it is easier for respondents to moderately agree with item 4 (use ICT to actively construct their own knowledge in collaboration with their peers and others) than item 5 (use ICT to analyze their knowledge) but easier to more than moderately agree with item 5 than item 4? What could this mean in practice in terms of teachers’ developing TPACK?

Conclusions

The extent to which researchers have adopted TPACK as a framework speaks to both the importance attached to better understanding teachers’ knowledge of integrating technology in education and the perceived value of the framework in describing and delineating it. This chapter has described an analysis of empirical data collected using an established TPACK survey tool to contribute to efforts to improve the clarity of the TPACK model, demonstrating how and why we might construct a map of what it means to have more or less TPACK. There are a number of limitations of the study. The analysis was undertaken on a relatively small set of self-report data without supporting evidence collected from other sources and so care must be taken not to overgeneralize the findings. Further, the TTF TPACK Survey tool used to collect the data is intended as a measure of teachers’ confidence in their capacity and perceptions of usefulness, and so represents a particular approach to understanding the TPACK construct. Further analyses of empirical data from studies in various settings and those which measure different aspects and components of the TPACK framework could be used to contribute to the development of a detailed TPACK construct map and construct maps for each of the seven TPACK components (Cavanagh & Koehler, 2013). These empirical descriptions of increasing proficiency would provide an opportunity to address key questions about TPACK definitions, the stability of definitions across contexts, the relationships between TPACK components, dependencies between components and questions about the ‘stand alone’ or integrative nature of TPACK. Detailed and well-defined maps of the construct can also support researchers to develop more consistent, transparent and valid measurement tools, the evidence from which can, in turn, support further development of the construct definition. Finally, better descriptions
of increasing TPACK proficiency will provide valuable input for teacher educators in the evaluation of teacher professional learning needs and design and delivery of teacher pre- and in-service education.

References


Appendix. Survey items.

The Teaching Teachers for the Future (TTF) Project was funded by the Australian Government Department of Education, Employment and Workplace Relations (DEEWR) through the ICT Innovation Fund. This enabled the development of the TTF TPACK Survey. The instrument used in this study was adapted from that instrument, which is described further in the following published research:


**Confidence:** How confident are you that you have the knowledge, skills and abilities to support students’ use of ICT to…

**Usefulness:** How useful do you consider it will be for you, as a teacher, to ensure your students use ICT to…

1. provide motivation for curriculum tasks
2. develop functional competencies in a specified curriculum area
3. actively construct knowledge that integrates curriculum areas
4. actively construct their own knowledge in collaboration with their peers and others
5. analyze their knowledge
6. synthesize their knowledge
7. demonstrate what they have learned
8. acquire the knowledge, skills, abilities and attitudes to deal with on-going technological change
9. integrate different media to create appropriate products
10. develop deep understanding about a topic of interest relevant to the curriculum area/s being studied
11. support elements of the learning process
12. develop understanding of the world
13. plan and/or manage curriculum projects
14. engage in sustained involvement with curriculum activities
15. undertake formative and/or summative assessment
16. engage in independent learning through access to education at a time, place and pace of their own choosing
17. gain intercultural understanding
18. acquire awareness of the global implications of ICT-based technologies on society
19. understand and participate in the changing knowledge economy
20. critically evaluate their own and society’s values
21. facilitate the integration of curriculum areas to construct multidisciplinary knowledge
22. critically interpret and evaluate the worth of ICT-based content for specific subjects
23. gather information and communicate with a known audience
Tracking T-dimensional TPACK in Elementary Pre-service and Clinical Teachers

Robin Nelson
Interdisciplinary Learning and Teaching
University of Texas at San Antonio
United States
robin.nelson@utsa.edu

Abstract: This survey served as a needs assessment to examine the development of confidence in the T-dimensional confidence of two elementary pre-service teacher groups (pre-service and clinical teachers) using the technology sections of the Survey of Pre-service Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009). The results showed a statistically significant difference between the TK and TCK confidence, with clinical teachers having higher confidence in both. There was no statistical difference between the TPK and TPACK of the two groups, with the means of both groups closely aligned. The findings demonstrated the variability in TPACK development between pre-service and clinical teachers.

Introduction

Current national and state educational standards require teachers to prepare students to use technology as a tool for learning (International Society for Technology in Education, 2016; Texas Education Agency, 2013), and some educators are evaluated based on their ability to use technology to ensure student mastery of lesson objectives (Texas Education Agency, 2018). Many studies have examined ways to transform teacher education programs' technology instruction to better prepare pre-service teachers for this responsibility (Chai, Koh, & Tsai, 2010; Koh & Divaharan, 2011; Kramarski & Michalsky, 2010; Pamuk, 2012). However, there continues to be debate over how best to address this problem (Koehler, Mishra, & Yahya, 2007; Ottenbreit-Leftwich et al., 2012).

Research has shown that many teacher education programs do not adequately prepare pre-service teachers to integrate technology (Angeli & Valanides, 2008; Ottenbreit-Leftwich et al., 2012; Stokes-Beverley & Simoy, 2016; Tondeur et al., 2012). Consequently, the National Educational Technology Plan (NETP) advised that teacher education programs must better prepare pre-service teachers, in-service teachers, and teacher educators to create and use technology to transform learning (U.S. Department of Education, 2017). Others argued for the use of evidence-based standards and frameworks to structure technology learning to prepare pre-service teachers to integrate technology (Stokes-Beverley & Simoy, 2016).

The Technological Pedagogical and Content Knowledge (TPACK), developed by Mishra and Koehler (2006), is one such framework. Mishra and Koehler (2008) posited that identifying how to develop the knowledge of pre-service teachers need to integrate technology effectively is a "wicked" problem (p. 2) and suggested that the TPACK framework helps teacher education programs focus on three crucial areas of teacher knowledge: content, pedagogy, and technology. Recently, TPACK research has examined various aspects of the technology-related dimensions of TPACK (Graham et al., 2009; Hamilton, 2013; Scherer, Tondeur, & Siddiq, 2017; Scherer, Tondeur, Siddiq, & Baran, 2018; Tondeur, Scherer, Siddiq, & Baran, 2017). The technology-related dimensions, or T-dimensions, are the four TPACK constructs. The constructs are created through the overlap of knowledge between content, pedagogy, and technology, and support learning and teaching with technology.

Since the teacher education program within this study did not require a technology course or have a comprehensive technology focus, the study provided valuable information to support future program decisions on technology integration. Currently, individual instructors may choose to model or use technology in methods courses, fieldwork, or clinical teaching, and students may attend supplemental technology workshops offered by the college. However, much of the program did not address technology specifically but focuses instead on developing pre-service teachers' Pedagogical Content Knowledge (PCK). In light of this, the study acted as a needs assessment to understand the effects of current technology efforts. Moreover, the survey examined and compared the development of T-dimensional confidence among pre-service and clinical teachers within an undergraduate elementary teacher education program.
The research questions addressed were:

1. Research Question #1: How does TK, TCK, TPK, and TPACK develop in pre-service and clinical teachers?
2. Research Question #2: How does the confidence in TK, TCK, TPK, and TPACK in pre-service and clinical teachers compare?

Theoretical Framework

Technological Pedagogical Content Knowledge (TPACK)

The TPACK framework is a flexible knowledge construct and theoretical lens used to investigate the knowledge required to utilize technology effectively for instruction (Graham, 2011; Graham, Borup, & Smith, 2012). It is also a tool to evaluate pre-service and in-service teachers' technology integration practices (Pamuk, 2012).

Mishra & Koehler (2006) built the TPACK framework upon Shulman's (1986) idea of PCK. Shulman's (1986) framework blends content knowledge, PCK, and curricular knowledge to shape educators' decisions about teaching and learning. Although Shulman mentioned methods of teaching content, the framework did not recognize the rapidly changing knowledge teachers need to teach effectively with technology. Thus, Mishra and Koehler (2006) expanded Shulman's concept of PCK to include Technology Knowledge (TK).

The intersections of content, pedagogy, and technology result in seven distinct forms of teacher knowledge that make up the TPACK framework. These forms include Content Knowledge (CK), Pedagogical Knowledge (PK), TK, PCK, Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and TPACK. While each knowledge construct is distinct, the framework acknowledges the influence the constructs have on one another, and the implications TPACK has for effective teaching with technology (Koehler & Mishra, 2009).

As previously mentioned, the TPACK framework posited that technology integration requires pre-service teachers to be knowledgeable in three specific areas (Graham et al., 2012; Koehler et al., 2007; Kramarski & Michalsky, 2010; Niess, 2005):

- **Content Knowledge (CK)** - understanding the subject matter taught and how to develop knowledge in a specific content area (Koehler, Mishra, & Cain, 2013, p. 14).
- **Pedagogical knowledge (PK)** - recognizing how teachers teach and students learn, and how to plan, implement, and evaluate learning (Graham, 2011).
- **Technological Knowledge (TK)** - understanding how to effectively use and troubleshoot digital tools (Angeli & Valanides, 2009).

Developing competency in content, pedagogy, and technology knowledge, provide the foundation teachers need to simultaneously consider content objectives, instructional strategies, and appropriate tools to support student learning.

T-dimensions

However, unlike CK and PK, TK is in a state of constant revision. The rapid advancement of technology requires teachers to learn new digital technologies, adjust strategies, and align content to new technological affordances (Voogt, Fisser, Roblin, Tondeur, & van Braak, 2013). This constant disruption of knowledge forces teachers to continually re-evaluate their TK and how to support learners with technology (Mishra & Koehler, 2006). This unique aspect of TK and the other T-dimensions differentiate them from the other TPACK constructs. Koh, Chai, and Tsai (2010) confirmed that pre-service teachers distinguished T-dimensions from the other TPACK constructs through factor analysis. Scherer et al. (2017) found low correlations between non-technical (PK, CK, and PCK) and technical (TK, TCK, TPK, TPACK) TPACK dimensions. Thus, Scherer et al. (2018) argued that the framework forms two types of knowledge: general (CK, PK, and PCK) and technological (TK, TCK, TPK, and TPACK) knowledge:

- **Technological Content Knowledge (TCK)** - understanding the appropriateness of a specific technology to support content-specific teaching (Colvin & Tomayko, 2015).
- **Technological Pedagogical Knowledge (TPK)** - generalized understanding of how technology can support pedagogical practices in classrooms (Cox, 2008).
• Technological Pedagogical Content Knowledge (TPACK) - complex and rapidly changing knowledge of how to represent content with technology, how technology impacts the selection of teaching and learning strategies, and how teachers may use technology to support student learning (Schmidt et al., 2009).

Literature Review

T-dimensional Research

Over the past decade, researchers have identified important aspects of TK, TCK, TPK, and TPACK. Niess (2011) argued that TK is essential to effective technology integration and explained that it goes beyond the knowledge theorized by Shulman (1986) in PCK. Hofer and Harris (2012) found that studies which addressed individual TPACK constructs reported TCK less than TPK. The authors indicated that in-service teachers might concentrate more on pedagogy than content when using technology or combine pedagogy and content into curricular knowledge. Similarly, in-service teachers may have viewed TCK as a subdomain of TPK, focused exclusively on how to teach with technology, or were unfamiliar with content-specific technology tools. Similar findings show that pre-service teachers also reported lower confidence in TCK, as well as TPK and TPACK due to lack of instructional experience that limit their ability to distinguish between the constructs (Koh et al., 2010; Valtonen et al., 2017).

According to Koehler et al. (2013), TPK may help pre-service teachers structure learning interactions and identify innovative uses for technology supported learning. The complicated process of designing instruction with technology is best supported through this amalgamation of knowledge or TPACK (Chai et al., 2010). Mishra and Koehler (2006) also argued that TPACK is not necessary for simple administrative tasks or when using technology as a lesson add-on. It is necessary when creating and implementing higher-order active-learning lessons that use technology as a learning tool. Thus, authentic constructivist learning experiences have been found to support TPACK development (Ottenbreit-Leftwich et al., 2012).

A few studies have examined the specific development of T-dimensional confidence in varying contexts. Graham et al. (2009) found that science teachers developed TK, TPK, TPACK, and then TCK confidence during an 8-month professional development program using pre- and post- surveys. Hamilton (2013) discovered that age, gender, and position of faculty correlated with TK, but not TCK, TPK, or TPACK. Scherer et al. (2018) uncovered a positive correlation between ICT attitudes and TPACK and identified differences in attitude between general and educational technology use. Tondeur et al. (2017) identified that educational ICT attitudes, ease of use, ICT self-efficacy, and T-dimensional confidence were positively correlated. Pre-service teachers with high T-dimensional attitude mean scores also reported strong teacher education program support.

Finally, others worked to validate the framework using the T-dimensional constructs while examining subgroup differences (Scherer et al., 2017). By testing the factor structure for invariance, and conducting multi-group factor analysis, the study identified TK as a unique construct from the other T-dimensional constructs.

Pre-service Teacher Preparation

While little of the TPACK literature focuses explicitly on T-dimensional confidence, much of it examines pre-service teacher preparation. Since teachers must now design lessons using technology to enhance and support standards-based learning (Common Core State Standards Initiative, 2010; International Society for Technology in Education, 2016; Mouza, Karchmer-Klein, Nandakumar, Ozden, & Hu, 2014), it is crucial that pre-service teachers are not only competent in PCK (Schulman 1986, 1987) but also TPACK (Angeli & Valanides, 2009; Koehler, Mishra, & Cain, 2013; Koehler & Mishra, 2008; Mishra & Koehler, 2006; Niess, 2005).

Unfortunately, research has shown that pre-service teachers are often unprepared to teach with technology when they enter the classroom (Angeli & Valanides, 2008). In order to prepare pre-service teachers to integrate technology, some researchers argued for the alignment of critical technology topics across PK-12 and higher education institutions to address the issue (Ottenbreit-Leftwich et al., 2012). Others encouraged the active use of technology throughout teacher education programs and initiatives to support teacher educators’ continued education (Stokes-Beverly & Simoy, 2016). Further, institutions should extend opportunities for pre-service teachers to integrate technology and ground curriculum in theoretical frameworks (Stokes-Beverly & Simoy, 2016), such as TPACK.

Tondeur et al. (2012) developed an SQD model of essential themes that teacher education programs should implement to prepare pre-service teachers to integrate technology. The authors proposed teacher education programs should align theory and practice, model technology integration, reflect on attitudes about technology, and include
learning by designing instruction with technology. The authors also encouraged collaboration, hands-on classroom technology experiences, and aligning assessments with content. Moreover, Tondeur et al. (2012) recognized the institutional requirements crucial to the success of technology integration. Institutions should develop a technology plan, collaborate among and between institutions, provide technology resources, systematically integrate technology throughout the teacher education program, and offer training for all teacher educators.

Other studies focused on improving courses within teacher educator programs to further develop TPACK. Chai et al. (2010) developed a problem-based experiential learning course and found significant increases in all constructs except CK. The authors also found that PK predicted TPACK development. Kramarski and Michalsky (2010) promoted self-regulated learning within a hypermedia course to develop TPACK and design skills to scaffold future learning. Koh and Divaharan (2011) piloted a TPACK-Developing Instructional Model which promoted TPACK in 3 phases (acceptance, modeling, and application). TK was developed in phase 1 and TPK in phase 2, although TPACK was not developed in phase 3, as planned. Finally, Pamuk (2012) found that PK was difficult for pre-service technology teachers to develop and concluded knowledge alone is insufficient to integrate technology into practice.

Again, most of the TPACK literature focuses on the development of TPACK as a whole and less on disaggregated results, such as T-dimensional confidence (Hofer & Harris, 2012). Additionally, few studies addressed elementary pre-service teachers’ TPACK confidence (Wu, 2013). While content, pedagogy, and technology are crucial to developing the knowledge needed to integrate technology effectively (Mishra & Koehler, 2008), this study focused specifically on elementary pre-service and clinical teachers’ T-dimensional confidence. The study provided an opportunity to conduct a needs assessment to determine the strength of T-dimensional knowledge, compare T-dimensional confidence at distinct points, and discover how T-dimensional confidence developed within a teacher education program.

Methods

A quantitative cross-sectional survey approach was used to identify the self-assessed T-dimensional confidence in two pre-service teacher groups at a large Texas university. According to Scherer et al. (2017), self-confidence assessed by a survey is an indicator of intentions, the likelihood of carrying out those intentions, and the likely quality of future instruction. Harris, Grandgenett, and Hofer (2010) argued that self-assessment is also an excellent place to begin when considering instructional decisions. Moreover, surveys are an efficient way to administer and collect a large amount of data and provide a snapshot of pre-service teachers’ beliefs.

Setting and Participants

A nonrandom purposeful sample included two groups of undergraduate early elementary (PK-6) pre-service teachers. The first group, referred to in this study as pre-service teachers, were enrolled in the second semester of the program, field experiences, and methods courses. The program required students to co-enroll in science and math methods courses, an assessment and evaluation course, and a reading comprehension course. The second group, referred to as clinical teachers, enrolled in their fourth and final semester of the program to complete clinical teaching.

These two groups represented both the second and final semester of the program. Including both groups offered a glimpse into the development of T-dimensional confidence at distinct stages of an elementary teacher education program. Respondents included 64 pre-service teachers consisting of 62 females and two males, and 30 female clinical teachers. Sixty percent of the pre-service teachers were ages 18-22, 37% were ages 23-26, and 3% were 33+, while 33% of clinical teachers were ages 18-22, 53% were ages 23-26, and 13% were ages 27-32.

Instrument

Schmidt et al. (2009) developed the Survey of Pre-service Teachers’ Knowledge of Teaching and Technology as a specific instrument for PK-6 pre-service teachers. The 46 item survey is a self-assessment of CK, PK, TK, PCK, TCK, TPK, and TPACK using an interval five-point Likert scale ranging from 1 ”strongly disagree” to 5 ”strongly agree” (Schmidt et al., 2009). This study, however, only assessed the T-dimensions. The author only selected the TK, TCK, TPK, and TPACK questions from the original survey described in Table 1 (Scherer et al., 2017). The questions were collapsed to form a scale for each technology dimension, using a minimum of four items per construct. In this
case, the responses to a series of questions for each variable were averaged to determine a composite factor score. There were six TK questions, four TCK questions, nine TPK questions, and four TPACK questions. The collapsed survey scales were evaluated for internal consistency using Cronbach's alpha coefficient. Both the original Schmidt et al. (2009) alpha score (listed first) and the current study's alpha score (listed second) ranged from good to excellent and demonstrated internal consistency: TK (.82/.92); TCK (.80/.86); TPK (.86/.90); TPACK (.92/.87). The survey is reliable (Table 3) and content experts determined its contents valid during the authors' development of the instrument.

Table 1

Survey questions from the technology sections of Schmidt et al. (2009)

<table>
<thead>
<tr>
<th></th>
<th>Technological Knowledge (TK)</th>
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<tbody>
<tr>
<td>Q1_1</td>
<td>I know how to solve my own technical problems.</td>
</tr>
<tr>
<td>Q1_2</td>
<td>I can learn technology easily.</td>
</tr>
<tr>
<td>Q1_3</td>
<td>I keep up with important new technologies.</td>
</tr>
<tr>
<td>Q1_4</td>
<td>I frequently play around with technology.</td>
</tr>
<tr>
<td>Q1_5</td>
<td>I know about a lot of different technologies.</td>
</tr>
<tr>
<td>Q1_6</td>
<td>I have the technical skills I need to use technology.</td>
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<thead>
<tr>
<th></th>
<th>Technological Content Knowledge (TCK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q7_1</td>
<td>I know about technologies that I can use for understanding and doing mathematics.</td>
</tr>
<tr>
<td>Q7_2</td>
<td>I know about technologies that I can use for understanding and doing literacy.</td>
</tr>
<tr>
<td>Q7_3</td>
<td>I know about technologies that I can use for understanding and doing science.</td>
</tr>
<tr>
<td>Q7_4</td>
<td>I know about technologies that I can use for understanding and doing social studies.</td>
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<tr>
<th></th>
<th>Technological Pedagogical Knowledge (TPK)</th>
</tr>
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<tbody>
<tr>
<td>Q8_1</td>
<td>I can choose technologies that enhance the teaching approaches for a lesson.</td>
</tr>
<tr>
<td>Q8_2</td>
<td>I can choose technologies that enhance students' learning for a lesson.</td>
</tr>
<tr>
<td>Q8_3</td>
<td>My teacher education program has caused me to think more deeply about how technology influences the teaching approaches I use in my classroom.</td>
</tr>
<tr>
<td>Q8_4</td>
<td>I am thinking critically about how to use technology in my classroom.</td>
</tr>
<tr>
<td>Q8_5</td>
<td>I can adapt the use of the technologies that I am learning about to different teaching activities.</td>
</tr>
<tr>
<td>Q8_6</td>
<td>I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.</td>
</tr>
<tr>
<td>Q8_7</td>
<td>I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom.</td>
</tr>
<tr>
<td>Q8_8</td>
<td>I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school and/or district.</td>
</tr>
<tr>
<td>Q8_9</td>
<td>I can choose technologies that enhance the content for a lesson.</td>
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<tr>
<th></th>
<th>Technological Pedagogical Content Knowledge (TPACK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q9_1</td>
<td>I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches.</td>
</tr>
<tr>
<td>Q9_2</td>
<td>I can teach lessons that appropriately combine literacy, technologies, and teaching approaches.</td>
</tr>
<tr>
<td>Q9_3</td>
<td>I can teach lessons that appropriately combine science, technologies, and teaching approaches.</td>
</tr>
<tr>
<td>Q9_4</td>
<td>I can teach lessons that appropriately combine social studies, technologies, and teaching approaches.</td>
</tr>
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</table>
Data Collection and Procedure

Online survey data was collected to identify T-dimensional confidence at two points in the program and to compare pre-service and clinical teacher confidence. Sixty-four out of 96 elementary pre-service teachers (67%) and 30 out of 54 elementary clinical teachers (56%) responded to the survey. The survey was administered over two months through Qualtrics via an e-mailed link or in-class participation. In-class administrations occurred in three science methods courses and three clinical teaching seminars. Since there was only one nonresponse, the single clinical teacher nonresponse on TPK (Q8_2) was omitted.

Data Analysis

Descriptive statistics included mean and standard deviation for each question (Appendix A) and T-dimensional composite scale (TK, TCK, TPK, and TPACK) (Table 2). For inferential statistics, Welch's One-way Analysis of Variance (ANOVA) was used (Table 3). Since the difference in sample size between the two groups was large, and TK, TCK, and TPK did not meet the homogeneity of variance assumption, the Welch's test was selected to determine the variance in means between pre-service and clinical teachers in each of the T-dimensions (Kohr & Games, 1974).

Table 2

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Pre-service Teachers</th>
<th>Clinical Teachers</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
<td>S</td>
</tr>
<tr>
<td>TK</td>
<td>6</td>
<td>3.39</td>
<td>.9</td>
</tr>
<tr>
<td>TCK</td>
<td>4</td>
<td>3.57</td>
<td>.7</td>
</tr>
<tr>
<td>TPK</td>
<td>4</td>
<td>3.92</td>
<td>.5</td>
</tr>
<tr>
<td>TPACK</td>
<td>4</td>
<td>3.79</td>
<td>.6</td>
</tr>
</tbody>
</table>

Results

Descriptive statistics were used to identify the development of TK, TCK, TPK, and TPACK confidence. The pre-service teachers (N = 64) had an overall numerically lower mean for each of the T-dimensions compared to the clinical teachers (N = 30), and the range of responses for pre-service teachers was also much wider on average than that of clinical teachers.

Pre-service teacher responses typically ranged from 2 to 5, except for the TK responses which ranged from 1 to 5. Clinical teacher responses showed less variance and typically ranged from 2 or 3 to 5. Since pre-service teachers had received less instruction than clinical teachers, due to their recent entry into the program, their T-dimensional knowledge demonstrated a wider range of understanding and development (Mouza et al., 2014).

Numerically, pre-service teachers ranked their T-dimensional confidence (highest to lowest), TPK, TPACK, TCK, to TK, moving opposite of what one would expect (Graham et al., 2009). Clinical teachers, on the other hand, ranked their T-dimensional confidence (highest to lowest) from TK, TCK, TPK, to TPACK, building from the foundational TK up to the integrated TPACK. Mean and standard deviations for each question (Appendix A) and the composite mean scores for TK, TCK, TPK, and TPACK are presented above (Table 2).

In order to test whether pre-service and clinical teachers generally have statistically significant differences in T-dimensional confidence, a Welch's One-way ANOVA was conducted in SPSS 25 (Table 3). The results indicated a
significant difference between pre-service and clinical teacher TK and TCK confidence, \( F(1, 80.52) = 15.47, p < .001 \) and \( F(1, 74.81) = 9.84, p = .002 \), respectively. The results did not reveal a significant difference between pre-service and clinical teacher TPK or TPACK, \( F(1, 78.68) = .61, p = .438 \) and \( F(1, 62.03) = 1.06, p = .308 \), respectively. Thus, pre-service teachers demonstrated a statistically significant lower confidence in TK and TCK, but a similar TPK and TPACK confidence as clinical teachers. Cohen's \( d \) was estimated for each significant finding scale based on Cohen's guidelines (Cohen, 1992). Both TK (.81) and TCK (.66) had a large effect size.

### Table 3

<table>
<thead>
<tr>
<th>Subscale</th>
<th>df</th>
<th>( F )</th>
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### Discussion

The purpose of this investigation was to conduct a needs assessment and examine the difference in pre-service and clinical teachers' T-dimensional confidence. There were clear differences in confidence between the two groups in all T-dimensional constructs; however, only TK and TCK were statistically significant. Even though clinical teachers had completed more coursework and practical classroom experience, their confidence in TK and TCK are the only dimensions that separate them from the less experienced pre-service teachers.

The pre-service teachers expressed the least confidence in TK and the most confidence in TPK, followed by TPACK and TCK. Clinical teachers expressed the most confidence in TK, TPK, TCK, and then TPACK. All the clinical teachers' T-dimensional mean scores were within .24, which indicated an even development of technology-related TPACK dimensions among this group. Pre-service teachers' confidence, however, was not as evenly distributed and ranged from a low in TK (\( M = 3.39, SD = .92 \)) to a high in TPK (\( M = 3.92, SD = .57 \)). The literature suggests there is no set pattern to TPACK development (Koehler, Mishra, Kereluik, Shin, & Graham, 2014), and the pre-service teachers were an excellent example of this as they were more confident in TPK, TPACK, and TCK than TK. These results further demonstrated the "complex and ill-structured problem involving the convoluted interaction of multiple factors" that is technology integration (Koehler & Mishra, 2008, p. 10).

It is important to note, pre-service teachers, more confident in TK, are also more likely to use technology Chai et al. (2010). Since the pre-service teachers in this study showed the least confidence in TK, it implies they will be less likely to use technology in the future. It may also indicate an area for program improvement. Fortunately, the clinical teachers expressed more confidence in TK than any other T-dimension, which suggests that TK may develop later in this teacher education program.

The data also showed that while the program did not require a technology course or have a systematic method addressing technology integration, pre-service and clinical teachers developed T-dimensional confidence. Pre-service teachers developed more confidence in TPK and TPACK, which is not surprising due to the program's heavy focus on PCK. However, the lack of technology instruction and integration across the program and pre-service teachers' inexperience and lack of foundational knowledge in TK and CK may explain the lower TK and TCK scores of pre-service teachers (Koh et al., 2010).

As the pre-service teachers' progressed through the program, they were exposed to more content and technology as well as opportunities to teach with technology. The accumulation of early pedagogical knowledge combined with later content and technology experience seemed to support the later development of TK and TCK as seen in the clinical teachers' mean scores taken from the last semester of the program. The use of integrated coursework and practical experiences throughout the program (Mouza et al., 2014), as well as interdisciplinary and constructivist approaches, also supported TPACK development for both groups through authentic learning experiences (Ottenbreit-Leftwich et al., 2012).
Differences between pre-service and clinical teachers also uncovered questions about how practical experiences impact confidence. The mean scores suggested that with more practice and real-world experience come more conservative or measured levels of confidence, as seen in clinical teacher's TPK and TPACK. The literature indicates that significant barriers still exist to technology integration in many schools including first and second order barriers (Ertmer, 1999) as well as cooperating teachers' technology views (Niess, 2005), school policy, teacher beliefs, lack of reliable connectivity, and standards-driven instruction (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). Experiencing technology barriers in practice may result in a reduction in, or at least leveling off, of T-dimensional confidence. This might explain the similarity in clinical and pre-service teacher's TPK and TPACK.

Limitations of this study include a small sample size that limits the ability to validate TPACK dimensions and purposeful sample that prevents the results from being generalizable to other teacher education programs. Also, Kopcha, Ottenbreit-Leftwich, Jung, and Baser (2014) argue that self-assessed TPACK survey confidence may not translate into practice. As a result, future studies might explore whether T-dimensional confidence translates into practice by conducting mixed methods research with clinical teachers or first-year in-service teachers through the collection of survey data, lesson plans, and observations to triangulate self-assessed and observational TPACK measures (Harris et al., 2010).

Conclusion

As more educators are required to use technology to help students master learning objectives (Mouza et al., 2014), the debate on what kinds of knowledge we must use to support pre-service teacher technology integration continues. TPACK and its T-dimensions continue to provide a framework to guide teacher education programs in developing the knowledge necessary for effective technology integration (Koehler & Mishra, 2008). This study presented the development of T-dimensions in two groups of pre-service teachers and compared the frequency and variation of confidence in the elementary teacher education program. While this study is not generalizable, it provides examples of T-dimensional confidence and trends across different stages of knowledge development while supporting previous findings.

References

Hofer, M., & Harris, J. (2012). TPACK research with inservice teachers: Where’s the TCK? Society for Information Technology & Teacher Education International Conference, Charlottesville, VA


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*Note. Questions with statistically significant differences between pre-service and clinical teachers: Q1_1 (p < .001); Q1_2 (p = .004); Q1_3 (p = .005); Q1_4 (p = .003); Q1_5 (p = .001); Q1_6 (p = .004); Q7_3 (p < .001); Q7_4 (p = .001).
Abstract: Which topics were addressed, and in what sequence(s) did they appear, in experienced K-12 teachers’ instructional plans that incorporate students’ educational technology use? Eight volunteer classroom teachers with expertise in a broad variety of curricula and instructional levels participated in a day of professional learning at a local university that helped them to explore ways to plan technology-enhanced, curriculum standards-specific lessons, units, and projects. Data were generated through individual participants’ think-aloud and group reflection audio recordings, plus follow-up interviews with two participants that occurred after the planned units were taught. Many individual differences in planning topics and sequences were noted when the data were analyzed. Overall, the teachers’ TPCK/TPACK-based pedagogical reasoning first emphasized curriculum content, then knowledge of students and/or learning activities. Technological considerations were voiced far less often than those regarding content, students, and learning activities, even when participants used planning aids that matched recommended educational technologies to specific types of learning activities.

What are the considerations that enter into experienced teachers’ TPCK/TPACK-based decision-making when planning a particular lesson or project that incorporates educational technologies? Are there common patterns, sequences, and/or proportions of these considerations that can be discerned across teachers? How, if at all, do these planning approaches change when teachers use professional learning materials that are designed to help them to develop or revise their plans while actively considering technologies to use in lessons and projects? We addressed these questions in the following exploratory study after discovering that these particular dimensions of teachers’ planning are surprisingly under-researched. This study’s results suggest the possible primacy of teachers’ focus upon curriculum content, students, and learning activities during instructional planning, regardless of whether or not their plans incorporate digital tools and resources. Given the preliminary and small-scale nature of this study, we urge other researchers to join us in exploring the topics and sequences reflected in technology-using teachers’ naturalistic instructional planning.

Literature Review

Approximately 50 years ago, scholarship about teachers’ instructional planning was primarily prescriptive; it was not based upon understanding teachers’ decision-making processes in situ. Instead, planning procedures were derived from models of curriculum theory. Recommendations for curriculum-based lesson and unit design at the time suggested that teachers should first “specify objectives,” then “select learning activities,” then “organize learning activities,” then “specify evaluation activities” (Clark & Yinger, 1977, p. 280) in what became known as a rational means-end model for instructional planning. Data-based, empirical investigations of teachers’ planning didn’t begin until 1970. In that year, Taylor reported that secondary teachers considered students’ learning needs, abilities, and interests first during planning, followed by the content to be taught, learning goals, and teaching methods. By contrast, Zahorik (1975) found that most of the teachers he studied began their planning by considering content, which dominated their thinking throughout the process, followed by decisions concerning learning objectives. Both of these studies, however, generated data by asking the participating teachers to report their planning processes via surveys and discussions, rather than observing planning as it occurred (Clark & Yinger, 1977). These data generation methods dominated studies of teachers’ planning foci at the time (Shavelson, 1983); a pattern which has persisted to date.

Teachers’ planning began to be observed while in process, either in laboratory settings or in the field, in the mid-1970’s (Clark & Yinger, 1977). Yinger (1977) and Peterson, Marx and Clark (1978) were the first to ask teachers to voice their planning thoughts and decisions by thinking aloud during planning. The two studies revealed different
planning emphases for the participating teachers. Peterson et al. found that secondary teachers spent the most time considering the content to be taught, and the least time focused on learning objectives. Instructional strategies and activities were considered more than learning objectives, but not as much as the content of the lessons being planned. Similar results were reported by Brown (1988), who found that middle school teachers focused upon content topics most often during planning, followed by learning materials, learning activities, and evaluation of student learning. Brown was also among the first to note that content-based learning goals in teachers’ planning were taken from state, district, and school policies and documents, rather than being written by the teachers as part of the planning process. BY contrast, Yinger’s (1977) case study of five months of a first-grade teacher’s planning showed the predominance of selecting, organizing, and sequencing instructional activities and routines in a problem-based approach to planning.

Overall, in the 1970’s and 1980’s, researchers discovered that although teachers were able to name and explain learning objectives as part of their planning processes when prompted to do so, they did not use objectives as the primary focus for instructional planning in their everyday teaching practice. As Shavelson & Stern (1981) asserted, “while [the] prescriptive model of planning may be one of the most consistently taught features of the curriculum of teacher education programs, the model is consistently not used in teachers' planning in schools” (p. 477). Similar findings were reported by Young, Reiser and Dick (1998) almost 20 years later. Rather, learning activities were found to be the primary focus of teachers’ planning across multiple studies in the 1980’s and 1990’s.

In this literature, learning activities are conceptualized as the basic units of teachers’ planning and classroom-based action. The planning aspects of learning activities were seen as seven types of “tasks,” comprising the content to be learned; the conditions that students use for learning; the sequencing, pacing, timing, and actions related to content and materials; the general learning goals of the task; students' needs, abilities, and interests related to the learning goals; the socio-cultural context for instruction, including the groupings in which students will be learning; and timing considerations, which teachers consider concurrently at daily, weekly, monthly, term-delimited, and yearly levels. Planning, then, was understood to be teachers creating and sequencing instructional tasks (Shavelson, 1983). However, in teachers’ professional practice, “…the sequence of elements considered, and the compromises that have to be made” in the process were seen to be “…unknown” and probably predicated upon “the particular task at hand as well as the proclivities of the particular teacher” (Shavelson & Stern, 1981, p. 478). Calls for “…more intensive studies that either observe teachers during planning or probe their thinking in personal interviews that are held near the time that planning takes place” (Brown, 1988, p. 70) have gone largely unanswered. These particular aspects of teachers’ naturalistic planning – that is, the nature and sequence of planning foci – remain surprisingly under-researched, even 30 years later.

In fact, several reviews of scholarship concerning teachers’ planning and decision-making (e.g., Warren, 2000) have noted that explorations of teachers’ planning after the 1980’s became subsumed within much larger-s cope inquiry concerning teachers’ instructional thought processes and decision-making that occur during both planning and teaching. During recent years, teachers’ planning has been addressed more often as part of research that concerns instructional design (e.g., Romiszowski, 2016), pedagogical reasoning (e.g., Biggers, Forbes & Zangori, 2013), and pedagogical content knowledge (e.g., Stender, Bruckmann, & Neumann, 2017). At the same time, the focus on teachers’ planning processes, which emphasized individual cognition, expanded to include a more situated, ecological framework that emphasizes shared knowledge construction among teachers as collaborating professionals (Munthe & Conway, 2017). These patterns are also evident within the subfield of educational technology, which has addressed teachers’ planning to teach with digital tools and resources in empirical studies of their general planning patterns (e.g., Tubin & Edri, 2004); pedagogical reasoning (e.g., Feng & Hew, 2005); technological pedagogical content knowledge (e.g., Harris & Hofer, 2011); lesson design procedures and dispositions (e.g., Koh, Chai, Hong & Tsai, 2014); collaborative instructional design (e.g., McKenney, Kali, Markauskaite & Voogt, 2015); tool-based decision-making (e.g., Felger & Shafer, 2016); technological pedagogical reasoning (e.g., Niess & Gillow-Wiles, 2017); and models for professional development (e.g., Hutchison & Woodward, 2018).

Specific information about the nature of teachers’ everyday planning processes that incorporate consideration of educational technologies is scant, however. This small-scale exploration of eight teachers’ planning foci and sequences, therefore, was designed to address the temporal and technological gaps that exist between studies of the topics and progressions of teachers’ decision-making during instructional planning that were published three decades ago, and those that address the comparative absence of that inquiry at the present time.

Study Design

An open invitation to local classroom teachers was sent to two local school district technology coordinators via email to solicit participants for an interactive learning session. The one-day session introduced the teachers to
content-specific planning aids that the authors had previously created, vetted, researched, and published. These are comprehensive, freely available taxonomies of learning activity types (LATs) with corresponding recommended technologies in nine different curriculum areas (http://activitytypes.wm.edu/). Using these open educational resources as planning aids, teachers select, combine, and sequence multiple learning activity types to design plans for lessons, learning projects, and units based upon knowledge of their students’ learning needs and preferences, curriculum standards, and contextual conditions (Harris, et al., 2010). Teachers’ TPACK is built, over time, in the process of using the LAT taxonomies to plan learning experiences that incorporate educational technologies in curriculum-based and pedagogically focused ways (Harris & Hofer, 2011). After participating in the day-long session, all study contributors were given the option to complete, then implement the plans that they had started to create as the basis of a lesson, project, or unit that was scheduled to be taught before the end of the academic year.

Participants

Eight classroom teachers from one district volunteered to participate: three elementary-level, three middle school, and two high school; of these eight participants, seven were women. The suburban/urban district in the southeastern United States in which the teachers work serves just over 12,000 students across seventeen schools. Roughly 40% of the students in the district are from a range of non-dominant-culture racial and ethnic backgrounds, approximately 20% of whom are considered economically disadvantaged. None of the participants had prior knowledge of TPACK. The teachers were asked to pre-select a focus for their planning to be done during the day-long interactive session that was held at the local university. Lori is a kindergarten teacher who chose to focus her planning on an integrated mathematics and prereading project. Kathy and Megan teach 5th grade in the same school, and, like Lori, also focused their work on mathematics and reading. Holly and Maria are 6th grade teachers who decided to plan mathematics units that appropriated many different types of educational technologies in curriculum-based ways. Tina teaches 8th grade science and wanted to explore digital tools that would help her to better assess her students’ learning. Andy and Hilary work in the same high school, teaching English and art, respectively. Both decided to enhance an existing instructional unit; Andy’s was a multimedia book study project, and Hilary’s was an examination of famous artists’ works, characteristics, and processes. (All names are pseudonyms.)

The teachers’ participation in the day-long session yielded six recertification credits each, and they were given the option of earning an additional four credits if they engaged in a 60 – 90-minute individual interview after having completed and implemented the plans in their teaching prior to the end of the school year. Two of the eight teachers were able to teach their units in this time period and opted to participate in individual follow-up interviews.

Data Generation and Analysis

During the day-long session at the university, the participants each generated two individual think-aloud audio recordings (TA1 and TA2) that voiced their pedagogical reasoning and decision-making processes as they began to create or revise their instructional plans. TA1 was generated before the authors’ planning aids were distributed and introduced; TA2 was generated immediately afterwards. The teachers also engaged in two group interviews, during which they were encouraged to reflect upon their think-aloud recordings of their mental planning processes.

The think-aloud recordings occurred in separate, empty classrooms that were reserved for each participant, without the instructors being present. Prompts for each recording were printed on paper, and participants were given digital recorders to use. The prompt for the first think-aloud (TA1) recording said:

Choose one or two specific [state standards]-related learning goals for a lesson or short project that you will be using in your classroom later this school year. Plan the lesson or project, narrating what you’re thinking and deciding at each step of planning. Pretend that you’re talking to someone who is not familiar with how to do instructional planning, such as someone who is learning to be a teacher. Speak your thoughts, even as they may change, into the recorder as you form the plan.

The prompt for the second think-aloud (TA2) recording, during which the teachers used the planning aids that the researchers had just introduced to the large group, said:

1. Starting with your previous planning, which, if any, of the LATs from the taxonomies were included?
2. Which, if any, might you add or substitute for parts of the previous plan? Why?
Participants were given 45 minutes to complete each think-aloud independently. All returned to the main session room after making their audio recordings within the time allotted.

Andy and Holly were the two teachers who completed, then taught, their unit plans, then engaged in semi-structured interviews (one in person and one via telephone, per their preferences) with one of the researchers. Interview prompts began with the following questions, adding follow-up questions and member checking based upon the participants’ responses. Each individual interview was approximately 75 - 90 minutes in length.

1. Please describe the lesson/project that you implemented.
2. How, if at all, did you adjust how you implemented the plan as you were engaging in it in the classroom? Why did you make these adjustments?
3. Please describe how the students responded to the lesson/project.
4. Do you think that you will use this lesson/project again? Why or why not?
5. If you plan to use it again, what changes, if any, will you make and why?
6. What, if any, realizations did you have from implementing this lesson/project about the content taught? About the type of lesson/project? About using the technologies in these ways?
7. How did you use the [aids] plan the lesson/project? If you didn’t use them, why not?
8. Do you anticipate using the taxonomies in the future? If so, how and why? If not, why not?
9. Do you have suggestions for us about how to improve the LATs taxonomies?

The eighteen think-aloud audio recordings and four interviews (two group; two individual) were transcribed verbatim and analyzed using constant comparative thematic analysis by the two researchers, who worked independently from the same emerging codes-and-definitions list that was posted in a secured, shared virtual drive folder. Six coding categories emerged: content (9 sub-codes), context (5 sub-codes), digital technologies (6 sub-codes), learning activities (5 sub-codes), non-digital materials (5 sub-codes), and students (5 sub-codes). After analyzing each subset of transcribed recordings separately, we met to compare the codes assigned to each utterance, discussing any differences perceived until we could agree upon the codes to assign. Codes’ definitions and labels were adjusted by discussion and mutual agreement as necessary, based upon the nature of the study’s emerging themes and subthemes. We discerned the patterns and frequencies of codes, first individually, then collaboratively, across all analyzed think-aloud and interview transcriptions to identify the study’s results.

Results

As participants described their thinking while they planned units and projects during the two think-aloud sessions – first using their own planning approach, and then incorporating use of the LAT taxonomies – we noted both common patterns in and highly individualized approaches to instructional planning and decision making. Beginning with and maintaining a focus on curriculum standards was common to all participants. However, considering students’ learning needs and preferences, types of learning activities, and digital- and non-digital materials varied considerably, both in terms of relative frequency and sequences within the planning process. Introducing the planning aids seemed to influence participants’ planning somewhat, particularly in terms of the learning activities and digital technologies considered and chosen. In the sections that follow, we describe common patterns in and differences among participants’ planning emphases and sequences across the two phases of their planning think-alouds.

Common Planning Emphases During TA1

All participants began their planning processes by considering curriculum content and related learning goals, referencing state standards, curriculum guides, and/or district-level curriculum documents. They then considered learning activity options, students’ needs and/or preferences, or both. Their topic sequence patterns diverged later in their planning sequences as they considered a mixture of other elements.

Across participants, consideration of digital and non-digital tools and resources occurred comparatively later in the teachers’ planning sequences. Interestingly, comments about technology options totaled only eight percent of all codes assigned during TA1, comprising the least frequently mentioned of the six primary coding categories. It was also surprising how infrequently participants referenced contextual elements and influences in their planning. Only 11% of the codes assigned to the utterances in these initial planning sessions focused on context. Of these contextual considerations, time was the most prevalent factor referenced.
Although we noted these common patterns across participants, several differences were also apparent in the topics that they addressed in their instructional planning. Four of the teachers emphasized a particular category in greater proportion to the others. Kathy and Maria emphasized content in their planning, with 43% and 46% of the codes assigned to their TA1 recordings, respectively. Megan focused primarily on her students’ learning experiences, with 43% of her codes referencing some aspect of considering and selecting learning activities. Forty-five percent of Andy’s codes related to students, most often focusing on aspects of their motivation and engagement in learning. The other four participants’ considerations were more evenly distributed across the six coding categories. Tina’s categories were perhaps the most balanced, with five of the six categories represented in her TA1, each totaling between 16-23% of the total codes assigned. Figure 1 compares the relative proportions of codes for Megan and Tina, illustrating the differences between a more emphasized and an evenly balanced approach.

![Megan TA1 and Tina TA1](image)

*Figure 1. Comparison of Planning Emphases for Megan and Tina During Think-Aloud 1*

**Variation in Planning Sequences During TA1**

Despite the participants’ initial common focus on curriculum content, their planning sequences were unique and varied. To create visual representations of the participants’ planning sequences, we combined the sequences of topics considered by each participant with the relative emphases/frequencies of each coding category assigned. Sequences are depicted as flowchart elements; comparative frequencies are represented in proportional font sizes in Figures 2, 4, 5, and 6, with larger font sizes indicating greater emphasis/frequency. Three participant groups emerged when we represented their planning sequences in these ways. Three participants focused primarily on content throughout their planning sequences. Three others tended to consider content and learning activities simultaneously. The two remaining participants began and ended their planning sequences with a primary emphasis upon their students’ needs and preferences. For example, Figure 2 illustrates planning sequences for Lori and Andy, the two teachers who focused primarily on students during TA1.

![Lori and Andy Planning Sequences](image)

*Figure 2. Student-focused Planning Sequences for Lori and Andy*

**Emphases During Participants’ Planning Using the Planning Aids**

During the second phase of the professional learning session, participants were prompted to begin with their previous planning ideas and consider which, if any, activities listed in the planning aids were included. Then they were encouraged to consider which, if any, learning activities they might add or substitute for parts of the previous
plan, explaining why they would consider these changes. Surprisingly, even with this different, directed focus for the second think-aloud, the proportions of teachers’ considerations in the six coding categories remained comparatively unchanged in four of the six topical emphases, as illustrated in Figure 3.

Figure 3. Comparison of Planning Emphases During the First and Second Planning Sessions

In comparing overall planning emphases between the first and second planning sessions, we noted a decrease in focus on non-digital materials (10% to 3%) and contextual considerations (11% to 3%), and only a one percent increase in consideration of learning activities. This was particularly surprising because the planning aids are organized around curriculum-based learning activity possibilities. Teachers who were introduced to these same planning aids in prior research increased their consideration of learning activity possibilities (Harris & Hofer, 2011).

By contrast, most of the participants discussed educational technology possibilities and choices more often while consulting the planning aids during TA2 (8% of all codes during the first session to 27% during the second). While all participants considered educational technologies during their initial planning (between 2% and 20% of individual participants’ topics considered), only half of the participants considered technologies in eight percent or more of their codes. The remaining four participants mentioned technologies in five percent or fewer of their utterances. This increase in focus on technologies during the second planning session is intriguing, because participants were not prompted specifically to consider using technologies in their emerging instructional plans. However, recommended technologies appeared in the planning aids, connected directly with each type of curriculum-based learning activity that was included.

Technologies were mentioned more than any other sub-category during the second planning session (27% of all codes) as the teachers consulted the planning aids. Yet half of the participants discussed technologies comparatively later in their planning sequences, rather than from the outset. This seems to contrast with educational technology-related planning approaches that situate teachers’ consideration of technologies’ affordances and constraints during the initial phases of the planning process (e.g., Angeli & Valanides, 2005). Holly considered technologies (“Tools” in Figure 4) at each phase of her planning process. Andy was the sole participant who considered technologies only at the beginning of his planning process. As the example planning sequences in Figure 4 illustrate, there were no discernable commonalities in when the teachers included technology considerations in their planning sequences.

Figure 4. Comparing Andy’s, Holly’s, and Lori’s Planning Sequences

Comparing Planning Sequences

When contrasting participants’ planning sequences and relative emphases between the two planning sessions, some interesting patterns emerge. While we illustrate some of these findings visually in Figures 5 and 6, space constraints do not allow us to present diagrams representing each participant’s unique planning sequence. Instead,
these appear in the PowerPoint file that was presented at SITE 2019 and is available to subscribers via LearnTechLib at https://www.learntechlib.org/p/207993/mg9/.

Similar to the patterns that characterized their initial planning sequences, nearly all of the participants began by considering content to be taught during the second planning session. The only exception was Kathy, who focused almost exclusively on learning activities and possible technologies. This may be attributable to the prompt that guided the second think-aloud and/or the structure of the LAT taxonomies that participants consulted, which are organized according to learning activity types and suggested technologies for each. Not surprisingly, Kathy’s proportion of content-related codes was well below the 26% overall average. The visual representations of her two planning sequences, found in Figure 5, illustrate this shift in sequence and relative emphasis between the two planning sessions.

**Figure 5. Kathy’s Differing Planning Sequences and Emphases**

As referenced earlier, the planning sequences that emerged during TA2 also reflected an increased emphasis on technology considerations across all participants. Holly, Megan and Tina showed the largest increase in technological focus from the first to the second planning session. Holly’s technology-related considerations increased from 9% to 32%, Megan’s increased from 5% to 45%, and Tina’s increased from 3% to 41%. Holly’s planning sequences (Figure 6) depict her increased consideration of technologies from her first to second planning sessions.

**Figure 6. Comparison of Planning Sequences and Relative Emphases for Holly**

During the first planning session, all of the participants but Lori and Andy emphasized learning activities. All but Megan also considered learning activities in the second planning session. Interestingly, Andy and Megan were the only two participants whose overall emphases on learning activities did not increase between the first and second planning sessions. As mentioned above, it is possible that the focus on types of learning activities and corresponding technologies in the planning aids stimulated this increased focus on both technologies and learning activities during the second planning session. Interestingly, the relative emphasis on student considerations decreased for three of the participants between the first and second planning sessions, although overall percentages across participants held relatively steady (21% in TA1 and 20% in TA2). Again, it is possible that some participants considered students’ needs and preferences less during the second session due to the directed focus on learning activities and corresponding technologies. Moreover, as we looked across all participants’ planning sequences in the two think-aloud sessions, the number of topic categories that they considered did not change dramatically overall.
Results Summary

While all of the teacher participants began with and maintained a primary focus on curriculum content considerations during their two planning sessions, in many ways their planning emphases and sequences varied considerably. Some participants balanced consideration of many elements simultaneously, while others focused primarily on one or two at a time. Some participants seemed to follow a somewhat linear path in the topics that they considered as they planned, while others contemplated multiple topics in a more recursive way. Few of the participants discussed classroom context concerns at any point in the planning processes. Introducing the planning aids seemed to increase the participants’ focus on learning activities and digital technologies and decrease their consideration of contextual conditions. In the following section, we discuss possible implications of this study’s results.

Discussion

Local teachers were invited to participate in this professional development experience to help them to learn more about how to integrate digital technologies in their teaching practice; in essence, to help them to develop and apply their TPCK/TPACK (Mishra & Koehler, 2006) during instructional planning. Despite this focus, all of the participants considered technologies in only limited ways, overall, during their initial planning sessions. Even after we introduced them to the planning aids, which link possible technologies that can support curriculum-based learning activities overtly, most of the teachers’ thinking and decision-making about learning activities, materials, and tools were still eclipsed by considerations of curriculum content, students’ needs and preferences, and learning activity possibilities and selection. These same predominant foci appear in much teacher planning scholarship, as the literature review above illustrates.

When the teachers were prompted to work with the planning aids during TA2, their initial and primary focus on content and pedagogical considerations was maintained. This may suggest that -- as researchers and teacher educators -- rather than perpetuating the more common focus on the educational affordances of digital tools in educational technology professional development and teacher preparation experiences, we should seek to introduce digital tools and resources primarily vis-à-vis curriculum content and pedagogical methods. In doing so, we would align the design of and emphases for professional learning opportunities more closely with teachers’ typical instructional planning approaches (e.g., Bos, 2011; Harris & Hofer, 2009; Roblyer & Doering, 2012).

Our results are limited, however, to this small, though somewhat professionally heterogeneous, group of practicing teachers. More research needs to be conducted to see whether the patterns identified and explained here apply to the planning processes of other in-service teachers with differing years of teaching experience, curriculum areas, teaching levels (elementary, middle, and high school), and instructional contexts. And although this exploratory study’s sample size and data analysis granularity would not suggest that the results reported here are probably even logically generalizable, we note a larger and perhaps more generative aspect of this study’s findings. Our study’s results revealed a range of planning topics and sequences that are more closely aligned with Shulman’s (1987) comprehensive knowledge base for teaching (of which his PCK construct (1986) is only one element), combined with key elements from his model of pedagogical reasoning in action, than they are reflective of well-referenced TPCK and TPACK definitions (e.g., Angeli & Valanides, 2005; Mishra & Koehler, 2006; Niess, 2005). In future studies of and instruction addressing teachers’ planning, we urge researchers and teacher educators to broaden their foci to include these more comprehensive constructs of teacher knowledge and action. This, hopefully, will produce even more accurate, thorough, and applicable research results.

References


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Mathematical Mediation:

From Raw Experience to Spreadsheets via Data Tables

Michael L. Connell, Ph.D.
University of Houston-Downtown
United States
mkahnl@aol.com

Abstract: Technology enables mathematical objects requiring new modes of student interaction - for example, the exploratory power of spreadsheets. In addition to their novelty in the elementary classroom, spreadsheets can draw increased efficacy from prior embodiment as hands-on experiences that are easily experienced in elementary mathematics classrooms. In this chapter, the use of frame-based data tables will be explored as a mediational tool enabling such experiences to be successfully transmitted to the spreadsheet environment. Serving to record and format initial experience into rows and columns, these data tables prove to be an excellent device to help teacher candidates mediate initial raw experience into spreadsheets.

Introduction

Teacher candidates currently enter their mathematics methods class expecting to learn techniques enabling them to teach in an educational setting where technology plays a central role (Connell & Abramovich, 2016). However, despite this expectation they often have no personal experience of where this has been done effectively. For a methods professor this creates a series of major pedagogical challenges which are particularly acute in the K-6 methods courses, where the link between initial hands-on experiences and eventual mathematical abstractions manipulated by technology can be difficult to illustrate.

Furthermore, although teacher candidates often demonstrate an awareness of the need to provide hands-on experience in planning instruction for their students, they often jump to more abstracted technology enabled forms too quickly and lose the essential contexts best developed through the use of the initial hands-on experience. Adding to this challenge, as technology is used to represent increasingly abstracted actions, these more formalized object-based actions are capable of sophisticated computation and suggesting additional actions to the learner which further distance them from the initial hands-on experience (Connell & Abramovich, 2017a).

One approach, the explicit design and use of frame-based data tables serving to record initial hands-on experiences, has shown itself to be extremely useful in mediating between informal initial hands-on experience and the representational forms required in order to apply more abstracted technology based tools such as spreadsheets. Of particular importance, the data-tables described in this chapter were created around a “frame” model similar to that proposed by Davis (1979) and further described by West, Farmer and Wolff (1991) as either a “frame of Type I or Type II”. A Type I frame is characterized by having a logical or computational connection between either the rows or columns, a Type II frame is characterized by having both rows and columns related by logical or algorithmic rules. As such, data-tables constructed along these frame-based properties provide a nearly ideal mediational tool leading to later spreadsheet use and should be included when planning mathematics methods courses.

Entry points for mathematical mediation

When teaching and learning mathematics, a difficulty in the mediation process lies in the fact that the foundational experiences used to think with must be developmentally appropriate for the student. For the case of the elementary classroom, this means the original experience is some type of hands-on, or manipulative-based, experience. Yet, to be useful to an abstracted program such as a spreadsheet, these experiences must be successfully translated into a numerical representation in an Abstract row x column format where each row and column is understood by the
student and its derivation from the original experience clear. The Action on Object (AoO) framework (Figure 1), serves to show the challenge this gap between these differing developmental levels and supported question types creates.

Within the AoO framework (Connell, 2001) a major instructional goal is to enable student construction of meaning through the use of four transitional object types (Manipulatives, Sketch, Mental Picture, and Abstraction). Within each problem explored, three types of activities are typically encountered by the student: 1) memory/recall - often of terminology; 2) teacher posed problems - related toward student construction of concepts; and 3) student posed problems - based upon developing understanding of the problem space presented and its relations to other problem types. These activities are explored by the student through problems requiring the use of activities utilizing developmentally appropriate objects whether they be manipulatives, sketches, mental pictures, and abstractions.

![Figure 1. Action on Object (AoO) Framework.](image)

In the case of an elementary classroom, following developmentally appropriate practice requires that the initial activities should take place at the Manipulatives level. Yet, in order to be used in a sophisticated software tool such as a spreadsheet, these experiences must be successfully mediated into a highly-abstracted form that is capable of manipulation by the tool itself without losing the conceptual and procedural linkages created by the student – or teacher candidate – during the initial hands-on experience with the manipulatives. This difference in levels results in a mediational “gap” between the initial hands-on experiences of the students and the later abstraction of that experience (Figure 2) required by the technology-based tool - a spreadsheet for the two examples to be described.

![Figure 2. The mediational “gap.”](image)

Of particular importance for this chapter, in actual instruction when planning for instruction within the AoO framework, great care is taken to utilize activities that can be organized and recorded for later reference – often in the developmental form of a subsequent level. Thus, a Manipulative based activity can have a record of action that is at the Sketch, Mental Picture, or Abstraction level. So, we can have an initial experience with hands on objects and record our actions with sketches, think about the experience itself, or generate a personally meaningful abstraction of our actions. A dilemma arises for the methods professor, however, since due to individual differences in the decision paths used and representational choices made by individual teacher candidates, these latter abstractions often tend to be highly idiosyncratic.

It is at this point that frame-based data-tables can be successfully utilized. By providing a standard mediational mechanism such data-tables, patterned after frames of Type I and Type II (West, et.al., 1991) possessing a logically based row and column structure, serve to mediate teacher candidate’s initial experiences into abstractions.
sharing a common interpretive framework, rather than far too common idiosyncratic representations. The remainder of this chapter will provide two examples – Stamping Functions and Burning the Candle - showing how the explicit inclusion of such data-tables allow for this unifying mediational process to occur.

It should be noted that both of these examples are drawn from a larger research program investigating areas of overlap between Technology Immune Technology Enabled (TITE) problems implemented within an Action on Objects framework (Connell & Abramovich, 2017b and Connell & Abramovich, 2017c). This current work expands upon this earlier research by explicitly addressing the specific mediational role of a frame-based data-table as a mediational device.

**Stamping Functions and Burning the Candle**

*Stamping Functions* and *Burning the Candle* can both be classified as TITE problems (Abramovich, 2014). As such, they are characterized as being technology immune (TI), that is not able to be solved automatically by software at the push of a button. At the same time, they are technology enabled (TE), in that their solution and its demonstration can be significantly enhanced by the use of technology. *Stamping Functions* is an activity which requires the learner to use a variety of technologically supported tools to investigate changes in surface area as base ten blocks – in particular, the hundreds flat – are stacked in differing configurations. In particular, base ten blocks of different types (ones, tens, hundreds, and thousands) are provided as the objects to act upon together with computers/tablets with supporting software installed and Internet access. *Burning the Candle* requires the learner to use a variety of technologically supported tools to investigate various factors surrounding burn rate of candles. In particular, unused birthday candles of various lengths and diameters are provided together with lighters, timers of various sorts, computers/tablets with supporting software installed and Internet access. Both activities require careful measurement, record keeping, analysis, hypothesis creation and evaluation. From a technology perspective, multiple tools are made easily available with some more appropriate to the task than others. This enables a discussion of which tools were chosen, why they were selected, and how these decisions impact future actions.

In the examples described in this chapter, groups of 3 to 4 teacher candidates from an elementary mathematics methods course were formed and all work was done within these groups. The groups were free to discuss with one another and share insights, data, and suggestions. As they gathered data and planned their analysis, it was quite common for multiple student-posed questions to be presented as might be expected for a classroom utilizing the AoO framework. Framing each activity as a group project created natural opportunities for discussion and collaboration. As the groups explored the initial teacher-posed problems of determining predictive patterns of surface area change and their own self-generated problems they had to choose among the wide variety of tools and applications made available for their use. As these varied from classroom to classroom the principles of the AoO framework were used to guide the decision-making process and subsequent actions and recordings.

**Mediating the gap – Stamping Functions**

The objects used in this activity were the base ten blocks which are nearly ubiquitous in elementary classrooms. For this example, the Hundreds Flat and Ones Cube (Figure 3) were used as the objects being acted upon.

![Figure 3. Hundreds Flat and Ones Cube.](image)

Teacher candidates were told to imagine that the ones cube was a “stamp” which could be used to paint a single square of the hundreds flat. They were then given a group task of counting the number of times you would need to “stamp” the hundreds flat using the ones cube to completely cover all exterior squares – in other words, to determine the surface area of the hundreds flat. They had access to multiple hundreds flats and ones cubes and used these objects extensively throughout this problem set.
Each group quickly came up with the same answer, 240, but were rather surprised when they realized that there had been many different ways of coming up with this answer. For example, one group found the answer by literally counting the top (100 stamps), the bottom (100 stamps), and each of the sides (10, 10, 10) and (10). They recorded their method as: \[ 100 + 100 + 10 + 10 + 10 + 10 = 240 \]. Another group found their answer by first computing the area of the top (10x10) and multiplying this by two because the top and bottom were the same size and shape. They then added four times the length of one side \((4\times10)\) to account for each of the four “edges”. They recorded this method as \[ 2\times(10\times10)+4\times(10) = 240 \]. Other groups used alternate methods, such as \[ 42 + 9 \times 22 \], to obtain the same answer of 240.

The class had earlier made use of the “measurement principle” to show that things equal to the same thing are equal to each other. So, if any group’s efforts were the same as the standard it was understood that they were equal to each other. Thus if \( A = B \) and \( B = C \) then \( A = C \) relations was confirmed. From this background, based upon physical explorations using base ten blocks, the groups quickly came to the realization that methods used to generate their answers (assuming the problem had been done correctly and resulted in the standard answer of 240) were equal.

So for the example illustrated thus far, since

\[
100 + 100 + 10 + 10 + 10 + 10 = 240
\]

and

\[
2\times(10\times10)+4\times(10) = 240
\]

then

\[
2\times(10\times10)+4\times(10) = 100 + 100 + 10 + 10 + 10 + 10
\]

The question of how many stamps were needed to cover 2 hundred flats stacked atop one another was then given, followed in quick succession by the case of 3 hundred flats, 4 hundred flats, and \( N \) hundred flats. The sequence of these questions had been carefully selected so as to naturally lead to the teacher candidates investigations concerning how best to organize their actions. Quickly recognizing the connection between their initial actions and the resulting number (of stamps, i.e surface area) – hinting at an underlying Type I frame – and as might be expected, the teacher candidates naturally turned to a data-table which shared this same structure. This was done spontaneously and serves to illustrate the natural emergence of structural form from what could have been idiosyncratic experience.

![Figure 4](image.png)

*Figure 4. Sample of Data-Table for Stamping Functions.*

This data-table (see Figure 4 for a typical example) was viewed by the teacher candidates as their “instructions” to be used as the basis of for transferring their initial hands-on work with the physical objects into the computer (i.e., a spreadsheet). Following a brief review of how to enter their thinking into a spreadsheet a large variety of alternate scenarios were explored. Some of these scenarios were fairly straightforward, while others were extremely challenging (see Figure 5).
For each of these scenarios, the groups were tasked with coming up with a method of instructing the computer spreadsheet how to calculate the number of stamps necessary to completely cover N of the hundred flats. In each case, a frame-based data-table was used to record the initial actions and to serve as the object from which to create the abstracted spreadsheet. Since any number of flats could be chosen there was not a necessary correlation between rows and columns – however, once the number of flats were determined the remaining data – either row or column – was determined. This one-way structure is indicative of an underlying Type I frame and the resulting data-tables reflected these features.

Once this mediation had occurred, the spreadsheet technology provided powerful recording mechanism and tools for exploration that greatly enabled the problem exploration as shown in Figure 6.

Mediating the gap – Burning the Candle

*Burning the Candle* uses a variety of technologically supported tools to investigate various factors surrounding burn rate of candles. Unused birthday candles of various lengths and diameters are provided together with lighters, timers of various sorts, computers/tablets with supporting software installed and Internet access. As they gathered data and planned their analysis, it was quite common for multiple student-posed questions to be presented. Among these were: “Is the burn rate constant over the length of the candle?”, “How long would it take to totally consume a candle of x length?”, and “What causes the change in burn rate that one observed?”

As was the case for *Stamping Functions*, groups of 3 to 4 teacher candidates from an elementary mathematics methods course were formed and all work was done within these groups. The groups were free and encouraged to discuss with one another and share insights, data, and suggestions.

As definitions were developed and explored (burn rate, for example), the teacher candidates identified the knowns and unknowns, the relationships between them, and created plans for exploration. At this point, they
recognized the need to record their measurements of length and time. Most groups chose to standardize the length of time between measurements, however, not every group selected the same time interval. Groups also varied in their selection of tools to be used in the data collection. For example, one group used a ruler and stopwatch while another used their smart phones to create a digital recording of the candle as it was burned in front of a grid graduated in millimeters which was then played back on a laptop computer.

Regardless of the choices of method and tools, however, similarly structured data-tables were generated as records of the initial action. Since the underlying variables are tightly correlated it was inevitable that these data-tables were of Type II and easily amenable for mediation to the spreadsheet environment. A typical data-table is shown in Figure 7.

![Figure 7. Group raw data.](image)

It should be noted that in the Burning the Candle example there is a necessary correlation between rows and columns. This correlational structure is indicative of an underlying link between the eventual rows and columns – indicating a Type II frame. The resulting data-tables, such as the one shown in Figure 6, each reflected these features.

### What Data-Table based mediation enables

As was mentioned, quite often teacher candidates have extremely diverse methods of attacking hands-on problems. They may choose to use different tools, different units, different recording schemas, etc. As a result, hands-on problem solving can be viewed as a questionable activity involving occasional chaos, lack of communicability between participants, and weak closure that in some cases only makes sense to the individual participant. In addition to being frustrating to the teacher candidates, such activities clearly do not meet the goal of mathematical communication espoused by the NCTM and other professional groups.

Fortunately, if the activities themselves lend themselves to mathematical analysis there is an underlying structure. In some cases, this might only be along a single axis – the number of hundred flats, for example. In other cases, there might be a correlation between the variables at play – time versus length. In either case, however, there is an underlying cognitive “frame” which can be used to organize the recording of activities. Fortuitously, this frame naturally emerges as the teacher candidates create their record of actions within the AoO framework.

The data-tables thus generated share this underlying frame. For the Stamping Functions case the frame is of Type I, for Burning the Candle the frame is of Type II. Regardless of frame type, however, the use of data-tables proves to be equally effective in mediating their hands-on experience to an abstracted form that could be entered into a spreadsheet (Figure 8). Once this is done, the spreadsheet serves as a well understood record of their actions.

![Figure 8. The Burning the Candle Data-Table mediated into Spreadsheet Form as a Record of Action.](image)
After the creation of this Record of Action, the power of the technology can be utilized. In particular, the initial record of action can now be the Object of further actions on the part of the student. The nature of precisely what these actions are was often dictated by the form the data was recorded in and the tools available within the spreadsheet itself. Figure 9 shows one worksheet that illustrates a group’s choice of actions.

**Figure 9.** Spreadsheet record showing basic Graph and Table views.

Depending upon the experience and sophistication, more advanced actions are made available to the teacher candidates in acting upon the spreadsheet as an object. These include creating a regression equation, examining correlations between recorded variables, and looking for statistically significant outliers among the classroom records. In broadening the choice of available actions, the mathematics which can emerge is greatly expanded. Figure 10 shows some of these more advanced analyses. By creating a standardized mediational framework, frame-based data-tables allows the teacher candidates to organize their work in powerful structures, and to create formal records of action that may be used in later problem solving.

**Figure 10.** Spreadsheet record showing advanced analysis made possible by technology.

**Conclusion**

Teacher candidates routinely stress the importance of understanding a problem from a hands-on perspective. This includes actions with physical materials and creating a data-table as part of the record of action. As one put it, “Technology cannot always be depended on to solve a problem... For example, when our group moved to the computer lab to complete the Excel work, we decided to solve it on paper first, then input the numbers. I think it’s important for students to experience this in order to guide themselves to find the answer.” Another came to a similar conclusion, “We can have access to a thousand things in a matter of seconds... From the stamping function activity we first had
to write down all of our information… it was important that we do our work and use technology to check our work when it comes to solving math problems”.

In applying these approaches in designing teacher preparation mathematics methods courses it must be stressed that in order to be effective the initial hands-on activity must provide data that is in some way subject to mathematical analysis at both a physical object and abstracted level. Since we are dealing with a mathematics methods course, however, this is a trivial requirement and would be met by nearly any imaginable activity. When this is done, activities will naturally fall into a form amenable to at least a Frame of Type I format and in many cases a Frame of Type II. Regardless of which type, however, as these examples show data-tables provide a nearly ideal mediational approach for later spreadsheet use.

It is also important in using technology to confirm teacher candidate thinking, not to replace it. In the creation of data-tables, for example, a few sample calculations to test ideas were performed. Technology was then used to check calculations and confirm the candidates were on the correct path. Once this was done, and the spreadsheet object was created the new actions enabled by technology were available and understandable to explore emerging ideas more efficiently. In planning for these explorations be sure to take advantage of “beneath the rules” moments. Often technology can provide important clues as to connections which may be built in the emerging mathematics.

The importance of successful mediation from hand-on experience to the creation of an abstract object, such as a spreadsheet, is hard to overstate when planning a methods class. If the teacher candidates truly understand the questions that are being explored, it becomes possible to select an appropriate technology to help explore possible answers. If the questions being asked are not understood, then NO technology will be able of assistance. Numerical answers can be generated, but these numbers might not even relate to the questions being asked.

It is also important to recall that classroom technology is an ever-moving target. By focusing upon the mathematics that is to be taught and developing methods for successful mediation from hands-on experience to abstract representations, teacher candidates are more able to adapt when a newer program, instructional package, or textbook is to be adopted. Teachers should not allow themselves to become so centered on how to enter the correct keystrokes that they forget why they are doing so!

Finally, the problems surrounding idiosyncratic representations and approaches are standardized as a natural result of this mediation - with the result that the emergent abstracted objects (data-table, spreadsheet, spreadsheet-based analysis, etc.) are commonly understood as are the results of acting upon them. These unifying features brought about by the use of frame-based data-tables suggests strongly that they should be included when designing technology enabled activities when preparing teaching candidates.

References

Abstract: This study examined children’s mathematical language and connections among representations to determine how these were related to learning outcomes when children in Grades 3 to 6 played 12 digital math games. Data sources included pre- and post-tests of mathematics topics in the games and videos of children playing the games. Researchers coded and quantitized the video data to determine the relationship between children’s mathematical language and their learning outcomes. Researchers also used the video data in a qualitative analysis of children’s verbalized and gestured connections among the representations. Results showed significant pre- to post-test gains, and direct and indirect effects between children’s test scores and the mathematical language they used. Specifically, children’s prior mathematical language, and the mathematical language and mathematics that they learned while playing the game, played a significant role in their learning outcomes. The videos revealed that children made a variety of mathematics connections among representations, using language to connect images, symbols, and gestures, demonstrating the important relationships between mathematical language and mathematical representations when playing digital math games.

Purpose

Children’s use of mathematical language can be an important indicator of what mathematics the child understands. Similarly, children’s recognition and connections among representations has often been seen as an indicator of deeper understanding (Goldin, 2003). Children’s use of mathematical language and recognition of mathematics representations can be useful as children play a digital math game. This prior knowledge can serve as a foundation on which children build and construct new mathematical language and concept images of mathematical ideas (Tall & Vinner, 1981). Additionally, when children recognize the mathematics they are learning in the digital math game, this improves their learning outcomes. The purpose of this study was to examine children’s mathematical
language and children’s mathematics connections among representations when the children played digital math games to determine how these were related to changes from pre- to post-test.

**Theoretical Perspective**

The research in this study was designed and analyzed through the lens of Artifact-Centric Activity Theory (ACAT) (Ladel & Kortenkamp, 2016). ACAT is a useful framework for examining how the child’s actions with a digital math game on a touch-screen device can mediate children’s learning of the mathematics. The elements of ACAT include relationships among the subject (a child), the artifact (a digital math game), the object (mathematics), the rules (e.g., mathematics didactics and design principles), and the group (a child’s peers and teacher). Figure 1 depicts these relationships.

![Figure 1](image)

*Figure 1. Ladel and Kortenkamp’s (2016) Artifact-Centric Activity Theory (ACAT).*

In the present research study, our focus was along the main axis, where we examined the relationship between the subject-artifact-object. Along this center line is where the child (the subject) interacts with mathematical ideas (the object) mediated by the child’s actions with a digital math game (the artifact). The artifact serves as a mediator to the internalization and externalization of the child’s understanding of the mathematics, according to the researchers:

The subject externalizes mental representations through the artifact and in turn internalizes specific knowledge that is represented by the artifact as feedback to the subject’s actions. The artifact (i.e., the digital game) itself externalizes the object (i.e., the mathematics) as a psychological reflection of the programmer’s (or designer’s) knowledge. The programmer in turn designs the artifact according to the programmer’s knowledge about the object (Ladel & Kortenkamp, 2016, p. 31).

When Ladel and Kortenkamp (2016) say, “The subject externalizes mental representations through the artifact...,” this means that children are performing actions with their fingers on the touch-screen device to move, select, or trace visual images in the digital game. These are observable actions. Another observable action by children when they are playing a digital game is children’s language describing their activity and understanding of the mathematics in the game. Therefore, children’s externalizations when playing a digital math game can include their actions on the game screen as well as their reactions (e.g., language and gestures) to describe their internalization of the actions and mathematics they experienced during gameplay. This focus on children’s language to describe the mathematics they learned in the games, and children’s connections among different representations (e.g., images, symbols, and gestures) of the mathematics in the games, guided our research. Researchers have characterized these actions with externalized representations as thought and abstraction because the children’s actions with the
representations simultaneously support the development of abstract thought (Nemirovsky, Kelton & Rhodehamel, 2013).

**Methods**

The research design was convergent mixed methods, and included gathering quantitative and qualitative data concurrently (Creswell & Plano Clark, 2011; Teddlie & Tashakkori, 2006). The quantitative data included pre- and post-test scores and quantitized video data on children’s mathematical language use. The qualitative data included coded video data of children’s mathematical connections from two camera sources.

Research Question: What are the relationships between children’s mathematical language, children’s mathematics connections among representations, and children’s pre- to post-test changes when they play digital math games?

**Participants**

Children, ages 8-12, were recruited in four grade-level groups (Grade 3, 4, 5, and 6). Over 200 children agreed to participate in the study. There were complete sets of usable video data and test data for 193 children.

**Procedures**

Each child participated in a one-hour interview. At the beginning of the interview, children completed a written math pre-test. Next, the child played three grade-level appropriate digital math games. Finally, the child completed a written math post-test. Children in each grade level were assigned to play the games in a random order. Games were selected that contained mathematics topics aligned with the CCSSM for each of the four grade-level groups. The following games were selected: Grade 3: Dragon Box Shapes, Motion Math Bounce, and Montessori Division Board; Grade 4: Angle Asteroids, Motion Math Zoom, and Chicken Coop Painter; Grade 5: Dragon Box Triangles, Math Planet Place Value, and Map Maker; Grade 6: Grid Lines, Hungry Fish, and Pirate Percent. These digital games were selected because they contained virtual manipulatives, defined by Moyer-Packenham and Bolyard (2016) as “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” (p. 13).

**Data Sources and Analysis**

There were two data sources: game-specific pre- and post-tests, and two video/audio sources. The game-specific pre- and post-tests each contained 6 test items (per game) that matched the math topics in the games. Items on the post-test were similar in content to items on the pre-test, but were presented in random order. The two video/audio sources were a wall-mounted camera and a GoPro camera. The wall-mounted camera captured the actions and verbalizations of the interviewer and the child. The GoPro camera was worn by the child and captured a close-up view of the child’s hands on the touch-screen device and all of the child’s verbalizations. Having two video sources allowed researchers to capture two different views of the interview. We have used these data collection methods successfully in prior projects (Moyer-Packenham et al. 2016, 2019).

The first analysis was a quantitative conditional process framework analysis using SPSS software with the PROCESS add-on developed by Hayes (2013) and 5000 bootstrap confidence intervals for inference of direct and indirect effects, including various measures of effect size. This analysis focused on the relationship between children’s mathematical language use and children’s pre- to post-test changes. To conduct this analysis, we used the pre- and post-test scores along with the quantitized video data on children’s use of mathematical language. We employed magnitude coding as a way of “transforming or ‘quantitizing’ qualitative data” (Saldaña, 2016, p. 86). This process was used to evaluate the level of specificity of children’s use of mathematical language, with 5 being the highest score and 1 being the lowest score (i.e., 5 indicates specific and precise mathematical language; 4 indicates narrow category mathematical language; 3 indicates general category mathematical language; 2 indicates mathematical language was used, but it was incorrect; 1 indicates no mathematical language). For example, in the game where children learned about isosceles and equilateral triangles, the use of the language “isosceles and equilateral triangles” would be scored as 5; the use of the language “triangle” would be scored as 4; the use of the language “shape” or “geometry” would be scored as 3; and the use of the language “subtraction” would be scored as 2. We used the mathematical language
score and the test score to run mediation and moderation analyses to determine direct and indirect effects for each digital math game.

The second analysis was qualitative and focused on an in-depth examination of children’s mathematics connections among representations. The use of video/audio data is an excellent way to capture children’s externalizations of the mathematics they are learning in the digital math games. By video recording children’s gameplay, we captured the language children used to describe elements of the mathematics in the games, and children’s connections among representations through language, gestures, images and symbols. We used structural coding to organize the video data for each of these representations. Saldaña (2016) describes structural coding as “a labeling and indexing device” to identify all instances in the data (p. 98). Later we used pattern coding (Saldaña, 2016) as a way to summarize the themes across these categories.

Results

The results below focus on the quantitative analysis of children’s use of mathematical language during gameplay and the qualitative analysis of video data on children’s mathematical connections among representations.

Children’s Use of Mathematical Language

In the first analysis, we hypothesized that the precision of children’s mathematical language use might play a mediating role in the changes between children’s pre- and post-test scores. Table 1 provides a summary of the direct pre- to post-test effects (column 2), the direct pre-test to mathematical language use effects (column 3), the direct post-test to mathematical language use effects (column 4), and the indirect effects (column 5) from a mediation and moderation analysis. The direct and indirect effects from this type of analysis help us to see how children’s prior mathematical language knowledge (e.g., their pre-test scores and verbalizations during gameplay) and children’s learned mathematical language (e.g., their post-test scores and verbalizations after gameplay) are important to their development of understanding the mathematics in each of the games. As the results in Table 1 reveal, there are multiple examples where children’s prior mathematical language, and the mathematical language and mathematics that they learned while playing the game, played a significant role in their learning outcomes.

Table 1

<table>
<thead>
<tr>
<th>Grade, Math Focus, &amp; Math Game</th>
<th>Direct Pre-Post</th>
<th>Direct Pre-Math</th>
<th>Direct Math-Post</th>
<th>Indirect Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B Si g.</td>
<td>B Si g.</td>
<td>B Si g.</td>
<td>M ed. od.</td>
</tr>
<tr>
<td>Gr. 3, Geometry Dragon Box Shapes</td>
<td>.39 .00 5*</td>
<td>-.01 .90</td>
<td>.16 .41</td>
<td>-.00 .07</td>
</tr>
<tr>
<td>Gr. 3, Fractions Motion Bounce</td>
<td>.56 .00 3*</td>
<td>.14 .7</td>
<td>.17 .41</td>
<td>.02 .5</td>
</tr>
<tr>
<td>Gr. 3, Division Division Board</td>
<td>.57 .00 1*</td>
<td>.18 .8</td>
<td>.00 .98</td>
<td>.00 .2</td>
</tr>
<tr>
<td>Gr. 4, Angles Angle Asteroids</td>
<td>.33 .02 5*</td>
<td>.35 .9*</td>
<td>.40 .9*</td>
<td>.14 .12</td>
</tr>
<tr>
<td>Gr. 4, Decimals Motion Zoom</td>
<td>.50 .01 0*</td>
<td>.41 .10</td>
<td>.06 .68</td>
<td>.02 .6</td>
</tr>
<tr>
<td>Gr. 4, Fractions Chicken Coop</td>
<td>.88 .00 1*</td>
<td>.13 .2*</td>
<td>.17 .39</td>
<td>.02 .4</td>
</tr>
<tr>
<td>Gr. 5, Geometry Dragon Box Triangles</td>
<td>.55 .00 1*</td>
<td>.11 .29 6</td>
<td>.44 .04 0*</td>
<td>.05 .0 2</td>
</tr>
<tr>
<td>Gr. 5, Place Value Math Planet P.V.</td>
<td>.73 .00 1*</td>
<td>.07 .54</td>
<td>.35 .04 4*</td>
<td>.02 .07</td>
</tr>
</tbody>
</table>
The results in Table 1 show that children experienced significant pre- to post-test gains for all of the digital math games. Five games showed significant direct effects between pre-test scores and children’s use of mathematical language, with small to medium positive effect sizes (.13 to .35). This means that higher pre-test scores were associated with higher levels of precision in children’s use of mathematical language. Four games showed significant direct effects between children’s use of mathematical language and the post-test, with medium positive effect sizes (.34 to .44). This indicates that, as children’s use of mathematical language became more specific and precise during and after gameplay, their post-test scores also moderately increased. Three games showed significant indirect effects between pre-test scores, children’s use of mathematical language, and post-test scores. Children’s use of mathematical language mediated the relationship from pre- to post-test for one game, Angle Asteroids, which showed a small positive indirect effect (B=.14, p=.025). Children’s use of mathematical language moderated the relationship from pre- to post-test for two games. Motion Math Bounce showed a medium interaction effect (B=.50, p=.007) and Montessori Division Board showed a small interaction effect (B=.22, p=.050). Because the children in each grade level played different games, we make no comparisons across grade levels. These results demonstrate the important association and connection between the precision and specificity of children’s mathematical language and their performance on the mathematics pre- and post-tests. The qualitative video data showed that many children who used precise mathematical language (i.e., said “equilateral triangle” instead of simply saying “this shape”) also explained procedures or properties of the intended mathematics goals of the games. Throughout the qualitative results below, children’s mathematical language permeates the examples and shows how children connected images, symbols and gesture representations with and through language during game play.

Children’s Mathematical Language Describing Connections among Representations

There were three prominent representations used by the children and communicated through mathematical language while children interacted with the mathematics in the digital games. Children used their mathematical language to connect images, symbols, and gestures. In this section, we discuss a variety of these connections. While the sections below are organized as a way to present the three salient representations (i.e., images, symbols and gestures), there were multiple instances of children connecting several representations in the same utterance (e.g., connecting a math symbol with a math image while using a gesture and explaining all three representations with mathematical language). Therefore, the organization of the results presented below should not be interpreted to mean that the use of each representation was in isolation; rather, there was a great deal of overlap among the representations.

Connections with Images

A common connection that children made among the representations was image connections. For example, in the Pirate Percent game, children connected the image of the fireworks in the target bucket with the image of the fireworks in the comparative buckets. One child described these image connections: “Sometimes if I didn’t know it, I would see that it had three in there [pointing to one of four possible buckets with three fireworks in it], and three in here [pointing to the bucket they were trying to balance with three fireworks in it]. If I didn’t know it [the requested equivalent fraction], I could just count.” This shows that children were linking images in the games with each other. In the Angle Asteroids game, children understood that angle degrees were used to achieve goals in the game, and the image of the asteroid helped children locate the correct angle. One child explained this process: “Well the ones on the little asteroids, they helped me because, if I knew that there was one right like the one, then either the one would be a higher degree or a lower degree if it was around the circle.”
In some games, there were images of mathematical terminology (e.g., isosceles triangle, quadrilateral). These images helped children to develop their mathematical language. In the Dragon Box Triangles game, words appear on the screen saying “equilateral triangle” when a child creates a specific type of dragon. One child immediately noticed these words and said: “This guy [referring to the equilateral dragon] is equilateral triangle.” After playing the game, another child referred to the new mathematical terminology she was developing: “The warriors we create are either equilateral, quadrilateral [sic], or that name I can't pronounce.” In the Dragon Box Shapes game, the warriors were designed to mirror geometric shapes the children were asked to create. Children’s language to describe the warriors showed they recognized this connection with the images of the warriors and the shapes. For example, one child pointed to the four dragons in the bubbles [which was the intended goal of the level] and said: “I need four little triangle guys.” Another child describing the game stated: “I noticed that all the shapes that we get [pointing to dragons] have the same number of sides, like quadrilaterals [pointing to the quadrilateral dragon in the bubble] has four sides if you don’t count the legs.” In each of these examples, children used specific mathematical language (i.e., triangles, quadrilaterals, equilateral) to explain connections between the mathematics and the gaming images.

Children often connected images with other representations. One child described the images of the bubbles she was manipulating in the Hungry Fish game (seen in Figure 2), saying: “I noticed that the numbers were less than random. There were some randomish numbers, but for the most part there were at least one or two equations you could mix together to get the right answer. I noticed sometimes I had to converge them three or four times.” When children described the fish getting smaller or larger in the Hungry Fish game, they recognized that the changing image was related to the accuracy of their responses. One child noted: “The smaller one, you kinda know if you are doing good, also if it is getting smaller, you are like, Oh! I need to, and if it is getting bigger, you’re like, Oh! I’m doing good!”

Figure 2. Screenshot of the Hungry Fish game.

Similarly, in the Pirate Percent game, one child described the game features: “The weighing [indicating the large stone scale on the screen], it helps you see if they are equal, if they are equivalent or not equivalent.” These examples illustrate children’s connections between mathematical images, such as the bubbles or a scale, and how they made connections between the images and the mathematics tasks and ideas in each game.

Connections with Symbols

There were many examples of children using mathematical language to express connections with mathematical symbols. While playing the Hungry Fish game, one child incorrectly combined a -2 and a -9 with the goal of creating a -4. She observed the result saying: “So negatives add up with each other!” She went on to combine a -12 with a 7 to get -5 and commented: “Wait! Now I can, I just found out you can minus stuff!” In this example, the child observed the mathematical symbols in the game and tried to reconceptualize her ideas about addition and subtraction. Her language in this example shows that she is observing the connections among the symbols in the game and developing an understanding of the negative symbol and how it influences addition and subtraction. A similar observation and connection occurred in the Grid Lines game. One child explained how the red dot on the coordinate plane helped him to be successful: “I think it's cool because you can see where (4,3) is on the axis and the graph. So you can see if you do that ever, it is right there. So you can see where the point will be if you made it.” By connecting the image of the red dot with the mathematical symbols for the coordinate pair (4,3), the child successfully identified the coordinates.
The following transcript excerpt from a child playing the Math Planet Place Value game shows how children’s connections can develop during gameplay. In Figure 3, the child is asked to round 3.19 to the tenths place.

![Figure 3. Screen shot of the Math Planet Place Value game.](image)

The transcript begins with the child tapping the digit in the tenths place and the screen showed 3.29. Next the child tapped the digit in the hundredths place and the screen showed 3.30. Finally, the game buzzed and the problem was reset which indicated to the child that he had a wrong answer.

“What? I don’t get this… [Child points to instructions "round to tenths place"] So the tenths place?”

“So here… [Child points to tenths, then points back to instructions] Three nineteen to tenths.”

“Here? [Child points back to tenths place] Maybe here? [Child points to hundredth place].”

[Child points to instructions and then back to hundredths place. Child taps the up arrow and the screen shows 3.20 and indicates a correct response.]

This child was able to correctly round all subsequent similar problems. The child’s use of language and use of symbols in the game may have helped him make connections between the task, place values, and correct procedure for rounding to the tenths place.

In the Motion Math Zoom game shown in Figure 4, where children find numbers on a movable number line, children’s connections with symbols also helped them understand place value. For example, while playing this game, one child explained her thinking: “Say I was trying to find zero point three, and um, and I see zero point zero ten. It's telling me, okay, I don't need to, uh, zoom over anymore, because it's right there.” In this case the child was using another number as a reference to determine the placement of the target number on the number line. Children often recognized the mathematics symbols in the games. In the Pirate Percent game, one child pointed to a watermelon that had a 50% symbol on it and said, “This one is one-half [pointing to one watermelon] and this one is bigger than one-half [pointing to a different watermelon that had a ¾ symbol on it].” In the same game, another child was attempting to find a basket of fireworks with an equivalent value to the target basket (with a value of 10%). The child examined the different choices and stated: “One-tenth is equal to ten percent, that's what I think. Yes!” These two children connected the fraction form of the number with the percent form of the number. This demonstrates how children connected mathematical symbols in the digital games with other symbols, and used mathematical language to describe the connections.

![Figure 4. Screenshot of the Motion Math Zoom game.](image)
**Connections with Gestures**

Children frequently used gestures to express their understanding of the mathematics in the digital games. In the Angle Asteroids game, one child used gestures to explain the connection between the grid lines and the location of angles on the screen. The child explained: “There were lines for each, like half fourth way of a line [child gestures on the table to refer to the parts of the grid]. I just barely figured this out, like half way line [child gestures on the table to show the grid line in the middle].” This example shows the child using gestures to explain observations she made about locating the angles on the grid. This was similar to the connections children made between directional order and the coordinate numbers in the Map Maker game (see Figure 5). One child observed this connection during the game: “Oh, it's that way [pointing to the x-axis and then the y-axis]. I thought it was that way [pointing to the y-axis and then the x-axis].” Another child explained: “The numbers helped me to get it, because when it means (5,7) it is like 5 row [child drags finger to the right on the x-axis to the icon] and 7 column [child points between the y-axis and the icon].” A different child clarified his thoughts using gestures to explain: “The numbers came together at one point [child pinches his fingers together], with one number here [child moves hand to the left], and another number here [child moves hand to the right], and they came together [child clasps hands together].” These examples show how children used gestures to illustrate mathematical connections among the symbols and images in the digital games.

![Figure 5. Screenshot of the Map Maker game.](image)

While playing the Grid Lines game, one child moved the coordinate pairs around the screen and decided on the locations where she wanted the points to be placed. As she thought aloud she said: “I think this one is going to hit [as she said this, she used her finger in a sweeping motion to trace the line on the screen and determine if the line would hit the object on the screen].” In this case, the child was connecting the image of the line created by the coordinate pairs with her physical gesture of tracing a hypothetical line. One child used a gesture while explaining what he learned in the Hungry Fish game. The child stated: “Um, mainly negative numbers, like adding negative numbers with whole numbers, negative with positive numbers, adding negative numbers with negative numbers, seeing how that worked out” [The child was gesturing with his right hand as if he was grabbing something, and gesturing with his left hand as if he was grabbing something, and then taking both hands and putting them together]. The same child connected his mathematical language with a different gesture, saying: “Also with negatives and a whole number, say you have an 11 and a -6, it's going to make 5 so it's basically that subtracted 6 [child puts fingers on one side of the table and swipes to the left as if moving from 11 to 5 on an imaginary number line on the table].” Physical gestures were a required part of the Dragon Box Shapes game. As one child used her finger to trace the three shapes on the screen in the game, she said: “Two triangles and one quadrilateral” to indicate the name of each shape as she traced it. This illustrates the connections children made using physical gestures and mathematical language.

**Discussion and Conclusion**

This study focused on examining children’s mathematical language and children’s mathematics connections among representations to understand their relationship to pre and post-test changes when children played digital math
games. The quantitative results highlight the important connection between children’s use of mathematical language and their pre- to post-test outcomes. Research shows the importance of children connecting their actions in digital games with the mathematics. For example, Falloon’s (2014) research using 45 iPad apps reported that children who made connections between gaming activities and the mathematics had a deeper understanding of the intended mathematics outcomes.

The qualitative results show the importance of children making connections among representations, including their use of mathematical language, images, symbols and gestures. Through the lens of ACAT, we see how the relationships among the subject (a child), the artifact (a digital math game), and the object (mathematics) emerged in this study. For example, the results from the video analysis provide evidence that children used the digital math games to internalize and externalize their understanding of the mathematics in the games. Children’s gestures and language show what they internalize while playing the game and are revealed as externalized expressions as they talk about the game and use gestures to communicate their ideas. Nemirovsky et al. (2013) assert that children’s actions with representations simultaneously support abstraction and generate thought. We see evidence of this process when the child is talking and using gestures while trying to figure out how to round the number to the tenths place in the Math Planet Place Value game (and in many of the other examples presented).

These results have important implications for teacher education and for training teachers on how to use technology effectively during mathematics instruction. As the findings show, it is important for children’s learning to develop and use precise mathematical language. When teachers engage children in gameplay with a digital math game, an introduction to the mathematical terminology and symbols in the game and a debriefing session to discuss the mathematical terminology and symbols used in the game can enhance children’s learning and transfer of the mathematics in the game to out-of-game conditions (Falloon, 2014). Another important implication is the significance of making connections among different representations of the same mathematical concepts. Prior research shows that teachers can enhance learning transfer from the game when they bring design features of the game to the children’s awareness and when they explicitly help children to make connections among mathematical representations (Baccaglini-Frank & Maracci, 2015; Berger & Luckmann, 1966; Holgersson, Barendregt, Rietz-Lepannen, Ottosson, & Linstrom, 2013). By being precise about the mathematical terminology used in a digital game, and by being explicit about the connections among representations, symbols, and language, teacher educators can support pre-service teachers to use digital math games more effectively during instruction.

An abundance of research has shown the importance of children recognizing a link between different mathematical representations in mathematics apps and games. Moyer-Packenham and Westenskow’s meta-analyses (2013, 2016) reported the importance of simultaneous linking of digital representations to learning outcomes. In one study children observed links between algebra symbols and the movement of a balance scale, which resulted in higher learning outcomes (Suh & Moyer, 2007); in another study, children observed the link between the actions of a spinner and the changing graph of the spinner to observe changes in data (Beck & Huse, 2007). Sarama and Clements (2009) describe the importance of the artifact in “bringing mathematical ideas and processes to conscious awareness” (p. 147) to support internalization and externalization of the mathematics, suggesting that digital math games can bring the mathematics to an explicit level of awareness for the child. This prior research, as well as the current study, shows how important representations are to the development of mathematical thought and how children can externalize connections among representations through language.

References


Usability and Usage of a Citizen Science App by Teachers and Students

Richard T. Bex, II
School of Teaching and Learning
University of Florida
United States
rbex@ufl.edu

Lisa Lundgren
Department of Fisheries, Wildlife, and Conservation Biology
North Carolina State University
United States
lmlundgr@ncsu.edu

Kent J. Crippen
School of Teaching and Learning
University of Florida
United States
kcrippen@coe.ufl.edu

Abstract: The purpose of this study was to test the usability of a new citizen science mobile app, specifically for paleontology. The app, which was collaboratively designed and developed based upon extensive work understanding the needs and practice of a diverse online community, affords visually rich and scientifically relevant contributions to the domain of paleontology as well as connections and social interaction with the larger community. A usability study involves understanding how users interact with a product in order to improve its capacity for achieving its design goal. In this case, that goal was to support high school teachers and students in participating in the practice of science and see themselves as scientists. The study was completed in two phases. Phase one involved high school students (N = 10) and phase two included K-12 teachers (N = 25). Testing was conducted with both groups, who rated their experience for a number of user-centered variables. Findings show that the app was perceived as usable and participants expressed high satisfaction coupled with low difficulty of use. Feedback indicated that they enjoyed the familiarity of the layout, the ease of use, and the ability to virtually experience paleontology. Teachers were able to successfully use the app at three different field sites. This study will be of interest to those who wish to design, implement, and/or study science-specific mobile apps at the K-12 level.

Introduction

One of the main ideas in citizen science is that anyone with interest can participate in scientific research (Bonney et al., 2009). Thus, the introduction of mobile applications specific to citizen science has the potential to democratize the practice of science by allowing broader, more diverse groups of people to participate in and contribute to the practice of science. Citizen science combined with innovations in mobile- and web-supported technologies has demonstrated benefits by supporting scientific knowledge and research (Dickinson, 2012).

Since 2017, the FOSSIL Project in collaboration with Atmosphere apps, a private company, has been developing the myFOSSIL mobile app, an extension of the myFOSSIL website: an online space with over 1,125 members from various backgrounds and expertise, including professional and amateur paleontologists as well as K-12 educators who have shared more than 1,700 fossil specimen images in the website’s gallery (Bex, Lundgren, & Crippen, 2018). The myFOSSIL app, based upon extensive work understanding the needs and practice of a diverse online community, foments collaborative learning experiences via the sharing of paleontological information and experiences. One of the major goals of the app is to generate valuable paleontological data in order to contribute to scientific research while making the practice of science more accessible, including for K-12 teachers and students. The app is intended to afford users the ability to document discoveries as well as connect and converse with others about paleontological methods, activities (including teaching and learning), and finds. Use of the app is predicted to
facilitate communication among users as well as to increase public engagement and broaden participation with fossils and the science of paleontology.

The purpose of this study was to test the usability of a pre-release beta version of the app (14th build), which would identify issues and provide useful information for achieving the goals of 1) broadening participation in the science of paleontology; 2) contributing to scientific research; 3) supporting teachers/students in participating in the practice of science; 4) helping individuals see themselves as scientists. This study speaks to this conference’s mission, directly demonstrating how a new technology has been used in faculty professional development and shows potential for use with students in secondary education.

**Perspective for the Research**

User-centered design (UCD) is an approach to product development that begins with and continually maintains focus on the needs and experience of the people who will ultimately use it (Garret, 2010). With UCD, the usability of a product for the user is critical. Usability testing occurs during initial stages of development and releases of beta or trial versions of the product. UCD begins by considering the needs of the intended audience, then proceeds to active involvement of users and the collection of data related to their needs, activities, and preferences. As design proceeds to development, users are involved in all stages and usability proceeds through an iterative process with prototypes (Rogers et al., 2011). Our production of the app adheres to this process.

**App Design**

The design of the app is grounded in a framework that defines the relationship among the design inputs, features and scientific practices (Figure 1). The layout and general operation of the app is based on Instagram, the highly popular photo and video sharing social media platform. This design decision was primarily based upon the following reasons: a) a familiar layout is considered an important part of usability, especially when users are getting started because if users do not understand the system, they will abandon it (Cooper et al., 2014), and b) one of the main goals of the project is to broaden participation in paleontology, which has traditionally been dominated by older, homogeneous populations (Stigall, 2013). Instagram users have been shown to be younger, with 71% of Americans from ages 18-24 indicating that they use the platform (Smith & Anderson, 2018).

![Figure 1. App Design framework (Bex et al., 2018).](image-url)
The app includes nine interrelated features (Figure 1). To support documenting paleontological finds, Feature 4 affords the uploading of photos; Feature 6 automatically offers the option of including the geological/geolocation information from the point-of-discovery; and Feature 3 allows any user to add or edit attributes that are associated with photos of fossils. To support a conversation about paleontological finds or experiences, Feature 2 allows users to join or create an interest group and then to use Feature 4 to share a picture. To illustrate different forms of scientific practice, such as prospecting, screening, or jacketing, Feature 5 affords tagging, liking, commenting, and/or updating any data element that has been added with Feature 4 (Figure 2).

![Feature 1: personal activity feed](image1)

![Feature 2: interest groups](image2)

![Feature 4: adding photos to the gallery](image3)

Figure 2. Screenshots of three features of the myFOSSIL app.

Software development has been guided by four high level conjectures that define how use of the app will lead to learning processes and outcomes for users. The following two conjectures relate specifically to supporting teachers and students:

- Using the app to document, connect, and converse about a paleontological find via crowdsourcing and other forms of citizen science will result in increased participation, contribution, and relationships within the myFOSSIL app and website among a diverse group of participants.
- Using the app will lead to scientific contributions in paleontology via increased collecting and increased visibility of what has been collected to answer any number of scientific questions. (Bex et al., 2018 p. 465)

**Methodology**

This chapter reports the results from two initial studies of the 14th build of the myFOSSIL app, a pre-release beta version. First, high school students participated in a usability study in which they completed 10 app-specific tasks. Next, three groups of K-12 teachers tested the app during a separate paleontological professional development field experience (i.e. field study) at three distinct locations. The results focus on the perceived usability of the myFOSSIL app and the effect of the field site experience on perceived usability.

**Phase One - Usability study with high school students.**

**Usability study participants.**

Student participants (henceforth, participants) were recruited from a STEM summer camp in a small city in the
southeastern United States. All participants were in high school and their grade levels ranged from freshman to senior ($n = 10$).

**Usability study method.**

Testing took place at the school where the summer camp was being held; participants tested the app individually in a distraction-free room. The protocol for testing was based upon the DECIDE framework (Rogers et al., 2011), which is a six-step process for evaluating a prototype's capacity to address its design and development goals. The goals for usability testing were a) determine the participant’s perspective on usefulness, satisfaction, and ease-of use and b) clarify design requirements based on the version of the prototype. After completing a demographic survey and providing their informed assent, participants were asked to navigate components of the myFOSSIL app by completing 10 specific tasks that involve use of all of the app’s features (Table 1).

Table 1

**Usability Tasks Completed by Participants**

<table>
<thead>
<tr>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Log in to the app.</td>
</tr>
<tr>
<td>2. Navigate to the screen where you can view all of the groups in myFOSSIL.</td>
</tr>
<tr>
<td>3. Follow the “Summer Camp” group.</td>
</tr>
<tr>
<td>4. Take a picture of a fossil and upload it to the “Summer Camp” group.</td>
</tr>
<tr>
<td>5. Navigate to the screen where you would view a grid layout of all of the posts in myFOSSIL.</td>
</tr>
<tr>
<td>6. Post an update on myFOSSIL.</td>
</tr>
<tr>
<td>7. “Like” a photo that has been posted on myFOSSIL.</td>
</tr>
<tr>
<td>8. Navigate to the screen where you would view all of your notifications.</td>
</tr>
<tr>
<td>9. Navigate to the screen where you can view all of your activity and posts that you have created.</td>
</tr>
<tr>
<td>10. Log out of the myFOSSIL app.</td>
</tr>
</tbody>
</table>

After completing each task, participants responded to a series of 5-point Likert-type survey items asking them to rate their experience (e.g., level of difficulty, ease of use, satisfaction). At the end of the survey, participants indicated three elements of the application that they liked as well as up to three elements of the application that they did not like. Data were analyzed thematically using emergent iterative coding (Creswell & Poth, 2018). Additional data sources included researcher field notes, screen capture, video recording of hand gestures and participant interaction; these data are outside the scope of this chapter.

Once the participants had completed all tasks and rated their experience, they responded to the System Usability Scale (SUS), one of the most widely-used tools for assessing perceived usability of products (Tullis & Albert, 2013). The SUS asks users to provide the extent to which they agree or disagree to learnability statements (e.g., “I needed to learn a lot of things before I could get going with this app”) and usability statements (e.g., “I found the various functions in this app were well integrated”). Learnability is defined as how easily the system can learn when experiencing it for the first time, while usability is defined as the extent to which users perceive the system to be effective and efficient (Tullis & Albert, 2013). SUS scores and learnability scores were calculated for each individual and combined into an average SUS score (Figure 2).

**Usability study results.**

The average self-reported ease of task-completion score demonstrates that overall, users believed that they could navigate the tasks easily, and no participants reported difficulty in any of the tasks (Figure 3). These data demonstrate that participants found the app easy to navigate, indicating that they could focus on the connective and social networking aspects of the app.
Figure 3. Participants’ self-reported average ease of task completion.

Based upon the interpretation by Bangor et al. (2009), participants found the app to be usable ($M = 74.8$, $SD = 9.1$) with individual scores ranging from 60 (Marginal) to 90 (Acceptable) (Figure 4). Out of the ten participants, six perceived the app to be Acceptable with scores ranging from 72.5 to 90. Four participants considered the app to be marginally usable with scores ranging from 60 to 70. Two of those participants had an overall SUS score of 70, which is the upper limit of the Marginal range.

Figure 4. Individual System Usability Scores. The interpretation of SUS scores is as follows: <50: Not Acceptable; 50-70: Marginal; >70: Acceptable (Bangor et al., 2009). Note that for Participants 9 and 10, Usability scores were 71.9 and 80, which were obscured in the figure by the Overall SUS Scores.
The responses for what users liked and did not like about the app were sorted into major categories based on emerging themes (Table 2). Of the ten participants, six responded that there were not any features that they disliked. These data illuminate aspects of the app participants enjoyed or appreciated, namely, the streamlined function of the application, familiar layout which uses structural elements of social media platforms, and the ability to easily view happenings in the paleontological community. These qualitative data provide an explanation for the SUS scores. Participants reported specific frustrations related to technical difficulties that they experienced during testing such as not being able to upload photos or like pictures. One of the participants thought it would be useful to have instructions when logging on to the app for the first time. These data deepen our understanding of users’ initial experiences with the app.

Table 2

<table>
<thead>
<tr>
<th>Theme</th>
<th>Exemplar Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Likes</strong></td>
<td></td>
</tr>
<tr>
<td>Ease of use/navigation</td>
<td>“I liked how easy it was to find things.” “I liked the easy navigation to the app and how easy it was to post pictures of fossils.”</td>
</tr>
<tr>
<td>Familiar Layout</td>
<td>“People will adjust faster because it’s like Instagram” “I liked that I could relate it to my other social media”</td>
</tr>
<tr>
<td>Ability to virtually experience paleontology</td>
<td>“I like being able to see cool fossils that other people found.” “I could learn new things”</td>
</tr>
<tr>
<td><strong>Dislikes</strong></td>
<td></td>
</tr>
<tr>
<td>Providing descriptions</td>
<td>“I didn’t like that I had to write a description.” “I did not that you can't put things about yourself on it.”</td>
</tr>
<tr>
<td>Logging in</td>
<td>“I didn’t like that it said ‘username’ to login instead of ‘email address’.” “It didn't have the instructions that the beginning of an app usually has.”</td>
</tr>
<tr>
<td>Photo-specific</td>
<td>“I did not the like the grid layout of the photos”</td>
</tr>
<tr>
<td>Beta-testing-related issues</td>
<td>“I didn’t like that I couldn't upload my picture. I also didn't like that I couldn't like a picture”</td>
</tr>
</tbody>
</table>

**Phase Two - Field study with K-12 teachers.**

The second component of this research involved a field study in which K-12 teachers (N = 25) who were part of a paleontology-specific professional development experience were given the option to download and use a beta version of the app (14th build) and an associated collaboration guide (version 2.0), a potential new feature being considered. These teachers were independent from the student participants of phase one, those participants were not the students of these teachers. The purpose of the field study was to determine participant perspectives on usefulness, satisfaction, and ease-of-use when using the app in conjunction with the collaboration guide and compare across
different sites to determine whether context had an impact on participant perspectives. Participants completed a survey at the end of their field experience.

Field study participants.

Recruitment for the study occurred at a natural history museum in the southeastern United States during a paleontology-specific professional development experience being offered for teachers. Of the 64 teachers involved in the professional development, 25 (39%) consented to participate in the study and used the myFOSSIL app and associated collaboration guide. The teacher participants (henceforth, teachers) were subdivided into three groups and visited one of three different field sites and documented their finds and experiences using the app. Different sites allowed us to assess the dependence of usability on the context. The collaboration guide was constructed so as to support the user experience regardless of field site context.

Field study method.

At the end of the field experience, teachers completed a nine-question paper-based survey about their experiences with the app; five of the questions were specifically related to usability. A five-point Likert-type scale was used for usability questions and focused on difficulty of use, effort, meeting expectations, satisfaction, and effect of the collaboration guide on the experience. A one-way ANOVA was used to compare groups across the three different field site locations.

The survey also included two five-point Likert-type questions that asked teachers to describe their understanding about making scientific contributions and feeling like a practicing paleontologist. Lastly, two open-ended questions asked teachers to describe what liked and what they did not like about the myFOSSIL app. In order to measure the paleontological practices by the three groups, a content analysis (Krippendorff, 2012) of posts within groups was conducted.

Field study results.

Overall, when using the app in the field, teachers viewed it as easy to use, requiring little effort, meeting their expectations and generating high satisfaction. Also, on average, teachers felt like the associated collaboration guide improved their experience. Although the average results indicated high usability, the responses varied by site (Figure 5). Users at two of the sites (1 and 2) responded that they felt that the app was easier to use, met their expectations, and required less effort than the teachers who used the app at Site 3. The teachers at Site 1 and 2 also felt that the app required less effort to use compared to the those at Site 3. Level of ease of use was the only area that showed a significant difference between the groups, $F(2,21) = 7.781$, $p = .003$, suggesting that field site does not affect users' satisfaction, effort, or expectations.

Figure 5. Average usability results by site
Discussion

Usability concerns how effectively and efficiently users perceive a system’s affordances (Tulis & Albert, 2013). Usability testing is a critical step for facilitating interactions with new applications and ensuring the success of technology use. The results of these studies identified areas where the myFOSSIL App needs improvement as well as providing insight on how effective the app was at supporting students and teachers in participating in science and helping see themselves as scientists. Additionally, the results demonstrate that use of the app can improve experiences during teacher professional development related to paleontology.

From our study in which participants were high school students from a summer camp, we established that the app was usable. While scores varied, the majority were in the acceptable range and some found the app to be highly usable and highly learnable. However, there were some tasks where users experienced difficulty; those tasks should be studied more to determine if design changes will be needed in future iterations of the app. Given that this was the first usability study using the prototype of the myFOSSIL app, the research and development teams interpreted this finding as positive.

The field study revealed that regardless of field site, participants reported high levels of satisfaction, low difficulty of use, and high degree of success for feeling like a practicing paleontologist. The feedback from the respondents provided insight into some potential areas that may negatively impact the users and will be used to guide future developments with the app.

The results from both studies indicated high levels of perceived usability, which is positive sign for the first iteration of the myFOSSIL app. Furthermore, high usability may help attract users, which may lead to the myFOSSIL app being successful in achieving the goal of broadening the participation in the science of paleontology and helping students and their teachers feel confident in their abilities to contribute so science and see themselves as scientists. The myFOSSIL app is available for free from the Google Play and iTunes stores. Further information on the app and supporting community can be found on the myFOSSIL website http://www.myfossil.org

Limitations

Usability testing with the students was done in a laboratory setting, which is unlike real-world settings, meaning that students may have interacted with the myFOSSIL app differently. An additional limitation of this study was the small sample size of students (N = 10); we addressed this limitation via providing thick and rich descriptions from participant responses to the survey. The students in the study used an iPad when participating in the study, on which engagement might have differed versus students engaging with the app on a smartphone. Teachers who chose to participate in professional development may have been more interested in paleontology and citizen science than other teachers, meaning survey responses may have been artificially high. As this was a small-scale usability study, we anticipate that further user testing with a greater sample size may be needed.

Implications

Improving the usability of educational technology is often overlooked by the educational community (Buzhardt & Heitzman-Powell, 2005). Designing and developing an app involved gaining an understanding of perceived usability as well as expectations for design in order to ensure that the technology was easily adopted by teachers. Improving usability has the potential to reduce difficulties related to integrating technology into a science curriculum and facilitate teacher learning and implementation with students.

With the expansion of Next Generation Science Standards (NGSS), students are now expected to engage in science practices in order to develop a deep understanding of science concepts (NGSS Lead States, 2013). Through the development of citizen science apps, such as the myFOSSIL app, anyone, including teachers and students, has a greater ability to participate in science practices and contribute to scientific research. Involvement in citizen science projects has the potential to improve proficiency in STEM for both teachers and students by providing authentic experiences which emphasizes science as a process and connecting science to everyday life.
Future Research

Future research will involve scaling up use of the myFOSSIL app by K-12 teachers and students from usability and field-based studies to those situated in a range of classrooms under different contextual conditions. Of primary interest will be the ways that teachers and students adapt their use of the app and use it to construct meaning while in pursuit of curricular and personal goals in a science classroom. These studies will allow us to better understand the critical factors and elements of the context that support teachers in using the app successfully within formal classrooms.

References


Acknowledgements

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An Expanded Systematic Review of Augmented Reality in Informal Learning

Mark Petrovich Jr., mep64@drexel.edu
Mamta Shah, mamta@drexel.edu
Arouatis Foster, anf37@drexel.edu
Drexel University
United States

Abstract: The development of several digital technologies has enabled educators and researchers to approach education from a personalized perspective. At the forefront of this technological-pedagogical development is augmented reality (AR). Though research has demonstrated AR’s implementations within formal learning environments, there is a lack of research evaluating AR applications within informal contexts. In order to address this gap in literature, this study provides a systematic review of empirical publications involving AR applications in informal learning settings; specifically, museums. The intent of the review was to gain insights surrounding expected educational outcomes being investigated, the methodologies utilized in AR evaluation, the populations involved in AR research, and the claims regarding AR technologies. In total, twenty-five (25) articles were examined between the time period of 2010 to 2017. Analysis and results are discussed with implications for future AR research within informal settings.

Introduction

While mobile technologies continue their rise as an essential aspect of everyday life, individuals are granted greater access to the ability to work, learn, and play across various contexts (Johnson et al., 2010). The growth of mobile devices has afforded an equivalent rise in popularity for a number of digital media technologies. One of these developing technologies, augmented reality (AR), operates at the intersection of the virtual and the real. AR integrates the virtual and physical worlds through the layering of digital text, images, audio, and video over tangible environments in real time. The defining characteristics of an AR experience include: 1) Combination of virtual and real, 2) Interactive in real time, and 3) Registered in 3-D (Azuma, 1997).

A growing body of literature has presented reviews surrounding the broader impact of augmented reality (AR) in education, AR peripherals and applications, cognitive and non-cognitive learning outcomes of AR applications, and AR versus traditional applications in learning (Akçayır and Akçayır, 2017; Fotaris et al., 2017; Radu, 2014). Though these reviews briefly discuss AR applications situated within informal learning contexts, there is a substantive lack of research specifically targeting the rise of interactive educational experiences within these learning environments.

In this chapter, the following research questions were investigated:

- RQ(1) What expected learning outcomes are commonly associated with the implementation of AR in informal learning environments?
- RQ(2) What methodologies are utilized when assessing AR learning outcomes and how they are implemented in informal learning environments?
- RQ(3) Which age groups and settings/characteristics of settings are most often examined in AR research within informal learning environments?
- RQ(4) What are the claims surrounding AR and its future as an educational tool within informal learning environments?

Exploring this gap of AR applications in varied educational settings is important because museums can serve as contexts for transformative experiences (Garner, Kaplan, & Pugh, 2016).
Related Literature

The number of publications concerning the use of AR technologies in educational contexts has been increasing each year (Bacca et al., 2014). A recent study by Akçayır and Akçayır (2017) found just three relevant AR publications in 2011, though that number increased dramatically from seven publications in 2012, to 17, 18, and 15 publications in the years 2013, 2014, and 2015 respectively. Despite this fact, AR researchers have struggled to demonstrate concrete outcomes when comparing the use of AR mobile games to traditional games. In some cases, identical learning outcomes have been recorded (e.g. fact retention and understanding of concepts; Furió et al., 2013). Nonetheless, additional studies have demonstrated several positive outcomes including (a) interactivity and the creation of novel pedagogical approaches (Han et al., 2015), (b) support for the learning of complex spatial relationships (Arvanitis et al., 2009; Klopfer & Squire, 2008), and (c) the ability to facilitate the development of 21st century skills such as critical thinking, problem solving, and communication through the use of hybrid learning environments (Dunleavy, Dede, & Mitchell, 2009). Due to the widespread availability of mobile devices, Klopfer (2008) has argued that AR is an ideal platform for learning in elementary, secondary, university, and lifelong education. Though the number publications surrounding AR are steadily increasing, AR technologies are still in relative infancy in the field of education.

Although empirical studies are quickly growing more numerous (Akçayır and Akçayır, 2017), literature reviews concerning AR technologies and education are sparse. Due to its affordances for contextual awareness and situated learning, researchers cite informal learning environments as the best potential location for the integration of educational AR applications (Dede, 2009). Research presented by the National Research Council (2009) has discussed the potential of non-school settings such as science centers, museums, zoos, and aquaria towards the development of real-life experience and practical skills. Despite the research surrounding AR, there has been little empirical evidence of its impact on informal learning environments (Jahnke & Kumar, 2014). As informal education and technology further intertwine, questions arise regarding the utilization of location-based experiences within informal learning spaces.

As is evident from the aforementioned trends, there is little question regarding the growth of the field surrounding AR research; however, there is a lack of definitive consensus regarding the strength of learning outcomes across various learning environments. Specifically, there is a dearth of empirical knowledge available to ascertain the extent to which or the manner in which AR can support learning. The studies included in this review define learning outcomes in varying ways, though they can be separated into two distinct categories: cognitive and non-cognitive. Chang et al. (2014) measured learning outcomes as the acquisition of knowledge, retention of facts, and transfer to new content areas. Additional researchers reported learning outcomes in terms of motivation to learn and interest in a specific context (Guazzaroni, 2013), the development of critical thinking and reflection skills (Tscholl & Lindgren, 2014), and the development of learner autonomy and/or collaboration (Perez-Sanagustin et al., 2014). In addition, learning outcomes are rarely addressed in the context of informal learning settings where research has proposed AR is best suited for educational implementation (National Research Council, 2009). A similar issue is demonstrated when addressing the claims of AR. Dunleavy, Dede, and Mitchell (2009) identified technical problems as a hindrance for the future of AR as a learning tool. These issues fall into several categories, some of which relate to GPS failure, noise pollution, sun glare affecting viewing screens, and other general malfunctions. While few of these issues are a concern regardless of context (user training and limited resources, for example), a majority of the available claims of AR are focused within formal learning environments while ignoring informal environments almost completely. The lack of specific literature concerning AR implementations within informal learning extends to the data collection/evaluation methods as well as the characteristics of age groups and settings. Several literature reviews have commented on research design within formal learning, but no study has focused specifically on these subject areas and their outcomes within informal learning (Chia-Wen et al., 2014; Koutromanos et al., 2015). Thus, further research is required in order to better understand the potential learning outcomes, research designs, participants and settings, claims, and best practices in implementation of these AR applications within informal learning environments.

Methodology

Inclusion and Exclusion Criteria

As a means to maintain established quality and validity standards within systematic literature reviews, we identified several components required to conduct an effective literature review: coverage (explicit inclusion and exclusion criteria), synthesis (summary and analysis of extant literature), and significance (discussion of implications...
towards future research) (Boote & Beile, 2005; Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009). See Table 1 for a full listing of inclusion and exclusion criteria.

Table 1

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
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<tbody>
<tr>
<td>1. In an effort to reduce redundancy, studies must have been published between 2010 and 2017</td>
<td>1. Research not identified as a journal article, conference proceeding, or book chapter (i.e. book reviews, books, editorials)</td>
</tr>
<tr>
<td>2. The research study must directly relate to or address one of the research questions (AR, Informal Learning, Implementation)</td>
<td>2. Studies that mentioned the term “augmented reality” but clearly discussed virtual reality or studies that exclusively include AR within the references section</td>
</tr>
<tr>
<td>3. In order to contribute to the literature review knowledge base surrounding informal learning and AR, the reviewed literature must be empirical in nature</td>
<td></td>
</tr>
<tr>
<td>4. Research examined must be explicit in its discussion of methodology (population, methods, analysis, and so forth)</td>
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Procedures

In keeping with the methodological standards established by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), this review underwent several phases of data collection, coding, and analysis (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009). The first phase included the selection and searching of relevant databases. The database ERIC (https://eric.ed.gov/) was selected due to the breadth and depth of education-related journals contained within the index. ScienceDirect (http://www.sciencedirect.com/) was selected for supplementary education research, developing technologies, and digital media theory. A keyword search was utilized in cohort with Boolean operators in order to narrow the search based on the subjects of interest. The Boolean search string utilized in both databases was: (augmented reality) AND ((museums) OR (informal learning)) AND (education). Supplementary peer-reviewed materials were added through the use of a targeted search utilizing alternate combinations of the above keywords. Searches were automatically filtered by publication date (2010 to 2017), publication type (“peer reviewed”), and language (“English”) in order to limit the manual sorting and coding following the completion of the keyword search.

A research team member read through the titles, keywords, and abstracts of the identified papers on the basis of the inclusion and exclusion criteria. In order to ensure the quality of the gathered empirical studies, publications to be included in the final analysis were required to demonstrate: 1) clear research questions; 2) analysis and interpretations grounded in theory; and 3) “standards of evidence” acquired through explicit and systematic procedures (Freeman, deMarrais, Preissle, Roulston & St Pierre, 2007). Early outcomes of the initial searches and analysis garnered 129 publications for full-text review. Following the round of full-text review and initial coding, a total of 25 publications were chosen for inclusion in the final review from an initial yield of 840 records (See Figure 1).

Findings were coded and analyzed based upon their relation to the research questions posed previously. Two research questions (RQ1, RQ2) revolved around learning outcomes and data collection methods associated with AR applications within informal learning environments. Participant age groups (RQ3) were separated into subcategories: K-12, higher education, adult (workers in industry following school at some level), and unspecified. In order to determine answers to RQ4, the claims surrounding AR applications, the introduction and discussion sections of each article were analyzed. Claims (e.g. suggesting best practices of AR, past, present, and future uses of AR) made within the selected studies were assessed and sorted into appropriate sub-categories such as non-cognitive, cognitive, social, and technological, for further discussion.

Results

Overall, the number of articles published increased from the year 2014 onwards as a total of 64% of the articles examined (n=16) were published in the year 2014 or later (Figure 2).
RQ1 - Expected Learning Outcomes

Results surrounding learning outcomes demonstrate that AR-guided experimental groups completed experiences and left with a higher degree of learning outcomes, motivation to learn, interest in museum content, and enjoyment of the digitally enhanced experience than the control or non-AR groups (Figure 3). Several studies saw increased engagement as a learning outcome, though it was broadly defined as both engagement with content and engagement with the technology (Folkestad & O'Shea, 2011; Holden & Sykes, 2011; Richardson, 2016; Ryokai & Agogino, 2013; VanMeerten & Varma, 2017). While most of the learning outcomes focused on educational outcomes, several also discussed technological-related outcomes such as an increased sense of presence within the AR environment. Presence, or the sense of being in an environment, could lead to further non-cognitive outcomes such as interest in content and motivation to learn within these unique environments. Syliaiou et al. (2010) reported one such relationship between presence felt in an AR experience and enjoyment. These technological-related outcomes fall outside the scope of expected cognitive and non-cognitive learning outcomes and are therefore a unique occurrence based on the usage of these developing technologies. A lone study (Sommerauer & Muller, 2014) presented no discernible learning outcomes or effects as a result of an AR intervention.

Figure 1: PRISMA flow diagram for current study

RQ2 - Methodologies Implemented

Methodologies utilized varied across studies; however, mixed-methods research design were utilized more often than not (44%), followed closely by strictly qualitative design (32%), and strictly quantitative design (24%). Data collection techniques within these studies demonstrated a relatively even distribution across interviews (24.5%), pre-post questionnaires (15.1%), questionnaires (15.1%), and researcher observation (15.1%). Surprisingly, game data and/or tracking data was rarely utilized (5.7%) as a metric for measuring learning outcomes or changes throughout AR experiences (Figure 4). Atwood-Blaine and Huffman (2017) utilized science, technology, engineering, and mathematics (STEM)-related digital badges to track student progress and achievement through an AR curriculum. Badges could be shared and were utilized to create a collaborative community that enabled students to illustrate their progress to peers and instructors. This badging system illustrates one potential way in which integrated data collection methods could be used for assessment in future AR studies.
RQ3 - Participant Age Range & Settings

Analysis of age ranges of AR study participants has revealed that K-12 participants were utilized as a majority (57.1%) of targeted users. Higher education participants were utilized at a much lower rate (25%), while adult or professional participants were utilized the least (14.3%) (Figure 5).

The second half of RQ4 discusses the informal learning environments in which these empirical studies take place. The majority of these experiences (e.g. Atwood-Blaine & Huffman, 2017; Guazzaroni, 2013; Hsiao et al., 2016; Yoon et al., 2017) were situated within public spaces such as museums or science centers. The single largest category, field experiments, was described differently depending on the context of the study. For example, field experiments were presented as a botanical garden, a mathematics exhibition, an ecology center, or a cultural heritage site depending on the specific study examined. Likewise, the museum setting was presented in various forms across the studies. The museums here could be defined as fine art museums, science museums, or archaeological museums (Figure 6). Several studies were able to design experiences for both indoor and outdoor contexts. One such study by Folkestad and O'Shea (2011) examined a museum experience and a botanical garden. The outcomes of their study demonstrated less technical and performance issues for AR technologies in indoor settings and increased interactivity with the technology indoors when compared to the outdoor setting.
Findings revolving around the claims of AR revealed a focus on the technological affordances of AR as opposed to claims focused on educational outcomes. A selection of these claims can be found in Table 2. Several studies claimed that AR technologies are not being fully utilized within education and stated that, based on the current capabilities of the technology, educational experiences are still capable of being expanded across content areas and contexts (Christopher & Julie, 2011; Donald, 2016). Additional research has provided more positive outlooks on the utilization of AR technology, including suggesting that AR experiences will replace traditional audio guides within museum spaces in the near future (Sommerauer and Muller, 2014). Chang et al. (2014) claimed that AR-guided tours in an art museum caused a loss of focus and tunneling among group members. Conversely, Pérez-Sanagustín et al. (2014) suggest that AR afforded increases in student attention within their environment. Several studies presented social interaction as a positive element of informal learning environments in terms of complementing naturally occurring socialization (Atwood-Blaine & Huffman, 2017; Cheng, 2017; De Lucia et al., 2012; Pérez-Sanagustín et al., 2014; Tscholl & Lindgren, 2014). However, Nicolaas & Keisha (2017) claim that the activity, environment, and social processes associated with AR are constantly in flux, which leads to an inability to confidently design effective AR experiences across various contents and contexts. Coded results surrounding the claims of AR can be viewed in Figure 7.
Table 2

*Example of claims when implemented AR for learning*

<table>
<thead>
<tr>
<th>Claims</th>
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<tbody>
<tr>
<td>It is unclear how much of the obvious engagement is based on the inherent benefits of augmented reality and how much is based on the novelty of using GPS enabled handheld devices (Folkestad &amp; O'shea, 2011).</td>
</tr>
<tr>
<td>It is difficult to design an AR learning game that effectively situates cognition in an authentic context because the activity, environment, and social processes all interact in a sometimes unpredictable manner (Nicolaas &amp; Keisha, 2017).</td>
</tr>
<tr>
<td>AR is adaptable to other contexts and expandable based on the functionality and technology available now (Donald, 2016).</td>
</tr>
<tr>
<td>The majority of mobile assisted language learning projects do not take full advantage of mobile devices to extended learning beyond the walls of the classroom to other areas of students’ daily activities (Christopher &amp; Julie, 2011).</td>
</tr>
<tr>
<td>AR technologies encourage exploration and provoke more personal and contextual observations (Ryokai &amp; Agogino, 2013).</td>
</tr>
<tr>
<td>Reading AR books using wearable devices may create more intuitive user experiences and may also reduce users’ attention to the hardware (Cheng, 2017).</td>
</tr>
<tr>
<td>Few students have actually used tablet computers for personalized learning. This study hopes that validation of the efficacy of the proposed system could prompt new attempts to find appropriate applications for such technology in education (Huang, Chen, &amp; Chou, 2016).</td>
</tr>
</tbody>
</table>

**Figure 6: Informal settings utilized for empirical AR studies**

**Figure 7: Claims of AR categorized**

- **Non-cognitive**
  - Increased motivation
  - Increased interest

- **Cognitive**
  - Increased content knowledge
  - Memorization
  - Situated cognition
  - Fosters inquiry

- **Technological**
  - Increased sense of presence
  - Create intuitive user experiences
  - Expandable across contexts
  - Reduce visibility of technology
  - Creates new approaches to learning
  - Novelty of new technology
  - Encourages exploration

- **Social**
  - Collaboration
  - Competition
  - Cooperation
  - Interpersonal skills
Analysis

The educational potential of AR within informal contexts is clearly gaining recognition as 64% (n=16) of studies were published after 2014 and until 2017. However, as seen with the claims of AR, expected outcomes and affordances of the technology are widely varied. The research questions addressed within this study demonstrate several of these trends within empirical AR studies. Specific learning outcomes became more apparent depending on the setting in which the intervention was undertaken. For example, the observation of collaborative and competitive experiences occurred most often in structured play opportunities within museum classrooms and science centers. When comparing learning outcomes with the claims of AR, the claims were often accurate in terms of engagement and interest, however it remains to be seen whether this engagement stems from the content itself or the presentation of a new technology. Folkestad and O'Shea (2011) suggest that mobile-technology and 3D assets may increase engagement and interest in content due to a novelty effect. This raises interesting questions surrounding the nature of AR experiences that must be explored in future research. Finally, there were several studies which claimed engagement as a learning outcome while only utilizing observation as a data collection method. In this case, participants were usually observed for the amount of time they spent in front of an exhibit or while using the mobile technology. This exacerbates the previously mentioned issue in separating engagement with content and engagement with technology. If the locative nature of AR technology has proved difficult to assess based on current data collection approaches, future research should also focus on examining alternate approaches to understanding educational AR outcomes. Though a large number of the articles were not utilized for this review based on inclusion/exclusion criteria, there was a developing trend in unincluded articles revolving around empirical testing of specific AR technologies. A large range of these empirical studies look to develop specific implementations or frameworks in order to gauge their overall effectiveness through the lens of the participants. This finding could suggest that researchers have yet to find an AR implementation that can be utilized across contexts.

Limitations

Due to the structure and limitations of this systematic review, additional literature discussing the impact of AR technology on informal learning contexts could be identified through additional database, individual journal, and targeted keyword searches. The introduction of additional studies could affect the outcomes and analysis presented within. Additionally, the conclusions presented within this review assess only a portion of the empirical data collected across the studies reviewed. The merit of these studies should not be assessed solely on information reported within this review.

Conclusion and Implications

This systematic literature review seeks to contribute to educational experiences with AR by demonstrating the current gap in literature regarding informal learning contexts. Though this is only a small section of the available AR literature being published currently, several unique themes emerged from the research questions being studied. When addressing the potential learning outcomes of AR experiences in RQ1, a majority of outcomes were organized into cognitive and non-cognitive categories. However, the affordances of immersive technologies such as virtual reality (VR) and AR offer new ways of thinking and acting within educational and leisure settings. The technologival affordance of immersion, or presence, in these contexts is a powerful tool that could lead to increased interest, motivation to learn, and further engagement with content. This outcome highlights the need for further empirical research on AR implementations in order to demonstrate the unique affordances of the technology. The concept of presence should also be considered when designing such interventions for educational outcomes. Designers and educators should assess which approaches best elicit this sense of presence to facilitate the desired learning outcomes in each intervention.

RQ2 evaluated methodologies and data collection methods utilized across the collected AR studies. Similar to RQ1, the use of built-in assessment devices such as digital badges, achievements, and other gameplay tracking data could aid in the interpretation and assessment of how these environments can best be designed to facilitate educational outcomes. With the data sources being so evenly distributed, the use of in-game assessment techniques could enable researchers the ability to better evaluate how an individual interacts in these environments and if those interactions facilitate specific outcomes. The creation and use of additional data collection tools inside these virtual environments will necessitate an in-depth look at how these experiences can best be designed.
RQ3 addressed participant age groups and the settings for the implementation of AR experiences. The studies examined in this review presented varying degrees of success within indoor and outdoor environments. Though several studies claimed higher learning outcomes and interactivity levels when utilizing AR within indoor settings, future AR studies should continue to evaluate the reason or cause behind these perceived imbalances. One of the key affordances of AR is its locative nature, but if assessment indicates that outdoor environments provide weaker learning outcomes, we must re-evaluate if these outcomes are due to the nature of the technology or the design of the experience.

The combined significance of RQ1, RQ2, and RQ3 highlight several key points for future AR interventions: 1) AR experiences must be designed with a specific technology in mind; 2) Technological affordances (e.g. presence) must be accounted for and integrated into these experiences; 3) Integrated data collection methods could provide in-depth tracking and analysis of personalized outcomes and experiences in AR environments; and 4) Context must be considered as an integral part of AR experience design, and further research should highlight the differences in learning outcomes when comparing indoor vs. outdoor settings.

Based on the key points developed in this review, future AR research should highlight a comparison between formal and informal AR environments. Empirical studies have identified a myriad of potential learning outcomes when using AR, but the strength of these outcomes within specific contexts should be assessed so that further design recommendations can be made toward future AR research. This review has enumerated only some of the issues abundant within the realm of informal learning and AR implementations. Though the field of educational AR applications is still growing, these issues must be addressed in order to facilitate the development of personalized learning experiences within authentic contexts. This review looks to contribute to this development and understanding of best practices in the design, development, and implementation of future AR experiences in order to aid in the creation of future frameworks for students, teachers, and researchers.

References


Facilitating and Tracing Identity Change in Augmented Virtual Learning Environments

Hamideh Talafian, Ht343@drexel.edu
Amanda Barany, Amb595@drexel.edu
Mark Petrovich Jr., Mep64@drexel.edu
Mamta Shah, mamta@drexel.edu
Aroutis Fosteraroutis@drexel.edu
School of Education
Drexel University
United States

Abstract: This chapter introduces Projective Reflection (PR) as one way of conceptualizing learning as a process of identity exploration and gaining the knowledge and skills to reconstruct oneself through a theory called Projective Reflection (Foster, 2014). The chapter describes the application of PR in an ongoing NSF-CAREER study that informed the design and implementation of Philadelphia Land Science, an augmented virtual learning environment (AVLE) used to facilitate high school students’ exploration of role identities as urban planners and environmental scientists. A concurrent mixed methods design was used to assess and visualize identity change in participants as tracing change in their knowledge, interest and valuing, self-organization and self-control, and self-perception and self-definition. Results indicated a significant change in interest and valuing levels and intertwined changes across all constructs of PR. Implications for tracing identity change are discussed.

Introduction

Educational research on theoretical and methodological approaches to conceptualize, facilitate, and empirically examine learning and identity is gaining attention (Flum & Kaplan, 2006). In this chapter, we illustrate one way of conceptualizing learning as a process of exploring possible selves through experiences in virtual learning environments to gain the knowledge and skills to reconstruct oneself through a theory called Projective Reflection (PR) (Foster, 2014). The chapter describes the application of Projective Reflection in an ongoing NSF-CAREER study that informed the design and implementation of Philadelphia Land Science, an augmented virtual learning experience (AVLE) used to facilitate 20 high school students’ exploration of role identities as urban planners and environmental scientists over a 9-week period in a science museum in a northeastern city. Data corpus included in-game logged data, research memos, pre-post interview questions, written and visual artifacts created in-game and during external curricular experiences. These data sources used to examine the following research question,

To what extent did participants in a 9-week augmented VLE demonstrate change in their knowledge, interest and valuing, self-organization and self-control, and self-perception and self-definition as a result of exploring the role of environmental scientists?

Implications are discussed to advance future research on learning and identity in mixed reality experiences with a focus on framing, facilitating and tracing identity exploration and change through the use of emerging frameworks such as Projective Reflection.

Learning and Identities in Virtual Learning Environments

Technological and societal changes have spurred new ways for people to live and learn across sites. This transcendence of traditional boundaries of time and space of learning has prompted researchers to examine the skills and knowledge that will be essential for thriving professionally and personally (Flum & Kaplan, 2006). Educational psychologists argue that learners’ ability to develop an exploratory orientation will be valuable, and educational curricula that support the development of personal agency, disciplinary knowledge, transdisciplinary skills will be beneficial (Flum & Kaplan, 2006). Specifically, supporting learning in the 21st century will necessitate the
development of “[learners’] agency in figuring out who they are and who they are to become – the exploration and formation of their identities” (Flum & Kaplan, 2006, p. 249). Identity is conceptualized by Leander (2002) as consisting of both a) "big I" Identities, or the way individuals self-identify and identify each other as members of a community through acting, interacting, feeling, believing, and valuing as a group, and b) “little i” identities, or the individual cognitive and developmental shifts in one’s sense of self, or one’s psychological, physiological, and emotional development. Virtual learning environments such as digital games, simulations, and virtual internships can be used to innovate instructional practices in formal and informal settings (Clark, Tanner-Smith, & Killingsworth, 2016; Wouters, Van Nimwegen, Van Oostendorp, & Van Der Spek, 2013) for players to explore new and desired possible identities, to immerse in communities of practice, and to be prompted to develop knowledge and skills that can go beyond specific identities explored. These environments can also generate multimodal and massive data to track learners’ participation in these worlds, and their interactions with pedagogical agents, mentors, and peers. Additionally, with the possibility of experiences that can be designed on a continuum of reality, an opportunity is presented to augment learners’ experiences in locally situated and personally relevant experiences by building off from what is experienced in a virtual world. Research on how learning can be framed, facilitated and tracked in such an augmented virtual experience is in its embryonic stages.

This study is novel in that it applied the use of an emerging theory called Projective Reflection to frame and facilitate learning in the 21st century as a process of intentional exploration of identities leading to change towards desired possible selves. This research was also conducted as part of an ongoing 5-year NSF CAREER project awarded to advance theory and research on promoting identity exploration and change in science using augmented virtual learning environments.

**Theoretical Framework**

Projective Reflection (PR) is a theoretical framework that conceptualizes learning and identity in VLEs as a process by which a person engaging in digital gameplay or virtual environment enacts an activity-based identity with the potential to modify the person’s learning and identity in this and other domains beyond the activity (Foster, 2014). PR focuses on learners’ engagement to reflexively experience and intentionally acquire the knowledge and skills required for self-transformation or identity change by acknowledging where one is in terms of his/her knowledge, interest and valuing, self-organization and self-control skills, self-perception and self-definition in relation to a targeted future self (Foster & Shah, 2017). Assessing change from the starting self, over possible selves explored, to a new self is carried out by answering the following 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 (see Table 1 and Figure 1) (Foster & Shah, 2016).

![Figure 3. The Projective Reflection framework for conceptualizing learning as a process of identity change over time.](image-url)
Table 1

*Projective Reflection Constructs and Sub-constructs*

<table>
<thead>
<tr>
<th>Projective Reflection Constructs</th>
<th>Projective Reflection Sub-constructs</th>
</tr>
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<tbody>
<tr>
<td>Knowledge</td>
<td>• Foundational Knowledge</td>
</tr>
<tr>
<td></td>
<td>• Meta-Knowledge</td>
</tr>
<tr>
<td></td>
<td>• Humanistic Knowledge</td>
</tr>
<tr>
<td>Interest and Valuing</td>
<td>• Interest</td>
</tr>
<tr>
<td></td>
<td>• Subjective task valuation</td>
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<tr>
<td></td>
<td>• Relevance</td>
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<tr>
<td>Self-organization and Self-</td>
<td>• Self-regulation</td>
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<tr>
<td>control</td>
<td>• Co-regulation</td>
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<tr>
<td></td>
<td>• Socially-shared regulation</td>
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<tr>
<td>Self-perception and Self-</td>
<td>• Self-efficacy</td>
</tr>
<tr>
<td>definition</td>
<td>• Self-concept</td>
</tr>
<tr>
<td></td>
<td>• Possible-selves explored</td>
</tr>
</tbody>
</table>

**Methodology**

**Study Context**

Philadelphia Land Science (PLS) was implemented as an augmented virtual learning experience (AVLE) for the students as virtual interns to study urban planning and related economic, environmental, and engineering concepts. The students were roleplaying as interns in a professional setting and interacting with stakeholders and mentors synchronously and asynchronously to redesign the city of Philadelphia and address the needs of the citizens. In PLS, groups of students were synchronously guided by online and in-person mentors to collaborate with their peers in rezoning a map of the city to address specific environmental and economic issues. Activities within Philadelphia Land Science and those scaffolded outside of the AVLE were designed to facilitate intentional shifts in what learners know, how they think, what they care about, how they see themselves, what they want to be and expect to be in relation to environmental planning and urban science.

**Study Design**

To trace students’ identity change a concurrent mixed-methods design was used to study the impact of PLS as an augmented virtual experience on the students’ knowledge, interest and valuing, self-organization and self-control, and self-perception and self-definition (see Figure 2).

*Figure 2. Concurrent Mixed-methods Design for Tracing Identity Change in PR Constructs*
Participants

Our sample consisted of twenty (n = 20) 9th grade students who enrolled in a game-based learning course in an urban high school situated in the Northeastern part of the United States. They all consented to be part of this study and completed the course with PLS. From this population 60% of them were females (n = 12), 30% were males (n = 6) and the other 10% preferred not to reveal their sex (n = 2). Quantitative and qualitative data were collected from all 20 participants.

Settings

This study was conducted at a partnered science museum with 9th-grade high school students as a graded science course using Chromebooks and laptops to engage in the PLS, VLE and the curricula that augmented the experience. The duration of the study was nine weeks. The course was part of a game-based learning course created collaboratively with researchers and teachers and was offered to enhance learning as identity change by engaging them in real-world activities. Philadelphia Land Science (PLS) was used as an augmented virtual learning experience that allowed players to explore roles related to urban planning and environmental science careers as they connect to the Philadelphia context and redesigned/rezoned the map of the city with different stakeholders.

Data Sources

Pre-post survey and baseline demographic information was gathered for the quantitative phase. A Likert-scale survey, an open-ended survey, classroom artifacts, reflective journals, and observations notes (memos) by researchers were among the data sources which were used to gather data for the qualitative phase of the study.

Data Collection and Procedure

Quantitative and qualitative data was collected throughout the program from the beginning to the end. In the beginning of the course the pretest survey data was collected and in the last day of the program the posttest survey data was collected. Throughout the program, three researchers did extensive observation from the students’ interactions, their dialogues between peers and instructors, and their questions from the instructors. Other descriptive notes were also taken as daily memos. Once collected, data was organized chronologically to track PR changes from the beginning, at repeated points during the study, and at the end of the AVLE experience. Three researchers collaborated to take observation notes (memos) after weekly sessions. All qualitative data was organized chronologically for each and every student in the program to capture change over time systematically.

Data Analysis and Results

Quantitative Phase

SPSS version 24.0 was used for all the quantitative analyses in this study. Descriptive statistics of demographic information and paired sample t-test were run for the quantitative phase of the study.

In this study, 20 participants have completed the virtual learning experience. 60% of them were females, 30% were males and the other 10% preferred not to reveal their sex. The ethnicity of the participants is shown in Figure 3. The highest percentage of students were Black or African-Americans (30%), Native-Americans (25%), and white participants (20%).
Table 2

<table>
<thead>
<tr>
<th>PR Constructs</th>
<th>Pretest M (SD)</th>
<th>Posttest M (SD)</th>
<th>95% CI for Mean Difference</th>
<th>r</th>
<th>t</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>52.66 (8.87)</td>
<td>56.33 (7.1)</td>
<td>-7.96, 0.62</td>
<td>.</td>
<td>49</td>
<td>1</td>
</tr>
<tr>
<td>Interest and Valuing</td>
<td>10.53 (2.56)</td>
<td>24.69 (4.28)</td>
<td>-16.28, -12.01</td>
<td>.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Self-perception and</td>
<td>71.16 (9.64)</td>
<td>74.16 (9.84)</td>
<td>-7.95, 1.95</td>
<td>.</td>
<td>37</td>
<td>1</td>
</tr>
<tr>
<td>Self-definition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

The results of the paired-sample t-test indicated that the change in students’ interest and valuing was statistically significant during nine weeks of experiencing the PLS augmented virtual learning experience in posttest ($M=24.69$) than pretest survey ($M=10.53$), $t(12) = 14.44$, $p < .001$ (two-tailed). For other constructs, the mean changes from pretest to posttest speaks of the increase of students’ scores in knowledge as well as self-perception and self-definition. However, due to the small sample size these constructs were not shown to be statistically significant. More participants could make the mean changes significant and more meaningful.

Qualitative Phase

MAXQDA Pro 2018 was used for deductive and inductive coding for all open-ended survey responses. A sample dataset with 65 lines of coding allowed two researchers to reach inter-rater reliability agreement ($Kappa=.65$) and individually code the rest of the data deductively with the four PR constructs and inductively.

Change in Projective Reflection

Analyzing students’ open-ended responses to survey questions at the beginning and at the end of the AVLE rendered interesting findings, which will be discussed in subsequent sections. Generally, the students’ average codes for all the subconstructs of knowledge was ($M=138$) in which the weighted coding system in MAXQDA allowed for defining weighted codes from 0-3, allocating 3 to the comprehensive responses to knowledge questions. Considering the weighted system, the total weighted score that a student could earn was 144 from 48 knowledge prompts. Most of the responses in this construct were coded under “core-content knowledge” and “digital literacy skills” as a category of foundational knowledge, and “problem-solving and critical thinking” as a meta-knowledge sub-category. The mean,
which is relatively close to the highest possible score in knowledge, represents a great deal of knowledge gain during this augmented virtual learning experience.

Regarding the interest and valuing construct, the students’ average codes for all the sub-constructs of interest and valuing was (M=39.18) and the total number of prompts for this construct was 17 examples which were weighted from 0-3 making the total weighted score equal to 51. “Individual interest”, “global relevance”, and “personal relevance” were the top three coded sub-constructs for this construct. As to the self-organization and self-control construct, the average number of codes were (M= 18.54) with the total number of nine possible scores out of prompts for this construct. “socially-shared regulation” sub-construct was the most frequent code under it. Self-perception and self-definition average codes were (M=34.72) with 81 weighted possible scores for this construct. Both “self-efficacy” and “possible selves explored” were the most frequent codes for this construct of PR. It is worth noting that the number of prompts was different for each construct, thus, rendering a higher mean for knowledge construct and a lower one for self-organization and self-control is assuming.

**Change Across Knowledge**

Based on the results of the inductive-deductive qualitative coding of student data, three thematic patterns relating to student knowledge changes were identified: (1) demonstrations of core content knowledge and problem-solving and critical thinking, (2) shifts from general to specific knowledge demonstrations over time, and (3) connecting new information to existing awareness of situated context.

**Demonstrations of core content knowledge and problem-solving and critical thinking.** The majority of codes applied to student data identified instances in which students demonstrated core content knowledge gains, such as an understanding of what urban planning is and how it is conducted. These trends exist largely due to the design of the AVLE. For example, the intake survey prompted James to describe what urban planners do, to which he responded: “They collect data about the places around us and get important people to change it.” Similarly, as a result of the design of the AVLE, a large proportion of codes identified instances in which learners engaged in problem-solving and critical thinking by generating solutions to in-game problems, or by offering justifications for their design choices. For example, Alice explained her choice to add more industrial zoning to downtown Philadelphia, saying “people need more places to work and find jobs to work.” These findings suggest the particular affordances of AVLEs for supporting the development of content knowledge situated in immersive, authentic professional spaces, and to encourage agentic decision-making processes supported by these emerging understandings.

**Shifts from general to specific knowledge demonstrations over time.** A review of shifts in knowledge demonstrations over time within individuals reveals a general shift from broad understandings of urban planning and environmental science towards more specific recognition of the complex relationships between domain variables over time. For example, changes in Kimberly’s responses to the question “What factors might an urban planner need to consider when planning/designing a city?” reveal increased specificity and a deeper understanding of urban planning processes as a result of engagement in the AVLE. In week 1, she wrote that urban planners “need to factor in the needs of other people” while in week 9 she was able to explain how “[urban] planners must think and fit the needs of stakeholder. Stakeholders focus on things they like to see or not like to see for specific cases.” The degree of shift in individual learners was predicated by the degree of knowledge (starting self) a student brought to the experience and demonstrates the adaptability and flexibility of the AVLE design to support identity exploration along unique individual trajectories.

**Connecting new information to existing awareness of situated context.** As students demonstrated increases in urban planning and environmental science over time, they also regularly connected the urban planning problems, processes, and AVLE context (Philadelphia) to knowledge of similar issues as they experience them in their own communities. For example, as Ali encountered the economic and environmental issues emphasized in the AVLE, he was able to reflect on the issues he had noticed in his own neighborhood (pedestrian safety). He later applied his new knowledge of how to identify problems and design solutions to his own context: “if I would want to change things, I would put more safety signs on streets to make people feel safe. my changes may help because driving lately has been more of a problem because people are frightened of others on either the highway or just a simple street.” These connections demonstrate the potential of the AVLE for promoting deeper learning integrated in learners’ understandings of their own interest and values, patterns of self-organization and self-control, and self-perceptions and self-definitions.
Change Across Interest and Valuing

After the analyses of qualitative data for interest and valuing, two themes emerged: (1) change from personal interest to less personal goals and interests, (2) overlapping changes in interest and knowledge.

Change from personal interest to less personal goals and interest. The students’ interest and valuing changes showed a significant difference from the beginning to the end of the AVLE. Yet, the direction of the change from more personal goals and interests in the beginning weeks to less personal interest was an evident trend in all students. Deductively, many of the students’ reflections and responses to survey questions were coded personal interest in initial weeks, while similar questions towards the end of the AVLE led to more “global relevance codes” which demonstrates a shift to less personal goals when the player recognizes how tools and content related to a community or society and satisfies the needs of the group members. For example, when Andrea was prompted with the question of “How the design of Philadelphia has affected you?” in post-survey she responded: “… [environmental issues] can impact us by changing the city it can make a better environment. If we change the ecosystem to be better it can make Philly look good and it will be healthier for us” which shows a well-suited response for “global relevance” as well as “personal relevance” or when Ali was prompted with a self-reflection personal interest question, he responded “I think we should get people to start riding bikes, I think that because, if we ride bikes or walk, we can make the world non big pollution rate country. also, our animals can be safe, and us humans can breathe fresh air.” These are just a few examples of many responses demonstrating students’ less personal interests toward the end of the AVLE.

Overlapping changes in interest and knowledge. Another evident theme in students’ responses regarding interest and valuing was that change in this construct happened in concert with change in knowledge, they demonstrated their interest using new words and expressions which were inductively coded as knowledge, too. For example, when Cynthia was asked to “How the design of the city affects you?” she responded “I think X (the name of the city) was built by artist who are very artistic. this affect me because all the artwork and building was made” which is not only demonstrating “personal relevance” but also “core-content knowledge” coded inductively from the knowledge construct. Or when Ellen was asked to report her team’s recommended value of bluebirds which are among endangered species in the Northeast, she answered “The recommended value of bluebirds is 2270 bluebirds. The stakeholders believe this is the perfect amount because if there were more there would be too much environmental space and not as much housing. However, if there were less than the city would not have the environmental space that it needs.” This justification shows Ellen both has the knowledge of keeping endangered species in her surrounding environment and values people’s needs in having necessary environmental space.

Change Across Self-organization and Self-control

The emerged themes came out of the researchers’ memos from the students’ demonstration of self-organization and self-control: (1) Asking help from the more knowledgeable peers/stakeholder, (2) Working toward a common goal and demonstrating metaknowledge.

Asking help from more knowledgeable peers/stakeholders. Asking help from the knowledgeable peers/stakeholders came mainly from the researchers’ memos recording instances when students were asking for help when discussing their final map changes with their peers and stakeholders which was coded co-regulated learning. In co-regulated learning examples, the students were asking for help from more knowledgeable peers, stakeholder, and sometimes instructors, e.g. The researcher’s memo in week 8 : “Ellen continued helping Alice assuring Alice was doing the right thing for the first notebook entry.” or when Kimberly turns to Sienna who was working independently on the map and says: “ we need to work better together on this map” and then the researcher noted that they continued working together on the map.

Working toward a common goal and demonstrating metaknowledge. When the students were working in groups toward a common goal in addressing the stakeholders’ concerns, they were not only demonstrating socially-shared regulated learning but also problem solving, critical thinking, communication and collaboration skills which were meta-knowledge components under knowledge construct. For example, when they were asked to justify the rezoning of their map “…(zoning for business)This is important because there is not a lot of space for business so we are thinking to make more space for it.” First, they indicated that they are looking for a way to solve the issue (problem-solving and critical thinking), second, they were indicating that they are working toward a common goal by bringing a plural pronoun (we). This example with many other examples of this sort, informed us that the students worked toward the common goal with their stakeholder, and brainstormed ideas with the members of the group to resolve the issues and rezone the maps.
Change Across Self-perception and Self-definition

The change in this construct was traced by coding self-efficacy, self-concept, and possible self-explored as the three main sub-constructs under it which led to one overarching theme: (1) No eloquent change in students self-perception and self-definition.

No eloquent change in students’ self-perception and self-definition. The analysis of students’ qualitative data did not show drastic changes in students’ self-perceptions and self-definition. Nearly all the students responded the same to the prompt of “what do you want to be in the future? what do you NOT want to be in the future?” before and after the VLE. For instance, Ali said “basketball player” Ciara said “wealthy, happy, educated” Elijah said “business owner” and many other similar responses which were not changed in the post-survey. This indicates that the students’ perceptions of themselves, their interest and their future desires barely change.

Discussion and Meta Inferences

While the quantitative analyses of quantitative results showed a statistically significant change in interest and valuing construct from the beginning to the end of the program, the qualitative data told a more specific story. Deductive coding of all 20 students in four constructs of PR revealed individual changes rather than a trend of change among all students. The students’ foundational knowledge and more specifically core content knowledge showed more detailed responses toward the end of the program which is also supported by quantitative results when the post-test in knowledge construct revealed higher mean in post-test ($M=56.33$, $SD=7.10$) comparing to pre-test ($M=52.66$, $SD=8.87$). The same difference can also be seen both in the quantitative survey and open-ended responses in demonstrating self-perception and self-definition (Table 2). Yet, the change in the levels of interest and valuing is more specific in qualitative findings and showed to be statistically significant in quantitative analysis. Significant changes for all constructs could have been ensured with bigger sample size. However, mean differences from pretest to posttest in quantitative section ensures some increases in other constructs. Taking both qualitative and quantitative findings together, two inferences emerged from the analyses of data:

Identity exploration on initial and final weeks

The analysis of qualitative results showed that identity exploration does not usually occur during the initial weeks of exposure to a new environment. During the first weeks, qualitative results showed that the students were more struggling with the technology and at some points, they were struggling with wi-fi connection and inability to upload their maps. Later, they found some time to know their peers, get help, and reflect on their interests in rezoning the maps. So in response to the question of “‘when’ in the process do learners undergo meaningful transformations in knowledge structures and identities?” one can tell it is not definitely in initial weeks and the qualitative findings show more significant changes in final weeks. In the quantitative phase, we were able to trace students’ identity changes across constructs of PR in which interest and valuing yielded statistically more significant results which are well supported by qualitative results. Interest and valuing in qualitative analyses were expressed more specifically even in initial weeks and the change was more evident from the beginning to the end comparing to the other constructs. In addition, one of the emerging themes in interest and valuing was the shift from personal interests toward less personal goals and interests benefiting the community needs which in turn shows a change in perspectives toward social needs.

Intertwined Constructs in Projective Reflection

The analysis of qualitative data showed that the Projective Reflection constructs are intertwined in a way that a single quote from the student might demonstrate multiple constructs and coded multiple times. As it was discussed earlier, interest with core content knowledge as well as self-organization and self-control with meta-knowledge were two common themes rendered the construct of Projective Reflection do not separately contribute to the identity exploration in AVLEs.
Identity Exploration across PR Constructs

Not all the students changed in four directions of Projective Reflection framework. Even though the change was statistically more significant in interest and valuing construct, they all changed in unique ways. Considering their backgrounds, their initial interests in urban planning activities, and their interactions with peers and stakeholders each of them changed differently. Assessing these changes is not an easy job but it is not impossible when we both consider assessing students in groups and individuals across each construct. We suggest future researchers also assess students’ identity changes across the groups if they are doing similar group projects.

Future Implications

The findings of this study suggest that students’ identity change in augmented virtual learning environments can comprehensively promote identity exploration through the interactions with peers and stakeholders. When students were prompted to reflect on their interests and future selves in a professional environment with real stakeholders and urban planners, they demonstrated multiple intertwined constructs which in turn shows the complexity of identity exploration in AVLEs. Results from the concurrent mixed methods study suggested that students’ identity exploration in virtual environments can be multi-directional and unique to each student. However, some themes were identified across each construct of Projective Reflection that could help trace students’ identity exploration in these environments. These findings are valuable since research on complex nature of learning with AVLEs has shown to be effective in facilitating students’ goals, interests, and skills in relation to specific disciplines and career paths (Foster, 2008; Khan, 2011). Future research should focus more on a balanced experience across all four constructs of Projective Reflection rather than focusing on a single construct. In STEM classrooms, teachers should also be mindful of keeping balance between all these constructs to help students facilitate STEM identities using AVLEs. More team building activities can help increase the chance of developing self-organization and self-control skills among the students which were less the focus of this study’s survey. We hope future design features together with more comprehensive data sources and new methodological insights help researchers in assessing identity exploration over the time.

Acknowledgments

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References


Tracking Identity Exploration Trajectories in Game-Based Learning

Amanda Barany, amb595@drexel.edu
Hamideh Talafian, ht343@drexel.edu
Mark Petrovich Jr., mep64@drexel.edu
Mamta Shah, mamta@drexel.edu
Aroutis Foster, aroutis@drexel.edu
School of Education
Drexel University
United States

Abstract: This chapter reports findings from a comparative case study that investigated changes in high school students’ science-related identities over time as a result of their participation in an augmented virtual learning environment (VLE). The Projective Reflection (PR) theoretical framework informed the design and implementation of a 9-week course that used the VLE Philadelphia Land Science and supportive classroom augmentations to promote intentional exploration of future possible selves in urban planning and environmental science. Two illustrative student cases are descriptively characterize unique trajectories of identity exploration that were enacted by learners over time; each student’s trajectory of change was shaped by their individual characteristics and contexts (starting selves) and by their engagement with the augmented VLE. Results illustrate how augmented VLEs may support adaptive identity exploration based on the individual needs and preferences, and provide insight into the design of tools that can promote identity change as defined by PR.

Introduction

To prepare learners for a complex, evolving, and uncertain future workforce, the design of 21st century learning environments should develop the cognitive and affective skills learners may need to engage in flexible self-authorship and context-based adaptation (Partnership for 21st Century Learning, 2016). To address this issue, educational research has increasingly focused on ways to develop learner skills in identity exploration, or the intentional repeated self-examination of who a learner is (current self) and who s/he might want to become (Kaplan & Flum, 2012), which can promote adaptive and flexible identity change in targeted directions over time (i.e. making intentional longitudinal shifts towards a future in a STEM career) (Foster, 2014). Games and immersive virtual environments have been increasingly identified and researched for their potential to support such changes in both cognitive (i.e. knowledge) and affective-related (i.e. motivation) aspects of self (e.g. Kamarainen, Metcalf, Grotzer, & Dede, 2015). To rigorously leverage these affordances however, research illustrates the need for robust conceptual and design frameworks for developing game environments (Ferdig, 2006), and the purposeful inclusion of real-world pedagogy that can supplement game content as part of an integrated game-based learning experience (Clark, Tanner-Smith, & Killingsworth, 2016). We refer to this merging of a primarily virtual environment with real-world supportive curricula as an augmented virtual learning environment (VLE) (Milgram, Takemura, Utsumi, & Kishino, 1995), which integrates the affordances of both digital worlds and classroom contexts to comprehensively provide identity exploration opportunities.

Recent meta-analysis and review studies have argued for researchers to elucidate the nuanced processes of learning that augmented VLEs afford in order to impact how games and simulation can be designed and used to innovate instructional practices in formal and informal settings (Clark et al., 2016; Young et al., 2012; Wouters et al., 2013). From a situative perspective on learning and identity, digital games and virtual worlds are powerful because they support transformation of game-players’ knowledge and self through participation in the gaming activity that involves the whole person in a continuously changing individual-environment interaction (Foster, Shah & Barany, 2017; Barab, Bransford, Greeno, & Gee, 2007).

This work leverages the Projective Reflection (PR) theoretical and pedagogical framework to operationalize learning as identity exploration that leads to identity change over time, as facilitated by the immersive interactive affordances found in many games and game-based learning environments (Foster, 2014). PR was used to design the
VLE Philadelphia Land Science augmented by real-world curricular supports to promote student identity exploration of urban planning careers, which were implemented in a museum classroom context with high school students. This chapter provides an in-depth look at trajectories of identity exploration in two student cases to illustrate how an augmented VLE (game and supportive curricula) designed using PR can promote adaptive and flexible processes of identity exploration. Findings (a) reveal how the augmented VLE supported tailored trajectories of identity exploration based on pre-existing individual characteristics and preferences (starting selves), and (b) offer insights into how to better design augmented VLEs to comprehensively support identity exploration processes across learners. The research question asks: How can an augmented virtual learning environment support processes of identity exploration and change in learners with unique individual cognitive and affective characteristics (starting selves)?

Games and Identity Exploration

In recent years, the role of identity research in education has proliferated as an increasingly important aspect of learners’ development in a globalized and technologically connected society (Brophy, 2009; Kaplan, Sinai, & Flum, 2014). For instance, some researchers have focused on leveraging games and virtual learning environments for promoting school-aged children’s cultural (Chen, Lien, Annetta, & Lu, 2010; Forsman & Hummelstedt-Djedou, 2013) and national identities (San Chee, 2013). Other researchers have examined the connections between youth and the expression of their personal identities in and through new media technologies (Gardner & Davis, 2013). Researchers working at the intersection of educational psychology and educational technology, as well as national reports and committees, have called for leveraging technologically-enhanced educational experiences to foster the development of 21st century competencies that are both cognitive (e.g., critical thinking, multimedia literacy, collaboration, creativity and innovation) and non-cognitive or affective in nature (e.g., self-awareness, solving everyday problems, caring about self and others) (Mishra, Koehler & Henriksen, 2011; U.S. Department of Education, 2017; National Research Council, 2011). Specifically, there is a need for learners to develop personal agency and reflexive skills that will allow them to reflect on their current positions and adapt towards changing contexts, interests, and careers (Foster, 2014).

There is growing evidence to support the claim that games are indeed conducive for identity exploration (Bagley & Shaffer, 2015; Shaffer, Nash & Ruis, 2015; Foster, 2011; Khan, 2012), and in turn, the resulting identity change contributes to academic learning, motivation, and interest (Flum & Kaplan, 2012; Oyserman, Bybee, Terry, & Hart-Johnson, 2004). However, this area of research is still in its infancy and lacks empirically-tested theories and processes that can illuminate (a) characteristics for designing identity exploration opportunities such as augmented VLEs, (b) how learners may progress through a trajectory of identity exploration leading to change over time, and (c) the role of educators and context in supporting such processes of self-transformation.

Theoretical framework

Projective Reflection (PR) is a theoretical framework that defines learning as a process by which participants intentionally explore an activity-based identity through engagement with an augmented virtual learning environment, with the potential to engage in self-transformation over time in relation to a targeted domain (i.e. environmental science, urban planning) (Foster, 2014). Figure 1 illustrates how the Projective Reflection framework conceptualizes learning as a process of identity change over time; learners are encouraged to reflect on their initial current selves, through the exploration of possible selves as supported by the augmented VLE, and on their new self at a desired end point.
Figure 1. The Projective Reflection framework.

PR conceptualizes learning as identity change across four cognitive and affective constructs: knowledge, interest and valuing, patterns of self-organization and self-control, and self-perceptions and self-definitions (Table 1). Using PR, a learner’s self at a given point in the augmented VLE can be further mapped along six sub-questions: (1) what the learner knows – current knowledge, (2) what the learner cares about – self and interest/valuing, (3) what/who the learner expects to be during the virtual experience, and their long-term future self, (4) what the learner wants to be – possible self, (5) how the learner thinks – self and interest, and (6) how the learner sees him/herself – self-perceptions and self-definitions.

Table 1

<table>
<thead>
<tr>
<th>Projective Reflection theoretical constructs</th>
<th>Definition</th>
<th>Example Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge and Game/Technical Literacy</td>
<td>Shifts in what a player knows about environmental science, urban planning, and urban planning systems from the beginning to the end of an intervention</td>
<td>(Kereluik et al., 2013)</td>
</tr>
<tr>
<td>Self-organization and Self-control</td>
<td>Shifts in behavior, motivation, and cognition toward a goal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Self-regulated learning: conducted independently</td>
<td>(Hadwin &amp; Oshige, 2011)</td>
</tr>
<tr>
<td></td>
<td>● Co-regulated learning: conducted with real/virtual mentors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Socially-shared learning: conducted with peers</td>
<td></td>
</tr>
<tr>
<td>Interests and Valuing</td>
<td>● Shifts in perception of environmental science/urban planning as being just globally relevant to also personally relevant</td>
<td>(Wigfield &amp; Eccles, 2000)</td>
</tr>
<tr>
<td></td>
<td>● Shifts in identification with environmental science</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Seeing the need for environmental science for the self and for use beyond school contexts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Shifts in caring for environmental science</td>
<td></td>
</tr>
<tr>
<td>Self-perceptions and Self-definitions</td>
<td>● Shifts in confidence in self, shifts in self-concept, or shifts in environmental science knowledge</td>
<td>(Kaplan, Sinai &amp; Flum, 2014)</td>
</tr>
<tr>
<td></td>
<td>● Shifts in how a participant sees himself/herself in relation to environmental science</td>
<td></td>
</tr>
</tbody>
</table>
To understand learner changes over time, researchers and educators may leverage the four PR constructs and the six sub-questions to examine characteristics of learners’ starting selves, track their development at repeated points across the augmented VLE, and then assess learners’ new selves at the end of the experience. It is this tracking of identity exploration as incremental changes in these constructs over time, culminating at a particular end point defined by the designed experience, that we refer to as identity change (Foster, Shah & Barany, 2017).

The Play, Curricular activity, Reflection, Discussion (PCaRD) pedagogical model for game-based learning (Foster & Shah, 2015b) offers one way of applying PR to the design and implementation of augmented VLEs. Given the affordances of game environments for providing situated learning experiences, players may engage in identity exploration in such spaces by role-playing a future possible self (e.g. an urban planner), which may or may not be an identity they plan to strive for in the future (Markus & Nurius, 1986). During play, student exploration of the role is guided by the design features of the game (i.e. what content is covered) and pedagogical supports within and outside of the game (e.g. virtual and in-person mentors).

Depending on characteristics of a learner’s starting self, and the extent to which the game supports role exploration, curricular activities that include opportunities for reflection and discussion are designed as augmentations to the game or virtual learning environment. These curricular augmentations draw upon students’ funds of academic, personal and in-game knowledge and experiences to make identity exploration personally relevant to each student (Silseth, 2012). Designed opportunities for inquiry, communication, construction, and expression (ICCE) also underlie students’ experiences during PCaRD; students are engaged, thus making the process of identity exploration a transformative learning experience in a Deweyan sense (Pugh, 2011; Foster & Shah, 2015a). Finally, in order to best support each student in his/her process of identity exploration, gameplay and supportive experiences are designed to be dynamic so as to seamlessly but intentionally promote self-relevance and a perceived sense of safety, while triggering or scaffolding exploration in the academic domain (STePS) (Kaplan et al., 2014).

Methodology

This research was conducted as part of an ongoing 5-year NSF CAREER project awarded to advance theory and research on promoting identity exploration and change in science using game-based learning and virtual environments (Foster, 2014). Building on this broader agenda, researchers designed and implemented the virtual learning environment Philadelphia Land Science (PLS) and VLE-external curricular activities that were intended further augment identity exploration opportunities. Session 1 of the augmented VLE was offered to a total of 20 Philadelphia high school students from October, 2016 to January, 2017, who participated in weekly STEM career programming at their local science museum.

The VLE Philadelphia Land Science was built by modifying the existing virtual internship Land Science (shared by the Epistemic Analytics Group at the University of Wisconsin-Madison) using their Virtual Internship Authorware tool to optimally support identity exploration as defined by Projective Reflection (See Barany et al., 2018 for information on the assessment and redesign of Land Science). PLS is a virtual learning environment designed to synchronously guide students through the successive steps of developing a city redesign proposal as participants take on the role of interns in a fictitious urban planning firm. After introducing themselves to the company using an intake interview (pre-survey) and reviewing introductory instructions on the urban planning process, students accessed a company personnel page where they read about fictitious stakeholder groups and their members, who advocated for environmental and economic changes. The students navigated to a resource page to research what types of city zones were needed to enact these changes, then collaboratively redesigned downtown Philadelphia using an interactive city map that modeled Philadelphia’s real-world makeup (Figure 2). Using the interactive map, players rezone each area to influence economic and environmental variables (pictured right). Each color represented a different type of land use they chose from: pink - commercial, oranges and reds - housing, greens - parks and open space, and brown - industrial.
Student groups iteratively created city design proposals using the interactive city map by reviewing and responding to VLE-generated stakeholder feedback sent through a professional email portal in the VLE. The design process increased in complexity over time, as students first attended to the needs of a single person, then a single stakeholder group. Finally, individuals were jigsawed into new teams as intern experts for their former stakeholder group, and the new teams attempted to balance the needs of all four conflicting stakeholder values in a final design. The final design was included in a formal written proposal that each student submitted through the email portal to the mayor’s office for consideration. Students concluded the experience with an intern exit interview (post survey). After each stage of the process, students were asked to submit professional email reflections on their emerging knowledge, interests and values, patterns of self-organization and self-control (strategies for success), and perceptions and definitions of self. These reflections helped to ensure that student identity exploration was enacted and assessed in a targeted and intentional manner repeatedly across the augmented VLE.

As structured by the PCaRD model, each of the nine Wednesday classes in Session 1 involved one or more periods of uninterrupted play using PLS, followed by one or more curricular activities designed to further augment the VLE and more comprehensively support identity exploration. Researchers roleplayed as urban planners to more immersively support student in-class reflection and discussion in individual, small group, and large group settings framed as professional meetings. Other classroom augmentations were designed to target intentional reflection, such as an inquiry-based activity in which learners asked questions they found personally meaningful and researched the answers; the collaborative design of paper maps of the city that allowed learners to design based on their own interests and desired future careers (Figure 3).

**Data Collection**
Qualitative and quantitative data was obtained through the VLE (e.g. written reflections as urban planning interns) and classroom artifacts (e.g. handwritten notes). All data was organized chronologically for each student to track changes in his/her identity exploration starting from before, repeatedly during, and as a result of engaging in identity exploration. After each weekly class, researchers collaborated to write detailed memos of interactions with students; memos were later segmented by discussion of student and organized chronologically in each student’s data file. Player cases were informed by text gathered from the following sources:

- A pre and post survey consisting of (a) 5-point Likert-style questions (ranging from *Strongly Agree* to *Strongly Disagree* on questions such as "I can see myself in an urban planning career in the future") (pre $\rho' = .969$, post $\rho' = .993$), and (b) short answer questions (e.g. "describe your interests in learning about cities and the environment"). For the purposes of this study, quantitative data was treated interpretively.
- Responses to writing prompts in the VLE, framed as professional emails to the design firm.
- Written posts made on an online forum website as an augmented curricular activity.
- Written researcher memos on student interactions, discussions, and activities.
- Screenshots and images of student map designs, from the VLE and from in-class design activities.

**Data Analysis and Case Study Development**

Once data organization was complete for all students, raw data was uploaded into the qualitative analysis software MAXQDA. Researchers then engaged in a deductive or directed coding process for each case (Gilgun, 2014; Krippendorff, 2004) where lines of student data were characterized as illustrating self-reflection on/demonstration of the four Projective Reflection constructs (i.e. their current self at that moment in the experience), with agreement reached by two graduate-level coders on the research team. For example, a student’s reflection reading, “the big ones [issue] I care about is pollution,” was coded as an example of their stated interests and values. Upon completion of each student’s data, codes were reviewed chronologically to comprehensively track their changes across the six sub-questions over time.

To identify unique learning trajectories enacted by students in Session 1, the aggregated code frequencies for each student were examined. Group findings illustrated that the augmented VLE supported an overall higher proportion of reflection on/demonstration of (a) knowledge and (b) interests and valuing across all students in the sample. Two students, Alice and James (pseudonyms), were purposely selected as cases with complete data (no student absences) that were potentially illustrative of unique identity exploration trajectories; compared to the group average, Alice’s data was coded with a higher proportion of PR codes related to knowledge and interest/valuing, while James’ data was coded with a particularly high proportion of changes related to self-organization/self-control and self-perceptions/self-definitions (Table 2).

**Table 2**

*Proportions of student data coded for each PR construct*

<table>
<thead>
<tr>
<th></th>
<th>Group Average</th>
<th>Alice</th>
<th>James</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge and Game/Technical Literacy</td>
<td>48.0% 1.9% 2.8%</td>
<td>51.0% 44%</td>
<td></td>
</tr>
<tr>
<td>Interests and Valuing</td>
<td>20.0% 1.0% 9.2%</td>
<td>21.0% 19.2%</td>
<td></td>
</tr>
<tr>
<td>Self-organization and Self-control</td>
<td>8.0% 1.4% 2.4%</td>
<td>11.0% 11.4%</td>
<td></td>
</tr>
<tr>
<td>Self-perceptions and Self-definitions</td>
<td>24.0% 5.7% 5.6%</td>
<td>25.0% 5.7%</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>10.0% 0.0% 0.0%</td>
<td>11.0% 0.0%</td>
<td></td>
</tr>
</tbody>
</table>

To construct student cases, codes for each of the four PR constructs were reviewed chronologically for Alice and James. Iterative cycles of analytic memoing were then conducted by researchers to organize and systematize student change across the six questions (as advocated by Maxwell, 2013). These memos resulted in written student
cases that conceptualized their processes of change over time. Review and revision of cases was enacted through processes of peer debriefing with researchers familiar with PR and the augmented VLE (as advocated by Creswell & Miller, 2000). The following presents a brief synthesis of the case summaries developed for Alice and James, to conceptualize their starting selves, exploration of possible selves over time (identity exploration), and new selves at the end of the augmented VLE.

**Findings**

**Case Summary – Alice**

**Starting Self**

Alice was a fourteen-year-old female student who identified as Asian or Pacific Islander. While Alice strongly agreed that she was confident in her ability to learn using games and virtual environments (Likert), she also wrote that “I never had any experience with science and urban planning before. This is my first time doing this.” This level of experience was evidenced in her early written responses, which indicated inconsistent understanding of urban planning concepts. For example, while she understood that a city stakeholder might “invest in the environment,” she initially described environmental science as “a play where you could learn about the environment and explore it.”

Alice began the intervention by affirming in written reflections a variety of careers she had considered, which suggested that she had pre-existing skills in self-reflection and the exploration of future possible selves. She described her desire to become a doctor, pharmacist, nurse, meteorologist, science engineer, reporter, and even strongly agreed (Likert) that she could see herself as an urban planner or in a career that uses environmental science. Alice did not specify which of these careers she expected to have in the future, however. She also wrote that environmental science topics were valuable to her, as well as to family and friends, but related this developing interest to her personal enjoyment of research rather than to valuing or interest in specific urban planning content or roles.

**Exploration of Possible Selves Across the Augmented VLE**

During the intervention, Alice demonstrated gradual development in her understanding of urban planning topics and skill using the VLE. Observational notes indicated that she initially asked for help from peers, then began partnering with others at her table to complete in-game tasks. Besides occasional help-seeking and group work, Alice’s pattern of participation was marked by limited discussion in either large or small groups, and an apparent preference for working quietly and independently on writing tasks.

As the weeks progressed, she reflected on her growing knowledge of how to enact the virtual city design process, which deepened her awareness of the complexity of environmental science issues. For example, she initially wrote that urban planning was a process of city design which ensures that “power is to be balanced [between economic and environmental interests] and have equal share between the community.” Alice was later able to describe the complex relationships between variables in an urban planning system, and to articulate her strategy for success in writing: “I put high density [housing] in a different areas that are near the open spaces.”

Observational notes and Alice’s written reflections in Alice illustrated a developing interest in completing the virtual city design process, and designing “successfully” to meet the needs of Philadelphia stakeholders. For example, when she ran out of time to complete a task in-class in week 6, observational notes indicated that she volunteered to catch up on the task at home, with permission from instructors. Alice described her interest in the process in the week 6 written reflection: “The job that I liked in the RDA was designing the area of Center City. Another thing is that I liked how we worked together and come up with a good idea to make the economy better.” Despite Alice’s affirmed interest in the process of urban planning however, Alice rarely connected the experience to her own interests, values, or experiences, often leaving writing prompts regarding personal valuing blank.

Finally, Alice’s perceptions and definitions of self shifted over time in relation to urban planning. In week 3, she wrote that “when I grow up, my future job is to be a medical doctor, and I believe that being a medical doctor do not relate to urban planning.” As weeks progressed, however, Alice wrote that she could potentially see herself as “a designer of the economy” working to make the city wealthier.

**New Self**

Synthesis of Alice’s changes over time revealed the development of broad, then increasingly specific and
complex understandings of environmental science and urban planning. For example, she wrote in the final week that an urban planner “studies the housing and the business to know what need to be fixed” and “how to structure the city.” Changes in what Alice cared about and how she thought were illustrated by her affirmed enjoyment of the process and her desire to be successful. Alice volunteered in the final written reflections that her city design was “the best out of her group because her team had selected it for their final collective submission, perhaps indicating pride in her work. She also wrote that a well-designed urban planning proposal could benefit her personally by making her community better. Alice did not describe changes in how she saw herself in the final weeks. While her desire to pursue a career in medicine apparently solidified over time (from week 1 to week 3), Alice was also able to actively explore the role of an urban planner, find personal enjoyment and value in the process, and ultimately connect her enjoyment of the urban planning process to real-world community benefits.

**Case Summary – James**

**Starting Self**

James was a fourteen-year-old male student who identified as African-American on the intake survey. James wrote that he typically spent an average of “2 ½ hours” online per day, primarily using social and communication-centric sites (i.e. Facebook, Google chat, etc.). Beginning in week 1 and continuing throughout the experience, James offered detailed responses to most writing prompts, demonstrating his clear understanding of urban planning concepts. For example, he initially explained the role of urban planners by describing how “They collect data about the places around us and get important people to change it and actually take in consideration how in the future we could probably change it more.” He then listed 9 economic and environmental variables (e.g. “Land Type[s]” and “money…” ) that urban planners typically address.

James initially wrote that urban planning was a role he could potentially see for himself because it is “a useful thing to do.” He also acknowledged his personal interest and valuing of urban planning in Philadelphia “because I live [in Philadelphia] and the next generation has to live and thrive as well,” noting that “[Philadelphia is] not a pretty site to live in quite frankly, and I think that should change.” Despite the personal connections James made to urban planning, he wrote that he hoped to “one day be a cook, mainly because it’s fun and it’s my passion.”

**Exploration of Possible Selves Across the Augmented VLE**

During the intervention, James regularly sought technical assistance from classmates to navigate the VLE, and often spent more time than his peers developing detailed responses to in-game and in-class reflection and discussion activities. One instructor noted an instance in week 3 in which James continued writing through the class mid-point break; the instructor eventually had to ask James to move forward so that the class could continue onto the next activity in sync. As the weeks progressed, instructors noted James’ regular collaboration with peers, and recalled several instances in which James asked to complete activities he missed due to absence. Eventually, James expressed a desire to translate the augmented VLE into real-world community participation; he suggested during peer discussion that the class visit local watersheds and “get feedback from them” to better inform their proposal designs.

Over time, James continued demonstrating a clear understanding of urban planning concepts, connecting his understanding of the complex relationships between urban planning issues to his personal experiences, interests and values, and even to community issues and current events. In one instance, he wrote about how he worked to lower the levels of phosphorus runoff in Philadelphia rivers to meet the needs of his city stakeholder (who was concerned with water quality). He acknowledged that commercial and industrial areas are important to support the city’s economy but expressed his own valuing of environmental advocacy: “the wetlands [I added] were to ensure the cleaner world, in Philadelphia so we don’t have problems like Flint, Michigan or other places with unpure water.”

James’ desired future career remained unchanged over time – observation notes indicated that he affirmed his desire to become a chef during peer discussions. As the weeks progressed however, James began connecting this desired role to his new urban planning experiences, and expressed increasing motivation to engage in Philadelphia as an advocate for change. He wrote about how he will one day need a balance between environmental conservation and economic growth as a chef, to ensure the harvest of safe and healthy vegetables and to facilitate the development of commercial centers where he might one day cook. He described the value of the VLE experience as showing him and
his peers how to engage as community advocates. James wrote, “improving the city for better is really making me feel like I’m making a change where I live. It’s okay to start off small, then make a change in the world…I think that maybe when we’re successful in our careers, we could think back to those places that we helped out and researched and maybe help more as someone who’s older and can make a even bigger impact.”

New Self

A summary of James’ changes over time revealed consistently clear and detailed demonstrations of complex urban planning knowledge that he increasingly connected to his interests and values. As he put it in his final written reflection, “I didn’t have much interest [in urban planning] at first but now I just believe that where I live should be looked at more deeply because I live there.” James wrote that the design of Philadelphia affected him because “I do often travel in Philly so if things fall apart or cause problems how will my living quality be affected.” While James’ desired future career as a chef remained stable throughout the experience, he stated that he found his urban planning roleplay enjoyable and indicated strong agreement (Likert) when asked if he would continue to learn about his city in the future.

Discussion and Significance

Projective Reflection serves as one potentially valuable framework for supporting student learning as a process of identity exploration that leads to change over time. The ability to flexibly and adaptively engage in (a) the intentional reflection on the self, (b) the process of exploring possible future selves related to new careers and roles, and (c) the enactment targeted and intentional steps toward a desired new self, will serve as a particularly valuable skill for learners preparing for an evolving 21st century workforce. Findings from Alice and James’ cases suggest that augmented VLEs can promote these valuable identity exploration processes along trajectories that are tailored to an individual’s starting characteristics and specific needs (starting selves).

In terms of knowledge gains, results from Alice and James suggest that the augmented VLE can provide valuable learning opportunities for participants with both detailed prior knowledge of urban planning, and for those with limited experience. While Alice developed an increasingly specific knowledge of urban planning content over time, James was encouraged to supplement his existing understanding through connections to his personal interests and values, and his local and global context.

Alice and James’ distinct patterns of interest development also offer useful insights into the optimal design of future augmented VLEs for supporting identity exploration. While both learners affirmed enjoyment of the urban planning process and explicitly described their role explorations, it was arguably James’ identification of the personal valuing and relevance of his role exploration that supported changes in how he planned to act in the near and distant future (i.e. learning about the city, engaging as an advocate for city improvement). While a focus on extrinsic motivators such as achieving “success” can be valuable as a hook for drawing students into deeper engagement (Deci & Ryan, 2008), augmented VLE design should intentionally emphasize intrinsic motivation that connects back to learners’ interests, values, and self-concepts, promoting more meaningful self-transformation. James’ desire for real-world participatory experiences and community engagement have also inspired new immersive augmentations that will augment Philadelphia Land Science in future implementations (such as partnerships with real-world advocacy groups). As practical and theoretical understandings of identity exploration trajectories emerge through this research, the capacity of learning practitioners to design early targeted supports for learners based on their starting self characteristics increases.

References


Acknowledgements

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Design and Development of a Modular Maker Education Course for Diverse Education Students

Jonathan D. Cohen, jcohen@gsu.edu
Cassandra Gaul, cgaul2@student.gsu.edu
Julia Huprich, jhuprich1@student.gsu.edu
Leigh Martin, pmartin18@student.gsu.edu
Department of Learning Sciences
Georgia State University
United States

Abstract: This chapter describes the design and development of an innovative maker education course. The course was designed to be responsive to students with diverse interests in education and consistent with the principles of making that it aimed to teach. The design was a mastery-oriented learning environment which leveraged a modular design and a digital badging system to afford students opportunities to focus their learning experience on aspects of making relevant to their own contexts. It represents the first stage of a design-based research project that ultimately aims to develop a set of design principles for designing maker education courses.

Introduction

Making refers to two interconnected practices. One practice is the construction, reconstruction, or remixing of digital or physical objects. This practice is paired with participation in maker communities, in which makers freely share both the process and products of making (Halverson & Sheridan, 2014; Hatch, 2014; Honey & Kanter, 2013; Martinez & Stager, 2013; Peppler & Bender, 2013). These practices are both facilitated by digital technologies, which is the fuel that has fed the current growth of the maker movement.

Increasingly, the maker movement is providing inspiration for educators who seek to infuse maker principles and technologies into school environments in an attempt to recreate the type of interdisciplinary, constructive, and learner-centric atmosphere found in makerspaces (e.g., Blikstein, 2013; Kuznetsov & Paulos, 2010; Sheridan et al., 2014; Vossoughi & Bevan, 2014). Correspondingly, teacher preparation programs are beginning to include aspects of making into their curricula, though not in any kind of widespread or systematic way (Cohen, 2017). There is an opportunity, then, for research into the design and development of courses which not only teach students about maker centered education but also model the kind of applied, learner-centered, and interdisciplinary learning that maker-centered pedagogies can enable.

The applicability of maker-centered learning to multiple learning environments, from formal K-12 classrooms to informal learning environments to adult and professional learning spaces, is an exciting feature of the space, but it is also something which requires thoughtful design. It is reasonable to expect courses which focus on maker-centered learning to include students from diverse academic paths, with varying levels of experience and divergent learning goals and objectives. Moreover, the focus of such courses (i.e., teaching and learning based on maker principles and technologies) demands that the design of the course reflects and is consistent with the content. Or, put differently, in order to afford students the opportunity to develop a rich understanding of making, such courses should approximate a maker environment as much as possible. Therefore, the authors set out to design, develop, and research a curriculum design that could address both of these issues. To research the effect of the design, the authors engaged in design-based research (Reeves, Herrington, & Oliver, 2005) project which seeks to develop a set of design principles for maker-centered educator preparation courses. The purpose of this chapter is to describe the first phase of a design-based research program that explores the development of a flexible, technology-enabled, mastery-based course focused on integrating maker principles and technologies into various learning environments.

Literature Review

Mastery Learning
The design of this course was inspired by mastery learning models. Mastery learning is a method of instruction in which learners tackle discrete curricular units, and are supported in their progression through these units by regular formative assessment. Though variations of mastery learning implementations abound (Guskey, Kulik, Kulik, & Bangert-Drowns, 1990), there are two elements commonly considered essential for mastery learning: (1) feedback, correctives, and enrichment, and (2) instructional alignment (Guskey, 2008). In a mastery learning environment, students are provided regular and targeted formative feedback. That feedback is paired with correctives, which are targeted to the students’ specific needs, indicated through the feedback. Enrichment activities are made available for students who master concepts early in the instructional process. And finally, units in a mastery learning environment must be aligned to instructional goals and objectives (Guskey, 2008). The modular nature of mastery learning environments accounts for differences between individual learners and is effective when used in environments in which the goals are focused more on higher-level processes, such as problem solving (Guskey, 2008).

The efficacy of pure mastery learning designs is a matter of some disagreement (Kulik, Kulik, & Bangert-Drowns, 1990; Slavin, 1987). However, the principles which undergird mastery learning (i.e., formative assessment, correctives, alignment of instruction with goals and objectives) are common in contemporary instructional design, and its influence on curriculum design remains evident, notably in academic medicine and nursing fields.

Digital Badges and Mastery Learning

Digital badges represent more than a certificate of completion or a grade; rather they contain metadata that describe the learning context and activity, cite criteria for success, and provide evidence of achievement (Gibson et al., 2016; Peck et al., 2016). In mastery learning, designers divide curricula into fundamental concepts, so that a single traditional course may be comprised of multiple competencies, each with a set of learning objectives. Since digital badges can be earned upon completion of learning objectives and the performance of a skill, badge hierarchies represent a series of subgoals working toward mastery (Randall, 2013; Wills & Xie, 2016). The result is an integrated badge system that supports learners as they work toward mastery of skills (Berge & Muilenburg, 2016; Gibson et al., 2016; Peck et al., 2016).

Digital badges as microcredentials provide affordances that support learners’ development of autonomy, self-efficacy, goal-setting, and motivation. Learners progress through the badge system choosing activities and learning experiences that meet their needs, and the experience is personalized and individualized (Gamrat et al., 2014; Gibson et al., 2016; Wills & Xie, 2016). In this system, digital badges operate as alternative assessments, and learners’ self-efficacy is developed as they receive feedback in the form of a digital badge (Fedock et al., 2016; Gibson et al., 2016; Wills & Xie, 2016). As learners’ self-efficacy develops, they continue to set goals by choosing and planning which digital badges to pursue and earn (Wills & Xie, 2016). The result is an accumulation of specific accomplishments that communicate not only knowledge and skills but also the learners’ interest (Gibson et al., 2016; Wills & Xie, 2016).

Although digital badges are external motivators, they can support the development of intrinsic motivation. The literature on digital badges identifies several theories of motivation including achievement goal theory, expectancy-value theory, and social learning theory (Abramovich et al., 2013; Abramovich & Wardrip, 2016; Gibson et al., 2016; Wills & Xie, 2016). Although some researchers report badges can have different motivational effects for different learners (Abramovich et al., 2013; Yang et al., 2016), when badges align to mastery of skills and not participation, expectancy-value theory suggests that the accumulation of badges will increase students’ success expectancy, and therefore, they will be intrinsically motivated to continue to learn.

Learner Control and Flexible Design

Commonly associated with online learning, learner control refers to the “freedom of choice, self-governance, and independence” (Sorgenfrei & Smolnik, 2016, p. 155) of learners to steer their own learning. When students are afforded learner control, they make decisions regarding elements of instruction, including what and how much they learn (within a given domain), the ways that they learn, the pace at which they learn, and the sequencing of what they learn (Lowyck, 2014). In e-learning environments learner control has been theorized to lead to increased time-on-task, mental effort, and task motivation, which in turn positively affects both cognitive and affective outcomes. More research has been conducted on learner control in e-learning environments than in face-to-face environments, no doubt owing to the scalable and hyperconnected nature of digital environments, in contrast to those typically found in face-to-face classroom settings (Hung, et al., 2010). This research, then, draws parallels with research done on learner control.
control in online learning environments, and acknowledges the limitations of applying such principles in a face-to-face environment.

**Course Design**

As stated above, two design criteria framed our course design. The first design criterion was that the design needed to be fluid enough to be equally relevant to all students in the course. The second design criterion was that the course had to be consistent with maker principles; for example, we would feel uncomfortable describing the importance of student agency and active construction within making, then asking all the students to read a couple of chapters and answer a response question about them.

The design process began with a brainstorming session, in which we identified the essential question that would frame the students’ work: How can maker principles and technologies support teaching and learning? From there, the team created a shared document on which we listed all relevant technologies, skills, pedagogies and practices associated with the maker movement and maker education. Then, we categorized topics to create three competency domains: Practices and Pedagogies, Digital Fabrication, and Mechatronics. Practices and Pedagogies included work related to the history and values of the maker movement, learning theories, instructional design and design theory, and curriculum development. In the Digital Fabrication domain, students learned about the hardware, software, and CAD skills needed to use advanced manufacturing tools, like 3D printers, laser cutters, and digital die cutters. The Mechatronics domain focused on the use of programming to manipulate physical objects, which for our purposes included work with block-based, object-oriented programming (e.g. MIT’s Scratch), programming environments congruent with Arduino and Lilypad microcontrollers, electronic circuits, and introductory-level electronic sensors and outputs (i.e. LED lights and motors).

Instructional content for each competency domain was constructed in modules, or in the language of the LMS, Paths. These Paths were designed and developed to help students achieve mastery of specific skill-based subgoals prior to moving on to the next Path, which required the use of the previous Path(s)’ skills to accomplish the stated goal for that competency domain. Each learning Path awarded a microcredential, which the LMS termed an Award, and the students’ arrays of Awards could be found on their individual profiles. Additionally, the room contained a physical space in which students could indicate their mastery in particular skills (e.g., microcontroller use, e-textiles, etc.). Certain modules that the design team deemed to be foundational were made required, but, in general, students could shape their experience in the course through their choice of which modules to complete. This allowed students to pursue their own interests, while still ensuring that all students achieved a base of shared knowledge.

Paths were comprised of a collection of individual activities, which included mind-on activities (e.g., text-based information, files, videos, and documents uploaded to the system, or learning assets curated from the open web and linked to their original sources, such as YouTube videos, instructional blog posts, or Instructables) and hands-on activities (e.g., programming tasks, curriculum design and evaluation, 3D CAD, circuit design, etc.). Each Path began with a set of instructions and was followed by instructional content developed or selected to help the student achieve mastery of a specific skill. The path culminated in an assessment, during which the student was instructed to perform a particular skill or skills; the instructor would observe the student and confirm the observation in the system, which triggered the LMS to deliver an Award for that Path. Many Paths had prerequisite paths that needed to be completed in order to unlock subsequent Paths. Students worked independently, in dyads, or in small groups on Paths, depending on their needs and/or preferences.

We designated certain Paths as Projects. These were less scaffolded than regular Paths, and they asked students to combine the skills they learned from multiple domains in the creation of a more elaborate product. These products included not only physical or digital objects, such as microcontroller-supported carnival games or digital media products, but also curricular projects, in which the students designed maker-inspired lessons or mini-units.

The duration of the 2.5 hour classes was banded into several sections and typically operated on a specific schedule. Classes, which met once a week, began with an opening activity, in which students often worked in small groups which rotated weekly on some kind of hands-on activity. These activities served to foster the type of collaborative community students in this situation have associated with maker educational environments (Cohen, Huprich, Jones, & Smith, 2017). They also provided the opportunity to introduce to the whole group certain educational concepts which were more appropriately done as a class than as individuals or smaller groups, such as the use of thinking routines (Clapp, Ross, Ryan, & Tishman, 2017).

These activities frequently provided a foundation for the more didactic portion of class. This period, which typically lasted for about 15 minutes and led by the lead instructor, reinforced some of the foundational knowledge contained in introductory Paths and oriented students to course topics not covered by Paths, such as equity and making.
the role of failure, and empathy-inspired making. In this part of class, students were encouraged to ask questions and participate in the discussion with examples from their own experiences.

The bulk of class time, approximately 90 minutes, was designated for unstructured work time, during which students could leverage the physical and human resources available to them during class meetings. Working individually or in small groups, students would use this time to finish Paths they began outside of class, or would discuss their work with their classmates and instructors.

Finally, the last few minutes of class was time to debrief the day’s work. Instructors and assistants would use this time to highlight participant activities of interest, answer questions, make connections to the lecture topic of the day. Students often completed brief exit ticket-style activities, during which they would record particular accomplishments, breakthroughs, sticking points, questions, etc.

Methods and Context

The design and development of this course is the first step in a broader line of research, which is employing a design-based research (DBR) paradigm (Reeves, Herrington, & Oliver, 2005) to develop design principles for infusing making principles and technologies into teacher preparation programs. DBR is “a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories” (Wang & Hannafin, 2005, pp. 6–7). Because it is a practical research methodology with the potential to “effectively bridge the chasm between research and practice in formal education” (Anderson & Shattuck, 2012, p. 16), DBR is commonly used in the learning sciences. The main features of this project are consistent with DBR. The project goals are pragmatic, and they focus on improving educational practices. The design itself proceeds in phases which build iteratively on the previous phases, allowing for flexibility in the likely event of unanticipated insights gained from the research process. The research occurs in a diverse, real-world, naturalistic classroom setting in higher education. And crucially, one of the main outcomes of the project will be the development of a contextually-sensitive roadmap for teacher educators to use in adapting their practice to incorporate the principles of making into their programs.

To support this first phase of the research project, the design team obtained Institutional Review Board approval to collect and analyze student data from this instantiation of the course design in Fall 2018. To minimize potential threat of coercion, the consent protocol, which occurred during the first class meeting, was conducted by members of the design team without the instructor of record present. The instructor of record was not made aware of who in the course was participating in the research until after final grades for the course were submitted.

Design Argument

We ground the iterative phases of this study in design arguments, which “[specify] the goals, context, substantive focus (intervention characteristics), procedural focus (process required to create the intervention) of the design, along with arguments for why the intervention will achieve the goal” (Easterday, Rees Lewis, & Gerber, 2018, p. 143). Bearing in mind the ultimate goal of this project, which is to produce a set of empirically derived design principles which can inform the implementation of similar courses in educator preparation programs, we proceeded under the following design argument: To create a learning environment that (1) was equally relevant for education students from diverse academic backgrounds and with divergent educational goals and (2) recreated the type of constructionist, interdisciplinary, learner-centered environment for which maker-centered educational scholars advocate, maker education courses should include a flexible course design, be mastery-oriented, and feature an infrastructure that encourages a decentering of the learning environment. See Table 1 for justifications.
Table 1

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible course design</td>
<td>Students can choose the focus of their study and largely determine their own pacing</td>
<td>Flexible designs can support the development of learner autonomy, which can lead to increased engagement and feelings of relevance</td>
</tr>
<tr>
<td>Mastery orientation</td>
<td>Students are provided formative feedback and are assessed predominantly through performance assessments which allow students to demonstrate mastery of content and skills</td>
<td>A mastery orientation can encourage skill development while removing stress caused by one-shot assessments</td>
</tr>
<tr>
<td>Decentering infrastructure</td>
<td>Through open educational resources, digital and physical badging systems, and the encouragement of collaboration, the center of instruction is distributed among class resources rather than on the instructor</td>
<td>A decentered classroom can promote collaboration</td>
</tr>
</tbody>
</table>

Note: Design argument table adapted from Easterday, Rees Lewis, and Gerber (2017).

Learners

The course, Inventing to Learning: Teaching and Learning with Maker Technologies, is offered at a large, urban university located in the Southeastern United States. The course enrolls both undergraduate and master’s students (n = 10), which creates two distinct, diverse sets of students who come with their own academic, professional, and personal goals and interests. While there is some homogeneity among the master’s students’ prior knowledge and academic goals, the undergraduates, who pursue different concentrations within an interdisciplinary studies major, represent an expansive swath of potential prior knowledge bases. Included in the master’s group are students enrolled in traditional middle and secondary teacher preparation programs as well as students working towards a degree focused on creative and innovative education for educators in both traditional and non-traditional educational settings. The undergraduate group has included those with foci ranging from adult literacy to counseling to physical education and coaching. Additionally, the motives for taking the course vary. Some students, for example, would come into the course already self-identifying as makers, while others know little about making beyond the stray mentions in the popular press, to still others who take the course mainly to facilitate graduating on time, given scheduling and course availability constraints.

Physical Space

The classroom is a former computer lab, measuring approximately 25 feet by 15 feet. The exterior walls are lined with tables that hold digital fabrication equipment, including 11 3D printers of different varieties, 6 digital die cutters, a sewing machine, a CNC router, and a laser cutter. There is a collaboration table in the center that seats at least 20. Although most students bring their own computers, the room provides access to 10 laptops. Power strips line the walls and are also located at the collaboration table. On the front wall of the classroom hangs an interactive whiteboard. Flanking the interactive whiteboard are storage cabinets which contain other maker technologies, including various microcontrollers, e-textile equipment, hand tools, consumables, and soldering stations. Though it contains much of the equipment one could expect to find in a makerspace, the room is not a makerspace; it is only open for students taking a course in the classroom during class time.
Learning Management System

Though the course is purely face-to-face, we decided that an online learning management system (LMS) would be the most efficient way to facilitate the course design. The cloud-based LMS we employed is typically used by large-sized corporate clients. It incorporates a number of different tools into a single platform which enable delivery of instructional content and administration of a multitude of assessment types. Individual accounts were created for each student, allowing the student to maintain a record of completions in the system and to progress in the course. In addition to the LMS, an integrated social collaboration tool was also used to facilitate group discussions and to encourage social learning.

Data Collection

To support the investigation of these questions, we collected three types of data: student artifacts, log data from the LMS, and class observations. From the LMS, we were able to collect data about not only the students’ progression through the Paths, but also details about the students’ use of the LMS, including when the students logged in and duration of use of the LMS. Finally, at least one member of the design team was able to take unstructured field observations during each class meeting.

Of particular relevance to this manuscript are the student artifacts and observations. Student artifacts included items like written reflections, design journals, and various physical and digital construction projects. Researchers paid particular attention to the written reflections. These included students’ responses to prompts, such as “How can making support teaching and learning?”, “Reflect on how the course design did or did not impact how you learned in this course,” “Describe your ideal learning environment,” and “How has any part of the making experience resonated with you personally, if at all?” Observations took the form of unstructured field notes, collected by one member of the research team who did not have any other instructional or support role for that class meeting.

Data Analysis

Researchers separately read through the corpus of data to develop an inventory of topics related to the design argument (Miles, Huberman, & Saldaña, 2014). From these topics, researchers collaboratively developed a set of codes. The researchers further refined the codes through negotiation of definitions and examples, and ultimately developed a codebook which formed the basis for continued analysis of the data. This cycle yielded nine codes, included “decentering,” “collaboration,” “empowerment,” and “freedom to fail.” After coding the data, researchers explored how the emergent themes related to the design argument, if at all.

Findings

Here, we present findings in relation to the design argument, which guided this phase of the study: To create a learning environment that (1) was equally relevant for education students from diverse academic backgrounds and with divergent educational goals and (2) recreated the type of constructionist, interdisciplinary, learner-centered environment for which maker-centered educational scholars advocate, maker education courses should include a flexible course design, be mastery-oriented, and feature an infrastructure that encourages a decentering of the learning environment.

Flexible Course Design

A major design element of the course was that students could choose their own focus, whether it be more pedagogical or technological, and pursue that focus throughout the course. This design element was popular with the students, and they reported not just an increased level of engagement because of it, but also an increased sense of personal relevance. One master’s student drew a comparison between this course and another course she had recently taken:
The lack of flexibility in that course meant that I was completing assignments, not because of interest, but because of obligation. Completing assignments due to obligation left little room to find purpose or understanding in most course topics. That is, however, counter to the structure of this course. This class was not only flexible, but allowed for self-expression, something that many other classes lack.

Another student remarked about the connection between flexibility and engagement:

This ability to really go off in a direction of my own choosing was so new to me. Most classes that I have taken, I know that I’m following the syllabus. It becomes more of something that you do. You just move through it. You don’t really think about it, especially if it’s not really a relatable topic. Here I was more interested.

The general consensus among the students was that the ability to decide on not only which Paths to follow, but also on which content to engage with within the Paths resulted in a greater sense of connection to the course and the content.

However, there was also an awareness that this instructional design could pose issues for students who struggle with self-regulation. An undergraduate student made the point that “The Paths allow you to be your own boss, have your own schedule and get done what you want when you want to. For most responsible students, this is [great], but there are those that do procrastinate and like to put things off and that’s where things can get tricky.” This element of danger within the design was mitigated to an extent via the use of the online LMS to manage the course. Students remarked that having the ability to work at home on certain Paths helped them to keep up with the course requirements.

**Mastery Orientation**

Students tended to appreciate the mastery orientation of the course. In lieu of summative assessments which factor into a final grade, the students in this course completed scaffolded series of activities that culminated in performance assessments. The performance assessments asked students to demonstrate skills they learned during the series of activities. Students could complete these assessments whenever they chose, using whichever resources they required.

Many students discussed how this type of assessment structure minimized the stress they typically associated with work in a traditional university course, because it reduced negative feelings related to failure. One master’s student described how he typically dealt with self-diagnosed failure in academic settings:

I feel like I experience failure in stages. I start off upset or disappointed depending on what the specific failure is. I have a tendency to be very hard on myself, so when I fail I go through a period where I beat myself up about it…. Once I move past that, my next stage is reviewing and questioning my steps in the failed process. I want to know where it went wrong and why. If there is one thing I hate, it's to keep making the same mistake over and over again.

When reflecting on his experience using e-textiles to create an LED-embedded mask—an experience with which he struggled—this student described a different trajectory:

I had never made some the lights up just by building a circuit of wires, lights, boards, and a battery that worked. I didn’t even know how to do that to begin with. Then I had to stitch all of this to the mask. I ended up having to do the process 3 times because I could not get the light to work…. I had to diagnose why it wasn’t working, but since I wasn’t getting a grade for every failure I didn’t feel the stress of having to pass an exam.

He described a scenario in which he experienced a type of failure (i.e., not getting his mask to light up), but did not “beat [himself] up about it.” Rather, he skipped the stage he described in which he would typically experience a period of self-criticism, and instead landed on the stage in which he was “reviewing and questioning” the scenario and engaging in productive problem solving, a process he attributed to the absence of stress caused by traditional grade concerns.
Decentering Infrastructure

Unlike many of the courses that the students had previously taken, the locus of instruction in this course was distributed between the instructors, the environment, open educational resources curated by the instructional team, and other students. Different elements of the course design infrastructure facilitated this decentering, including: (1) presenting students with the options to work collaboratively, if they so chose; (2) the flexible course design, which allowed for students to develop expertise in different areas at different times during the semester; and (3) digital and physical badges for students to display areas in which they had achieved mastery.

Students reported that they typically enjoyed seeing the types of projects and thinking that their classmates had generated. However, few wrote about any effect the digital or physical badges had on their decision to seek out expertise, though they consistently enjoyed receiving the digital badges and physically adding their names to the public list maintained in the classroom of those who had achieved mastery in particular areas.

More commonly, students commented on the extent to which they came to rely on the classroom community as sources of their learning and on their roles as teachers within the classroom. Some students formed learning partnerships. As an example, one student wrote:

Towards the end of the semester, [Student] and I began to work together to plan what projects we would work on next week and discuss what we needed to do to be ready to complete them in class. Doing that allowed us to build the foundational knowledge separately and then come together in class to work through the execution. By using this method we were able to troubleshoot when things didn’t work the way that we thought they would and compare our understandings of the readings or videos that we had watched separately.

Other students were pushed by their classmates’ accomplishments to achieve more:

For example, when [we] designed the Halloween masks, I originally planned to keep it very simple with decoration. However, I saw two other students adding an LED to their mask using the LilyPad and thought to give it a try as well. With some assistance from the other students, I was able to successfully add an LED to the Halloween mask I designed.

This type of inspiration even took the form of healthy competition among some of the students, who pushed each other to create more interesting and complicated artifacts.

Discussion

This first phase of a DBR project explored the design of a maker education course that (1) was relevant to all students, most of whom came from diverse academic backgrounds with divergent course (and career) goals, and (2) to the extent possible, authentically recreated a maker-centered learning environment. The main features of this initial design were flexibility of the focus and pacing of the course materials, a mastery orientation, and an infrastructure that decentered and distributed the locus of instruction. Analysis of the data indicated that the design features created an environment that was indeed relevant to all students in the course and reflected some of the main features of a maker-centered learning environments.

The flexible course design facilitated a degree of learner control, which students indicated had a positive impact on both their affect and their feelings of relevance. This phenomenon is consistent with the model proposed by Sorgenfrei and Smolnik (2016), and indicates that the flexible course design should be a feature of future iterations. Similarly, the mastery-oriented design encouraged students to iterate more during activities, which appeared to have resulted in enhanced skill development. Some students also reported reduced levels of stress, due to the lack of one-shot summative assessment. These results suggest that the mastery orientation of the course design be preserved in future iterations. Finally, the design of the course encouraged a decentering of the locus of instruction. Indeed, the collaborative atmosphere that resulted from this decentering was remarked upon by all of the students as a positive aspect of the course, and one which ultimately benefitted their learning. The link between this type of collaborative learning environment and the inherent collaborative nature of maker environments is consistent with our earlier work on maker-centered learning with pre-service educators (Cohen et al., 2017). Contrary to expectations, however, the presence of digital and physical badges seemed to have minimal impact on the students’ behavior in the course. This could indicate that student motivations had been internalized to the point that such types of extrinsic motivators were not needed. Or, this could simply be a function of the small class size; students did not need a digital or physical
representation of their skills, because the relatively small number of people in the course facilitated this knowledge without any additional infrastructure. Timing of feedback and badging could also be a factor in the limited impact of the badging program. Delay in feedback and delay in social recognition for completion of tasks may limit the effectiveness of badging (Domínguez et al., 2012). The power of badging in this course may increase with the addition of a social activity where students receive recognition for badges they have earned during class and on their own. The reported value of badging in the course may also have been a function of insufficiently defined motivation for earning the badges. Research of undergraduate course badging by Reid, Paster, and Abramovich (2015) indicates that the function of badges and connected feedback must be well defined for students to fully understand and value badging systems.

Conclusion

The course design outlined here is the first step in a DBR process which aims to develop a set of design principles for maker education courses in teacher preparation programs. Taking cues from mastery learning and e-learning-inspired learner control, the course design is modular, and it is consistent with the principles of making that it aims to impart to its students. Though making holds great promise for formal education, it remains an “under-theorised, over-marketed, and rapidly proliferating endeavor” (Bevan, 2017, p. 76). This underscores the importance of developing and systematically researching methods for preparing teachers to leverage making in their practice in order to maximize its chances of success.

References


Designing a Blended-Makerspace Course for Pre-service Teachers in an Undergraduate Technology Minor Program

Ozlem Karakaya
School of Education
Iowa State University
United States
ozlem@iastate.edu

Abstract: This study focuses on designing a makerspace course module offered for pre-service teachers in an undergraduate learning technologies minor program. Computer Supported Collaborative Learning (CSCL) framework informs the design of the modules, activities, and assignments in this study. The findings show that collaboration in online platforms is important to better improve makerspace knowledge of pre-service teachers. The following emerging themes are found in this study: 1) Clear assessment criteria needed; 2) Several activities should be moved to the first module to monitor collaborative learning; 3) A semester-long course needed for more collaborative work; 4) Course workload should be lowered; 5) Organization of the course supports collaboration; 6) A textbook is needed for a more structured learning; 7) Collaborative tasks are supportive for learning; 8) Optional assignments are needed; and 9) Supplemental materials should be added to the modules.

Introduction

Teachers have had their students tinker, make, design and create projects throughout years. This movement has gained more importance in the last two decades, and has been named as the maker movement by Dale Dougherty after publishing the Make magazine in 2005 by O’Reilly Media. The maker movement didn’t start specifically for children and education; however, it has substantially attracted children’s and educators’ attention. Since schools, school districts, and colleges have placed great emphasis on their students to be not consumers of high and low technologies but producers, they have started to design their own makerspaces and offer makerspace courses. Thus, it is significant for teacher education programs to offer makerspace courses to prepare pre-service teachers (PST) with maker movement knowledge and the ability to teach with it. Therefore, this study focuses on designing a learning module of a blended course aiming to help PST broaden their horizons about makerspaces and convey their maker knowledge to their students in the future. Overall, this study aims to answer the following research question: How does collaboration in an online makerspace course support the development of makerspace knowledge of PST teachers?

Literature Review

Makerspaces, which are designed not only to foster people to think, design, make, tinker, and create but also to see failure as success, have recently gained national (Bers, Strawhacker, & Vizner, 2018) and international attention (Bers et al., 2018; Burke, 2014; Chang, Keune, Peppler, & Regalla, 2015). The Maker Movement has been growing rapidly and attracting individuals from diverse communities including engineers, librarians, educators, and more (Martin, 2015). Makerspaces including low and high technologies provide several opportunities for students in educational environments including but not limited to project-based learning, peer-supported making, community building, participatory culture, and tinkering activities (Bers et al., 2018). All these elements of makerspace environments help learners to develop their social and technical skills, their identities (Bers et al., 2018), and their potentials (Paganelli, Cribbs, Huang, Pereira, Huss, Chandler & Paganelli, 2017). Therefore, it is important for schools to have makerspaces providing maker activities and the teachers equipped with makerspace knowledge. To train teachers with this makerspace knowledge, teacher educator programs should get the responsibility to offer makerspace...
courses. To this end, the present course is designed to improve the maker knowledge of pre-service teachers. Since makerspaces are the “learning environments where participants work independently or collaboratively with materials to design and make” (Halverson & Sheridan, 2014b, p. 508), and Shapiro (2016) states that “the maker movement demonstrates a new model for how mass collaboration and mass learning can be distributed across online and in-person participation” (p. 197), the makerspace module in this study is designed using computer supported collaborative learning.

On the other hand, this study draws on Papert’s views on constructionism as Thompson et al. (2017) recommended to precipitate in performing Papert’s ideas because “at a time when most did not find computers or technology particularly compelling or exciting, Seymour Papert provided a vision for using technology to create active and exciting learning environments for learners, environments where PST could build, create, and think about their thinking” (Thompson, Lindstrom and Schmidt-Crawford, 2017, p. 4). Papert’s constructionism theory “aligns with and builds on, constructivism, … that holds knowledge as actively constructed by learners through experience and that sees learning as the ongoing construction and revision of mental representations” (Sheridan, Halverson, Litts, Brahms, Jacobs-Priebe, & Owens, 2014, p. 507).

### Conceptual Framework

The computer supported collaborative learning (CSCL) frame helped to design the modules, activities and assignments in this study. CSCL is a pedagogical approach where learning occurs as a result of social interaction and collaboration via computers (Stahl, Koschmann, & Suthers, 2006). CSCL can be characterized as consisting of three methodological traditions: experimental, descriptive, and iterative design (Stahl et al., 2006). According to Stahl et al. (2006), the studies following an experimental design compare an intervention to a control condition. They are mostly quantitative research designs and data analysis is mostly performed with a coding. Studies following descriptive designs are mostly qualitatively designed data-driven works to uncover emerging themes and patterns in the data. In these studies, video and voice files are transcribed and brief texts are examined in great details. Lastly, according to Stahl et al. (2006), studies following iterative design of CSCL can be either quantitative or qualitative. These types of studies involve different stakeholders into the process and work with design-oriented researchers to improve the artifacts. This study utilized a qualitative iterative and experimental design process.

CSCL has arose as a reaction towards to the idea of students’ learning as isolated individuals (Stahl et al., 2006). CSCL does not mean just throwing the content (i.e. articles, videos, slides, etc.) of a course to the online environments but it also connects people in innovative ways. The seven affordances connecting students in online environments are as follows: 1) engage in a joint task, 2) communicate, 3) share resources, 4) engage in productive collaborative learning processes, 5) engage in co-construction, 6) monitor and regulate collaborative learning, and 7) find and build groups and communities (Jeong & Hmelo-Silver, 2016). The elements of CSCL framework are important to develop online course platforms in a collaborative way. CSCL supported the design of the activities and assignments in this course in order to better encourage PST to improve their makerspace knowledge not only in face-to-face environments but also in online platforms. PST’ feedback and CSCL framework helped to redesign each activity and assignment in a way that provides more collaborative work in online environments.

Additionally, the three approaches used in this chapter to design this module using CSCL were 1) scripting (Cress, Stahl, Ludvigsen, & Law, 2015; Dillenbourg, 2002; Kobbe, Weinberger, Dillenbourg, Harrer, Hamalainen, Hakkinen, et al., 2007), and 2) construction of artifacts (Cress et al., 2015; Kafai & Resnick, 1996; Stahl et al., 2014), and 3) knowledge building (Cress et al., 2015; Scardamalia & Bereiter, 2014). Dillenbourg (2002) describes the word “script” as “a more detailed and more explicit didactic contract between the teacher and the group of students regarding their mode of collaboration. This contract may be conveyed through initial instructions or encompassed in the CSCL environment” (p. 63). In this module, PST were provided scripts as an “external guidance” (Cress et al., 2015, p. 111) to provide instructions and to plan their activities (Cress et al., 2015). The second approach was to use artifacts in a course design to increase the collaboration of learners. Stahl, Ludvigsen, Law, and Cress (2014) indicate that artifacts in a CSCL environments play important roles and there are several artifacts including technological artifacts, instructional artifacts, or learners may produce their own artifacts. In the context of this study, Google tools (e.g. GoogleDocs) and the university’s learning management system (LMS) were used by the PST to collaboratively create course assignments. Lastly, the discussion platform of the LMS was used as an environment where students can build makerspace knowledge by sharing ideas, providing feedback to each other, improvement ideas, and identifying problems (Cress et al., 2015).
Methodology

This study utilized qualitative research method design and multiple sources of data collected in this study were: 1) field notes from a meeting held with different stakeholders including a faculty, a technology specialist, and two PST enrolled to the course in order to determine the format, goals, content, and possible activities of this makerspace course, 2) an open-ended survey administered at the end of the course; four PST were asked to reflect on their course experiences, and 3) related course artifacts created by PST during the course (e.g., Flipgrid video reflections, written discussions).

This study has gone through several steps (i.e. designing, developing, testing, and redesigning) in order for this makerspace course to reach a complete developed version. The purpose of this project was to redesign an educational technology minor course with better content and medium to increase PSTs’ engagement with makerspace technologies. First, in order to explore PSTs’ and other stakeholders’ needs, preliminary data were collected from the meetings held with a faculty member and a technology specialist, and two PST who were going to enroll in this course. Through this preliminary data, some determinations related to the format of the course, topics, content of each module, activities and assignments as well as grade points for assignments were achieved. Second, a survey that has 10 open-ended questions was administered to collect data from the 24 enrolled PST in order to explore their perceptions and attitudes towards this makerspace course design after the course is completed. Third, PST’ video reflections and written discussions were examined to find out the emerging themes. Lastly, the 10-item survey was also administered to collect data from the four PST. Based on the analysis of triangulated data collected from 24-enrolled students, only the first module of this course was revised and tested in this study with four PST.

Context

This is a one-credit/four-week technology minor course offered every spring semester for undergraduate PST primarily majoring in elementary and early childhood education. However, PST from secondary education and even students who are not majoring in education can take this class. After having initial meeting with the aforementioned stakeholders (a faculty, a technology specialist, and two PST), it was decided to offer this course as blended in Spring 2018 semester. Because this course was taught in a blended format, the online portion of the course was provided to PST through Canvas, which is the LMS of the university. The blended format of the course allowed PST to practice what they learn in online sessions and play with low and high technologies as well as produce new projects in face-to-face sessions. Therefore, as the first week of the course was an introductory module to makerspace movement and the last module was planned to focus on the final project of the course, these two modules were decided to be online. The second and third modules were designed to be face-to-face because PST were welcomed to the classroom environment to play and practice with hands-on experiences provided by the instructor. The last week of the course was left for PST to finalize the collaborative ongoing tasks from the beginning to the end of the course and finish up their makerspace design project. This four-week course was redesigned and piloted with 24-enrolled PST in Spring 2018. Although this is a four-week course, only the first module designed based on the CSCL framework is reported in this study. Because the first module was decided to be online, all of the activities and assignments were designed via CSCL and submitted online through Canvas.

Participants

The audience of this course were PST primarily majoring in elementary education, early childhood education, and secondary education (i.e. math, history, etc.) as well as students from other majors (i.e. industrial engineering). The PST were supposed to have a Learning Technologies Minor to be able to take this one-credit makerspace course. This course is offered every spring semester and the number of the PST enrolled this course in a semester is around 24. The data of this study was collected from 24 undergraduate PST enrolled to the makerspace course in the semester Spring 2018. The number of female PST (n = 20) is greater than the number of males (n = 4). The majority of the PST were elementary education PST (n = 17) while there were PST majoring in the secondary education such as Math (n = 2), Family and Consumer Sciences (n = 2), and History (n = 1). The rest of the PST were majoring in early childhood education (n = 2). All of the PST were having their Learning Technologies Minor and taking this one-credit makerspace course as a part of their minor degrees. The majority of the PST were senior (n = 13), while there were eight junior and two sophomore PST. There was not any freshman enrolled to this course. Prior to taking this minor course, all of the PST had taken an educational technology course that improved their educational technology knowledge. Additionally, most of the PST enrolled in this course had also taken and/or were taking another minor
course, which was a technology field experience course. In that course, they had the experience of observing and using educational technologies in real school contexts and school districts.

**Procedures**

The results of the meetings with the faculty member and the technology specialist showed that the following topics should be covered in this makerspace course: 1) Introduction to Maker Movement, 2) Digital Fabrication and Computer Programming, 3) Physical Computing, and 4) Makerspace Design Project. These are considered as core topics in maker movement. The faculty member and the technology specialist stated that they already designed an online makerspace course for inservice teachers as a workshop and included these emerging topics. Also, they stated that they assigned inservice teachers to create an end-of-course makerspace design project. The initial meetings with two PST were not as effective as the one with the faculty and the technology specialist to determine what topics should be taught in this course because the PST stated that they did not have any idea what makerspace was and what topics they were looking for exploring. However, the PST said that they would like to learn hands-on makerspace activities both in online and face-to-face platforms, and would like to apply what they learn in this makerspace course into their future classrooms. One student pointed out that she expected to learn how to apply math into real life so that she could demonstrate and teach this to her students. The emerging themes arising from student conversations were developing PST’ creativity, problem solving, critical thinking, and collaboration skills.

One goal of the researcher was to design the course as visually appealing and easy to navigate. In order to provide an overall idea of the course and categorize the contents in an organized way, a homepage with text and illustrations linked to the related materials was created first (see Figure 1). This helped the researcher to separate the course materials, documents, discussion, and assignments. Second, all items were listed in modules with short titles and PST needed to click on each item to see the details of the item (see Figure 1). Third, multiple mediums such as texts, articles, external links to important websites, images, and videos were used to design the modules. These items were included in a logical order to increase the quality of the flow in the modules. Each item was expected to contribute to the PST’ maker movement knowledge. Fourth, the items in each module were created in a sequential order so that once a pre-service teacher completed the first item in the module, she/he started working on the second item. Additionally, all of the items in the module were named with the related module name such as Week 1.

Assignment --- Design a Maker Manifesto (see Figure 1). This helped PST to see all of the assignments starting with the name of the week they belonged to. When they click on not the modules but assignment button on Canvas, they were able to see what assignment belongs to what week.

![Figure 1. The visual design elements of the course](image)

These were the elements researcher focused on for the visual design but the main goal of the researcher was to build a rich course content supporting collaboration in an online platform using the CSCL framework. Because this study focused on only the first online module, the topics, objectives, activities, assignments and grade points in this module were determined. The first module had overall four main objectives for PST to gain (See Table 1). As stated in methodology section, the activities and assignments were designed considering the CSCL framework. Although there were seven elements of CSCL (Jeong & Homelo-Silver, 2016), five of these elements were used while designing the activities (see Table 1) in this module.

The first objective of this design project was to have PST get to know each other and identify the reasons of being interested in makerspace course as well as determine what they expect to learn in this course. To achieve this goal, monitoring and regulating collaborative learning element of CSCL was used in a video reflection platform,
called Flipgrid. PST were expected to introduce themselves, and stated why they were interested in this makerspace course and what they would like learn once they finished the course. They were also supposed to respond to at least two of their friends in order to monitor each other. Also, they provided feedback and asked questions to their peers so that their peers can revise their goals and expectations from this course.

The second objective was to define what the maker movement phenomenon is and what a makerspace looks like. For this purpose, PST were asked to read the two articles provided and watch four short videos. They browsed the content created and visited the external links of some useful makerspace technologies. After covering the content provided, PST were provided appropriate instructions to answer certain questions in their discussion posts and responded to at least two of their friends. It is believed that providing instructions would enhance PST’ collaboration skills as Dillenbourg (2002) emphasizes the importance of instructions by stating “a collaboration script is a set of instructions regarding to how the group members should interact, how they should collaborate, and how they should solve the problem. When teachers engage students in collaborative learning, they usually provide them with global instructions...” (p. 63). This item was also designed using CSCL framework, monitor and regulate collaborative learning. Using the discussion feature of Canvas and following the instructions of the instructor, PST monitored each other's work and participation and regulate their collaborative learning. In their responses, PST provided constructive feedback to their peers. After receiving feedback from their peers, PST made additional discussion posts to showcase how they regulated their understanding based on their peers’ feedback.

The third objective was to collaboratively prepare a list of tools and furniture that could be used in a makerspace. To achieve this goal, Google Docs were created for PST to collaboratively build makerspace tools and furniture documents. PST were asked to search and learn about possible low and high technologies and furniture that could be used in a makerspace and add their knowledge into a collaborative Google Document. PST were able to edit it and used the comments and chat feature of the Google Docs to collaborate even to share resources. Five elements of CSCL were used to design this activity (see Table 1). Because all PST were required to contribute to the Google Doc to build the makerspace tools and furniture by putting their names next to the items they wrote, each of them was able to monitor and regulate others’ contribution. Building a joint task (Google Doc) also helped PST engage in a productive collaborative learning process and a co-construction process. Lastly, PST were also able to share additional resources with their friends using the chat and comment feature of the Google Doc and this met the criteria of CSCL element share resources.

<table>
<thead>
<tr>
<th>Learning activities</th>
<th>Technology Tool</th>
<th>Learning objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>PST will be able to identify each other and the reasons of being interested in taking this makerspace course as well as expectations from course.</td>
<td>CSCL, monitor and regulate collaborative learning.</td>
<td>Flipgrid Video-reflection activity</td>
</tr>
<tr>
<td>PST will be able to define what the makerspace phenomenon is and what a makerspace looks like.</td>
<td>CSCL, monitor and regulate collaborative learning.</td>
<td>Canvas Written discussion</td>
</tr>
<tr>
<td>PST will be able to collaboratively prepare a list of tools and furniture that can be used in a makerspace.</td>
<td>1) CSCL, monitor and regulate collaborative learning. 2) CSCL, engage in a joint task. 3) CSCL, share resources. 4) CSCL, engage in productive collaborative learning processes. 5) CSCL, engage in co-construction.</td>
<td>Google Docs Building a document including high and low technology tools for a makerspace</td>
</tr>
<tr>
<td>PST will be able to design and share a makerspace manifesto.</td>
<td>1) CSCL, engage in productive collaborative learning processes 2) CSCL, engage in co-construction</td>
<td>Drawing tools for 3D modeling Creating a manifesto for their makerspace</td>
</tr>
</tbody>
</table>

The last objective of this project was to have the PST design a makerspace manifesto and share their work on a discussion platform of Canvas as a draft. The two CSCL elements, monitoring and regulating collaborative learning and sharing resources were used to achieve this goal. They also provided feedback to each other so that they could improve their drafts for a final submission. In this platform, they could also share additional resources that may help to improve their design.
Data Analysis

The data were manually analyzed and an open coding process was conducted to code the triangulated data using Blair (2015) and Saldaña (2016). First, the data was examined and compared for similarities and differences. Then, similar codes were grouped together to determine the emerging themes (Blair, 2015; Saldaña, 2016). The following themes have been found as emerging in this study: 1) Clear assessment criteria should be provided; 2) Several activities should be moved to the first module to monitor collaborative learning; 3) A semester-long course is needed for more collaborative work; 4) Heavy workload of the course should be lowered; 5) Organization of the course supports collaboration; 6) A textbook is needed for a more structured learning; 7) Collaborative tasks were supportive for learning; 8) Optional assignments should be provided; and 9) Supplemental materials should be added to the modules. In order to ensure the trustworthiness of this study, multiple sources of data were collected and a rich description of data collection and procedures were provided.

Results

Based on the qualitative responses of field notes, survey responses, and related artifacts, emerging themes that PST highlighted were determined as follows;

Assessment Criteria

The two PST who had completed a 10-question survey were concerned about their grades because of not having an assessment tool for their assignments to be graded. They have stated that they did not know if they were going to get a low or high grade. This feedback helped the researcher to create both formative and summative assessment tools for the new module design. The rubric and checklists were designed around CSCL framework based on PST’ feedback in order to assess assignments and discussions. As for the formative assessment, PST were asked to make video-reflection posts and text-based discussions as well as collaboratively build Google documents. While PST contributing to Flipgrid and text-based discussions, they received peer-evaluation by responding to each other. The summative assessment for the first module was to design a makerspace manifesto flyer and PST submitted a link or a document to Canvas to be graded. A checklist was created to evaluate each of the activity. Also, a rubric was designed to evaluate the final project of the PST in this course (see Table 2).

Table 2

| Items and Assignments in the First Module |
|-------------------------------|------------------|---------|
| **It #** | Module Items | Points | Assessment tool |
| em 1 | Course Overview | | | |
| em 2 | Assignment | Introduce Yourself - Flipgrid | 5 | Checklist |
| em 3 | Module Overview | Content Page | | |
| em 4 | Discussion | Text-Based | 10 | Checklist |
| em 5 | Assignment | Design a Manifesto Flyer | 25 | Rubric |
| em 6 | | | | |
| em 8 | Assignment | Google Docs - Tools & Furniture in Makerspace | 5 | Checklist |

Moving an activity to the first module to monitor collaborative learning

The Google Docs for makerspace tools activity was starting in the second week of the course through the end of the course while the Google Docs for makerspace furniture was starting in the third week. However, one student
stated that it would be better to have these Google Docs activity in the first week of the course and to keep contributing more in the following weeks. She stated that they could add more tools in the following weeks and see how she developed herself about learning new makerspace technologies. Thus, the Google Docs of makerspace tools and furniture were decided to be moved to the first module instead of having it in the second and third modules only. In addition to these, several PST stated that they really liked to use the chat and comment features of Google Docs. They pointed out how these features kept them engaged with the topic and collaborate with each other. Also, PST are asked to put their names next to the items they wrote in Google Doc so that it was clear who contributed into the document. A pre-service teacher stated that this helped them to monitor and regulate their collaborative learning.

A semester-long course for more collaboration

The results of the survey have revealed that there are PST who would like this makerspace course to be a semester-long course rather than its being a four-week course as a student stated:

“There is so much to learn regarding Makerspaces and the maker mindset. I think this should be a semester-long course as part of the minor. Another option would be to have two 1-credit seminars in sequence, so it would be an option to take two credits of Makerspace or just one. That would give the opportunity to get exposed to making but also allow us to go more in depth and try more things. Having a semester-long course would also help to monitor each other’s learning in a longer period of time. Having the time to be fully immersed in the maker mindset is the main reason for a semester-long course” (Student 1, survey, 4/11/17).

Another student indicated similar reasons for this makerspace course to be a semester-long course as he provided the following:

“I would prefer this Makerspace course to be a semester-long course because we could go more in depth in how to use these concepts in our own content areas and classrooms. For example, how can I, as a future high school math teacher, use Makerspace concepts and ideas in my future classroom? I would like to see examples of how real-life teachers are using these concepts in their classrooms and how they create collaborative activities. I would be more productive in that way” (Student 3, survey, 4/10/17).

On the other hand, a number of PST stated that this one-credit/ four-week makerspace course should be still a four-week course because PST have difficulties to handle several courses at the same time as one student indicates, “I like this course being a four-week course as it is now because it worked well in my course schedule. … it is hard to have lots of classes on the other days…” (Student 1, survey, 4/11/17).

Although there were different reactions to the question of the makerspace course’s being a four-week course or a semester-long course, it seems not possible to offer it as a semester-long course in near future. But this idea will be considered and taken into considerations for further development.

Heavy workload of the course

Another theme arising from the analysis of the data was the workload in each module. There were several PSTs complaining about the number of the activities and assignments in each module; as one of the PSTs stated, “We had quite a bit of online things to do every week, so those weeks I would spend around 5 hours on this class, which was a lot to do in one week for a one-credit course” (Student 4, survey, 4/9/17). Another student complained about the same situation as follows, “The course was overall very loaded and tiring. There were too many tasks assigned in each week. Being asked to share an assignment I submitted on a discussion platform for others to see it has created more work for me.” (Student 3, survey, 4/10/17). Asking students to share their work for other students to see was to apply the “sharing resources” element of CSCL; however, it brought more work for students.

However, there were PST who liked the heavy workload in each module because the workload forced them to think more in detail in this course. A student said, “I know there was a lot of work and assignments for this course, but I appreciated that. I found value in doing each assignment, and it forced us to really spend some time with the ideas in the course” (Student 1, survey, 4/11/17).

Although there were PST complaining about the heavy workload of the course, it does not seem possible to ease it because the course aims to teach as much as possible in a limited time. Thus, no changes or revisions were decided to be made for further semesters.

Organization of the course for collaboration

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Another theme emerging from the data analysis was the organization of the course. All of the PST were pleased with the organization of the course and found it easy to navigate as one of the PST stated, “The Canvas course was very well-organized, and it made it easy to see what needed to be done when. It was easy to collaborate on assignments and provide feedback each other through Canvas discussion platform.” (Student 4, survey, 4/9/17). Likewise, another student said, “All of the online stuff went smoothly. I never had problems with navigation ever and liked how it was arranged. I did not face any problems to collaborate classmates, either. For example, working on Google Docs helped me to comment on my friends’ posts and chat with them.” (Student 2, survey, 4/10/17).

An expectation for a textbook

An additional theme was to have a textbook in this course to guide the discussions. The materials were not enough to understand the ‘historical’ background of the maker movement as one student remarked:

“I think you could use either “Making Makers, Invent to Learn”, or “Free to Make” as a textbook to guide discussion and provide a historical context for this class. Web articles and blogs are nice, but I love these books and the research they bring to the table. All three are backed up by studies and journal articles and show why making in the classroom is so important. I know some people don’t like buying textbooks, but these are cheap, and anyone who wants to get involved in making should own them anyway” (Student 3, survey, 4/10/17).

Having a textbook for a 1-credit course would make a lot of pressure for PST. But, as a result of these feedback, it was decided to provide some chapters from a makerspace book for the following semesters.

Collaborative task

Another theme was related to the collaborative work they were involved in the course. Most of the PST were pleased to work on activities and assignments collaboratively using computers in online platforms. For example, a pre-service teacher stated “I really appreciate the collaborative assignments we did in class. I really liked how we build a Google Doc with makerspace tools. I can use this document when I start teaching if I need to build a makerspace for the school I work at” (Student 2, survey, 4/10/17). Another pre-service teacher stated “My favorite feature of this course was its making assignments transparent for other students in class by posting them on Canvas discussion platform. This allowed us to see how others are doing and learn from each other. I like collaborative learning” (Student 1, survey, 4/11/17). These feedbacks indicated that PST were pleased to work collaboratively in online environments.

Optional assignments

An additional theme standing out from the analysis of the survey data was to provide some optional assignments in addition to the required assignments. In relation to that, a student stated;

“One idea would be to keep what you have now as required assignments, but then have an optional assignment to check something out from the [technology unit] (such as a Sphero, LittleBits, Bee-Bots, etc.), play around with it, and write a reflection. This can be done collaboratively with other people in class. Fifteen minutes of exposure to the physical computing tools in the classroom is not nearly enough to actually learn what they are capable of” (Student 3, survey, 4/10/17).

Based on this feedback, a revision was planned to be made for the following semesters. It was also significant that this student emphasized the collaboration in her/his feedback.

Adding materials to the module

Another theme was to include information of the additional makerspace materials that are essential to be known. A PST stated her/his recommendation as follows, “Consider putting in a module about e-textiles and non-traditional circuit-building materials like conductive paint, copper tape, etc. I think there are a lot of directions you could go with that” (Student 3, written discussion, 4/10/17)

Discussion

The findings of this study have suggested that a one-credit/four-week makerspace course, specifically offered for PST enrolled in a technology program, may not be enough to investigate the perceptions of PST about a
makerspaces. Therefore, in order for PST to better learn makerspace technologies, teacher education programs could design and offer semester-long courses for not only students minoring but also PST majoring in all teacher education programs. Although Cress, Moskaliuk, and Jeong (2016) define Makerspace as “a rapidly emerging community that connects face-to-face collaboration around the design and creation of tangible products…” (p. 18), the findings of this makerspace course designed around CSCL framework recommend collaboration through computers in online platforms to strengthen the makerspace knowledge of PST. PST like to collaboratively produce tasks and assignments as Gaved, Jowers, Dallison, Elliott-Cirigottis, Rohead, & Craig (2016) found similar results in their study where design students of Open University were paired with maker learners at MAKlab. Team communicated through online platforms and collaboratively created design projects. The findings of Gaved et al. (2016) showed that learners “had gained insight into a range of processes, and the pilot showed potential as a model for future university-makerspace collaborations” (p. 1). Thus, in order to provide hands-on experiences for PST who are taking an online, blended, or face-to-face makerspace course, teacher education programs could open makerspaces. These makerspaces will give PST the chance to craft projects with laser cutters, make models with 3-D printers, assemble electronic circuits, and design and prototype with common materials like cardboard, rubber bands or Legos.

**Limitations & Recommendations**

While the results of this study were informative to redesign a makerspace course, several limitations emerged that require future investigation. Based on the results of this study and limitations, several recommendations could be made for further research to focus on similar studies.

One limitation of this study was related to the sample of the study. The number of the female participants (84%) outnumbered male participants (16%). According to enrollment statistics for elementary education and early childhood education program, this could be considered normal; however, this study can be replicated in a setting that has almost equal number of females and males.

As mentioned above, the context in which this study was conducted was comprised of elementary, early childhood education, and secondary education majors as well as other majors. However, the enrollment of PST from other majors (i.e. early childhood education, secondary education) in the present study is lower than the elementary education majors. Therefore, although the findings of the study may translate into different majors, the number of the PST participated in this study was low enough to generalize the results to elementary education, early childhood education and secondary education majors. Future studies could be designed with a number of participants and a wide range of majors to generalize findings to all PST.

Another limitation of the present study was its being context specific because this makerspace course is offered only for PST minoring in Learning Technologies. However, future research could replicate a similar study for all PST if they take a semester-long makerspace course.

Last but not least, CSCL was chosen as conceptual framework to guide this study; however, more research developing an appropriate conceptual framework to design a makerspace course is needed. Future research could utilize conceptual frameworks specifically focusing on creativity, making, tinkering, and designing. Moreover, future research should focus on developing a makerspace framework to guide similar studies.

**References**


Bridging STEM and the Civic Mission of Social Studies: Integrating Spatial Reasoning & Computational Thinking Into Decision-Focused Secondary Social Studies Instruction

Thomas Hammond, hammond@lehigh.edu
Julia Oltman, julie.oltman@lehigh.edu
Lehigh University
United States

Abstract: Social studies has faced a crisis of relevancy, particularly in the ascendance of perceived high-value fields such as STEM. Furthermore, secondary social studies has struggled to reconcile the disciplinary organization of social studies curriculum (history, geography, economics, and civics) with the central mission of social studies, citizenship preparation. We suggest a new framework for bridging both of these divides, adding value to both social studies and STEM education. From the social studies literature, we adopt Engle’s decision-focused approach to social studies education; from the emerging literature on STEM skills, we adopt spatial reasoning and computational thinking as highly relevant skills to social studies, and particularly a decision-focused approach. Illustrative examples are provided, and implications for teacher education are discussed.

Introduction

The field of social studies involves many discipline-specific ways of thinking and knowing: historical thinking, geospatial awareness, economic reasoning, and more. These disciplinary frameworks often overlap with other fields of study—historical thinking, for example, has much in common with literary textual skills, geospatial awareness is needed in earth sciences, civic thinking overlaps with language arts, and economic reasoning is, in essence, applied math. However, these connections are often difficult for social studies teachers to make salient and engaging for students. As a result, social studies can, from a student’s perspective, seem superfluous to the rest of their academic career and irrelevant to any professional pursuit other than academia (Thornton, 2017). Secondary social studies teachers also struggle with the boundary between social studies as a field (a unified but disparate collection of curricula, all aimed at citizenship preparation) and the specific social science discipline that a given course focuses upon (i.e., history, civics, economics, or geography). Consequently, social studies instruction can become disjointed—how does the curriculum of the geography class connect to the curriculum of a history class?—and fail to serve the central aim of the field, preparing citizens. These relationships and disjunctures are shown in Figure 1.

![Figure 1. Social studies, its component disciplines, their thinking skills, and connections with other fields.](image-url)
A second challenge faced by social studies in the 21st century is relevance, or rather a perception of irrelevance. Many students’ experience of learning social studies suggests that social studies is, as a curricular subject, entirely self-referential: one learns history topics to later reference them...in other history classes (Zhao & Hoge, 2005). Concepts and skills learned in a geography lesson may show up in other social studies classes but generally not in one’s math or language arts class. True, in an economics class students need some math, and in civics they often need persuasive writing/speaking skills, but these are in-bound transfers – the students bring other subjects into social studies; social studies is not (perceived) as having bearing on other subjects. As a result, social studies can feel hived off from the rest of a student’s program of studies, a vestigial organ within the body of school curriculum.

To address both of these challenges—the bridging of the field versus the discipline and the connection between social studies and the rest of the curriculum—we have devised an integrated strategy, reaching back to both core social studies principles and emerging areas of the STEM skill set. First, to connect the social studies curriculum to other content areas, we propose integrating two relevant STEM frameworks—computational thinking (Wing, 2006) and spatial reasoning (NRC, 2006)—into secondary social studies subjects. Both frameworks are pertinent to high-need college and career paths and are highly relevant to all social studies disciplines and beyond. (See Table 1 for a listing of relevant spatial reasoning and computational thinking concepts.)

Table 1

<table>
<thead>
<tr>
<th>Spatial Reasoning (per NRC, 2006)</th>
<th>Computational Thinking (from Wing, 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solving problems by “by managing, transforming, and analyzing [spatial] data” (p. 230)</td>
<td>Problem-solving strategies that integrate with computational tools</td>
</tr>
<tr>
<td>● Place &amp; location (data definition)</td>
<td>● Data definition</td>
</tr>
<tr>
<td>● Distance vs. proximity</td>
<td>● Decomposition</td>
</tr>
<tr>
<td>● Boundary &amp; containment</td>
<td>● Abstraction</td>
</tr>
<tr>
<td>● Density vs. dispersion</td>
<td>● Generalization</td>
</tr>
<tr>
<td>● Outlier vs. trend</td>
<td>● Algorithms (rules)</td>
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<td></td>
<td>● [Automation]</td>
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<td></td>
<td>● [Recursion]</td>
</tr>
<tr>
<td></td>
<td>● [De-bugging]</td>
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Note: Items in brackets [ ] are part of the domain but presumed irrelevant to social studies purposes.

Second, to reconcile the tension between the field and its disciplines, we suggest focusing on decision-making. According to social studies education pioneer Shirley Engle, decision-making is the “heart of social studies” and takes place “at two levels: at the level of deciding what a group of descriptive data means...[and] at the level of policy determination” (1960, p. 301). Computational thinking and spatial reasoning are clearly relevant at both levels of decision-making (data analysis and policy) and at all stages of the process: studying an issue, identifying salient information, conducting the analysis, communicating with others, and so forth. Figure 2 identifies the roles these two integrations play in resolving the challenges of the field.
To illustrate the problem and our solution in an authentic instructional context, consider the American Civil War. The Civil War is a central topic in any US History survey course, the most frequently taught course in the secondary social studies curriculum. A traditional instructional approach to this topic will focus on a political master narrative (Nullification Crisis, Fugitive Slave Act, Bleeding Kansas, and so on, up to the election of Lincoln) that transitions to a military narrative (Fort Sumter, First Manassas, and so on, up to Appomattox). Whether the teacher emphasizes a “great man” approach (Lee placing his loyalty to Virginia ahead of his oath to the Constitution, Lincoln’s struggles with his generals, the death of Stuart) or a trends-and-forces approach (relative economic, demographic, and diplomatic power of the north and south), the same narrative and chronology-intensive organization will take place. Unfortunately, this satisfying disciplinary approach will fail—it will neither serve the broader goals of the field of social studies (preparing citizens) nor will it allow students to make connections with other curricular areas beyond the social studies.

Our contrasting approach addresses both problems. Consider, for example, the maps displayed in Figure 3 (below) – the map on the left presents a fairly traditional (if thoroughly geo-referenced) approach to the military narrative of the war’s primary theater of operations. Students are presented with a list of campaigns, and presumably will be expected to recall the major battles on a test. The map on the right, however, presents the same data with a purposeful color scheme: early battles (1861-62) are green; later battles (1864-65) are red. The factional capital cities (Richmond for the Confederacy, Washington for the Union) are also emphasized. This map embodies and supports computational thinking (specifically decomposition, data representation, generalization/abstraction) and scaffolds students decision making (as data interpretation) via spatial reasoning: the later battles are in close proximity to Richmond, and the early battles are either in the vicinity of Washington, D.C. or along the emerging boundaries (West Virginia splitting from Virginia and the coastal regions of the Confederacy). By analyzing this map, students can observe these patterns and infer the structure of the military narrative in this theater of operations: early, thwarted attempts to capture Washington, D.C., the emerging geographic isolation of the Confederacy (splitting off West Virginia and cordonning the coast), and the grinding campaign to capture Richmond and end the war. By making thinking skills—specifically, computational thinking and spatial reasoning—part of the explicit instruction in the classroom, the teacher will simultaneously engage the students in the relevant social studies curricular content, enhance their thinking skills, and allow them to connect these skills to other parts of their academic and career work.
These maps are two visualizations of the same dataset, displayed in a geographic information system (GIS). GIS is a highly appropriate tool for both spatial reasoning, due to the data visualization capabilities, and computational thinking, thanks to its built-in toolset for sorting (via data definition), filtering (decomposition), and analysis and visualization capabilities (abstraction, generalization, algorithms, and more). Prior projects, such as the American Migrations project from the University of Illinois-Chicago (https://americanmigrations.uic.edu) or the book Mapping US History with GIS (Bunin & Esposito, 2014), have explored integrating geospatial tools into selected topics of the social studies curriculum, and they have provided some attention to spatial thinking. However, no current work provides both a robust connection to thinking skills (such as spatial reasoning and computational thinking) and an emphasis on decision-making as a curricular design feature.

We therefore propose a four-part instructional model for enhancing social studies education to connect it with its civic mission as well as highly-valued STEM thinking skills, all without compromising its attention to the information, skills, and dispositions valued within the disciplinary frameworks of secondary social studies.

1. Engaging, decision-focused social studies instruction in alignment with the existing curriculum;
2. Explicit instruction on both spatial reasoning and computational thinking, including the technologies that will be used during instruction;
3. Application of these thinking skills in the context of learning a curriculum-aligned social studies topic through the use of technology to examine and manipulate the relevant data; and
4. Guided note sheets and other learning materials that integrate the critical thinking skills and the social studies content, as well as scaffold the decision-making process and (if necessary) the technology use.

To briefly illustrate this model—or at least the first three elements—we offer a civics education example, this time driven by a different technology: a spreadsheet instead of GIS. The driving questions in this case are, What patterns exist in the party affiliations of LGBTQ members of the House of Representatives? How and why have these patterns changed over time? These questions point at the dynamic nature of civil rights in the United States, and particularly the role played by the two major parties as they shift their stances over time. The questions present a decision to the students, this time aiming at data interpretation. The questions align with existing curricula; for example, the National Council for the Social Studies’ C3 framework presents Civic standard D2.Civ.10.6-8: “Explain the relevance of personal interests and perspectives, civic virtues, and democratic principles when people address issues and problems in government and civil society” (2013, p. 33). The accessible data is a Wikipedia listing of LGBTQ House members (https://en.wikipedia.org/wiki/List_of_LGBT_members_of_the_United_States_Congress), which at the time of this writing lists 18 Representatives who were either out, outing, or posthumously identified as LGBTQ. To prepare students to address these questions, the teacher should address the relevant spatial reasoning and computational thinking components. In terms of spatial reasoning, the relevant concepts are density and dispersion: are the listed LGBTQ members of the House distributed in any particular spatial pattern? In this case, they are not—there is no concentration by state or region; they roughly map onto the population density of the United States, ranging from Massachusetts to Texas to California—the only potential outlier is Kyrsten Sinema of Arizona. The relevant computational thinking concepts are data definition and algorithm—what data are most relevant to the question, and what rules should guide our decision-making? The final step is data manipulation, in which students can use a
spreadsheet to sort and refine the data presented in Wikipedia. They will then observe that in terms of the data provided—years of service, district represented, and so forth—there is a sharp disparity in those members currently serving (six, all Democrats) and those previously serving (mixed Republicans and Democrats). Clearly, the algorithm for determining the distribution of Republican and Democratic Representatives needs to account for time. After sorting by time and by party, students will discover that the divergence in party affiliation comes in 1996. Prior to that year, the distribution of LGBTQ members of the House was roughly equal across parties (7 Republicans, 5 Democrats) and slightly over-represented among Republicans (considering that they were the minority party in the House from 1954-1994). Since 1996, only Democrats have elected new LGBTQ representatives to the House. The pivotal event in 1996 was the passage of the Defense of Marriage Act (DOMA). During these debates, Republican Steven Gunderson was outed by fellow caucus member Bob Dornan for opposing the bill, marking the divergence between the parties: Democrats were increasingly in support of LGBTQ rights while the Republicans are almost uniformly opposed. Through the application of computational thinking, students can come to recognize that the party affiliation of LGBTQ members follows two different algorithms: pre-DOMA and post-DOMA, with distinct policy differences between the parties in the post-DOMA era. This understanding allows students to understand the future policy directions of the parties (for or against LGBTQ rights) and monitor indicators of change, such as a future election of an LGBTQ Republican House member (which, once it comes to pass, either signals or confirms a policy shift).

Finally, to show a more iterative and open-ended approach to students’ decision-making, consider a final example, this time addressing the Great Depression. Within this time period, a salient topic is Franklin Delano Roosevelt’s communication pattern, particularly his Fireside Chats and other use of emerging media. A project at Lehigh University is in the process of mapping correspondence between citizens and the White House, looking at themes of citizen comment and response to the issues addressed by FDR. A first question is, What is the pattern in citizens’ communications with FDR’s White House? Looking at the contiguous United States (see Figure 4, below), we see that the distribution of correspondence with the White House (purple dots) correlates closely with the distribution of the population at that time (the underlying polygons). Clicking on any individual dot allows the student to see the metadata for the correspondence and to follow a link to a digitized version of the archival primary source (inset).

**Figure 4.** Map showing 1930 population density (polygons) and locations of correspondents with FDR (dots) plus a linked primary source—in this case, a telegram sent to FDR from Provincetown, Massachusetts.

Once we begin to apply computational thinking, we can explore patterns within the data and begin to unpack the embedded primary sources. For example, using the capabilities of the GIS, we can decompose the problem, focusing on a part instead of the whole. In this case, we will filter out only correspondence from Pennsylvania, an area that would be relevant to students in our region. Next, we will change the data definition, coding the correspondence by whether or not the person received a response (red = yes, blue = no). Finally, we will take advantage of the automation provided by GIS to change the level of abstraction: individual points are now clustered, with the size of dot determined by the number of correspondents. The resulting map of Pennsylvania (see Figure 5, below) shows that the major urban areas of Philadelphia and Pittsburgh had contrasting patterns. Philadelphia sent 205 pieces of correspondence to the White House, and the majority of these were answered; this is similar to the national pattern, in which about 60% of all correspondence received a reply from the White House. In contrast, Pittsburgh sent less correspondence to the White House (70 pieces) and the majority of these were not answered. At this point, thanks to the application of computational thinking and spatial reasoning, new questions emerge: Why did FDR respond to one group at a higher rate than the other? Another question that may surface is what is similar between Pittsburgh and...
Harrisburg? Both urban areas had a similar pattern of non-responses, in contrast to every other urban center in Pennsylvania (Philadelphia, Allentown, Erie, Scranton).

Figure 5. Map showing aggregated clusters of correspondence with FDR coded by whether the correspondent received a response (red = Yes, blue = No). The Philadelphia area sent 205 pieces of correspondence, most of which received a reply.

To explore these newly-formed questions, students will need to draw upon both their primary source analysis skills and their computational thinking skills, and they will find that these two bodies of knowledge reinforce one another. For example, the data definition stage of computational thinking maps perfectly onto contextual analysis of primary source heuristics (author, audience, purpose, etc.). As students integrate other datasets—perhaps there is a difference between Pittsburgh and Philadelphia’s political party affiliation? Economic cost or benefit relative to FDR’s New Deal policies?—they will draw upon their spatial reasoning. In the end, students exit this process with a much more sophisticated understanding of both the historical topic being studied (that is, FDR’s communications, politics, and policies during the Great Depression) and the process of historical investigation. Furthermore, by situating this inquiry within the far-reaching of frameworks of computational thinking and spatial reasoning, students’ work with these topics may translate outside the social studies classroom and become part of their work in other content areas and daily life.

Social studies teacher education can benefit from this approach. First, the focus on decision-making, whether at the data interpretation or policy level, links social studies to its core mission of citizenship preparation. Second, the integration of spatial reasoning and computational thinking skills link social studies to the STEM fields, providing a curricular home for explicit instruction in skills that are otherwise in the deep background of secondary curricula. In-service teachers can re-vitalize social studies with this approach, and pre-service teachers can enter the profession equipped to radically change the expectations of the social studies curriculum for students, colleagues, and community stakeholders.

References
Reconceptualizing Digital Citizenship Curricula: Designing a Critical and Justice-Oriented Digital Citizenship Course

Marie K. Heath, mkheath@loyola.edu
David Marcovitz, marco@loyola.edu
Education Specialties
Loyola University Maryland
United States

Abstract: Current conceptions of digital citizenship conflate character with citizenship, which re-inscribes historical exclusions and perpetuates normative values of citizenship. While scholars have challenged the prevailing definitions of digital citizenship and argue for integrating a more critical and justice-oriented approach to digital citizenship, we have seen little research on the ways that teacher education and masters programs might teach these more inclusive and activist aims of digital citizenship. In this chapter, we argue for a change in the ways that digital citizenship standards are taught to teachers. We suggest ways to develop new models of digital citizenship in teachers, and subsequently, in their students. This chapter, part of a larger study, examines the work within our program to rewrite our digital citizenship learning standards; to redesign our coursework around the standards; and to study the ways in which our candidates and their students learn and practice digital citizenship in their classrooms and lives.

Introduction

Current conceptions of digital citizenship conflate character with citizenship. That is, currently the field of educational technology portrays digital citizenship as a series of character traits emphasizing behaviors such as politeness, kindness, and responsibility. At first glance, asking young people—or really, all people—to be polite and responsible seems an admirable goal for a kinder society. However, dominant groups in society have historically called for “respectable behavior” and “civil discourse” as a means to silence voices from marginalized or racialized people. This re-inscribes historical exclusions and perpetuates normative, dominant, values of citizenship (Heath, 2018). Several scholars have challenged the prevailing definitions of digital citizenship and argue for integrating a more critical and justice-oriented approach to digital citizenship (Heath, 2018; Choi, 2016; Gleason & Von Gillern, 2017; Krutka & Carpenter, 2017). While this work provides a useful starting place for re-examining digital citizenship, we have seen little research which examines the actual practices of teachers who are working to develop digital citizenship. Moreover, we have seen no research on the ways that teacher education and masters programs might teach these more inclusive and activist aims of digital citizenship.

In this chapter, we argue for a change in the ways that digital citizenship standards are taught to teachers. We suggest ways to develop new models of digital citizenship in teachers, and subsequently, in their students. This chapter, part of a larger study, examines the work within our program to rewrite our digital citizenship learning standards; to redesign our coursework around the standards; and to study the ways in which our candidates and their students learn and practice digital citizenship in their classrooms and lives.

Literature Review
Westheimer (2015) proposed a thought experiment for effective citizenship instruction. He suggested that a person ought to be able to walk into a classroom in which students were learning about citizenship and determine in what type of governmental system the students lived. In other words, if a person were to happen into a citizenship lesson in Nazi Germany, that person might expect to find an emphasis on duty, respect, and obeying the laws. Moreover, the teacher would be the source of authority and power in the classroom, mirroring the dominant role of the state in citizens’ lives. The observer in the classroom would easily note the power dynamics and the lessons internalized by the students, preparing them to be dutiful, respectful, and uncritical of power and unaware of where to source information (outside of the established authority), in order to critique power.

However, if a person were to drop in on a citizenship lesson in a democracy, one would expect to see students engaged in vigorous deliberation, managing compromises, and working to ensure their community (be it the classroom, the school, and/or their neighborhoods) included all peoples and worked to benefit the greater good of all. In addition, the students would share governance with the teacher. Students would craft a class constitution outlining the general operations of the classroom and would be critically engaged in developing curricula for the classroom. It would be obvious to the observer that these students were preparing to be active, engaged, and critical citizens in a democracy. Westheimer (2015) suggested that if one cannot correctly determine the type of government which the citizenship lesson is meant to sustain, then the citizenship lesson has failed.

Consider this thought experiment within the context of digital citizenship. Do our current definitions (and attendant pedagogies) for digital citizenship support the continuation of our democracies? Is it self-evident, when we teach digital citizenship, that we live in a democratic republic? In this literature review, we explore the prevailing definitions and pedagogies for digital citizenship in the P-12 schools in democracies. Then we examine proposed directions emerging from critical bodies of literature. Finally, we consider how the current practices and scholarship position our study to influence policy, teaching, and research on digital citizenship.

The International Society for Technology in Education (ISTE) provides standards for effective technology integration, including standards for digital citizenship. Every state in the United States, and many countries across the globe, use ISTE standards to create curriculum development and technology integration in P-12 schools (International Society for Technology in Education [ISTE], 2018, ISTE Standards FAQ). ISTE’s standard for digital citizenship reads, “Educators inspire students to positively contribute to and responsibly participate in the digital world” (ISTE, 2017).

ISTE added some interpretation to this statement in several blog posts in 2017 (e.g., International Society for Technology in Education, October 12, 2017, and Stoeckl, 2017), advocating that digital citizenship should move beyond the protective to the proactive, and should encourage student participation, not just a list of rules and regulations. While this move toward a more participatory conception of digital citizenship is welcome, it lags behind scholarship surrounding digital citizenship in a democracy and the broader understandings of citizenship education in P-12 schooling. Moreover, we found little research which examines actual practices of teachers within schools.

Although ISTE remains the dominant force in technology integration and interpretations of digital citizenship, educational technologists and scholars within the field of citizenship have proposed other conceptualizations. Choi (2016) provided a concise overview of the historic paradigms of citizenship and outlined challenges to current conceptualizations of citizenship—including challenges of migration, globalization, and rising populism. She used a content analysis methodology in order to develop a model of the components of digital citizenship. The model proposes four categories of digital citizenship: ethics, media and information literacy, participation/engagement, and critical resistance. This suggests that digital citizenship is dynamic, multi-layered, and not wholly different from citizenship outside the digital realm. Heath (2018) took a firmly critical stance when incorporating Choi’s work into their study, proposing that digital citizenship which failed to address inequity fails our students and communities in ensuring justice for all in a democracy.

Another proposal for a new form of citizenship comes from Jenkins and colleagues (2009, 2016) who argued that the participatory nature of the internet provides opportunities for new forms of engagement. New online communities create space for young people to develop a sense of identity and mattering—what Duhlgren (2003) refers to as pre-conditions for citizenship—while allowing for opportunities to enact citizenship through deliberation and participation (Jenkins et al., 2009). Bennet (2008) suggested that online spaces create opportunities for young people to practice active citizenship, perhaps in new and non-traditional forms, that could re-invigorate our democracies. Krutka and Carpenter (2017) proposed applying Westheimer and Kahne’s (2004) framework for citizenship education to digital citizenship education. That is, Krutka and Carpenter (2017) suggested pedagogies for digital citizenship which align to participatory or justice-oriented definitions of digital citizenship, including critically examining who benefits from social media platforms and teaching children to read “laterally” across tabs in order to source information.
ISTE has also attempted to provide pedagogical direction for their more proactive and engaged redefinition of digital citizenship. They suggest embedding digital citizenship in all lessons (Marrs, 2018), instead of making it a stand-alone activity. Mattson (2017) published a book through ISTE that offers different examples of lessons and activities for developing more participatory citizenship. Some suggestions include showing examples of other young people making a difference online and examining whether slacktivism (i.e. liking or re-tweeting political social media posts) is a form of activism.

Other organizations have also developed pedagogies and practices for teaching participatory and justice-oriented approaches to digital citizenship. eTwinning, an organization in Europe which leverages the power of the internet to develop a sense of community across Europe, provided a comprehensive list of their pedagogical practices which allowed students to critically examine issues related to values, peace, democracy and civic engagement, migration, and the environment, in order to develop digital citizenship. Jenkins’ (2016) book included examples of participatory practices which resulted in activism. In cooperation with the Youth and Participatory Politics Research Network, funded by the MacArthur Foundation, Jenkins designed the Digital Civics Toolkit, meant to move young people from online participation to online and offline action.

We find it heartening to see ISTE moving toward a more participatory approach (although we note that it is still not a more critical or justice-oriented approach) to digital citizenship. We also find it encouraging to see the examples provided by Cassells and colleagues’ (2016) work with eTwinning. However, we note that there remains a significant gap in understanding daily practice in P-12 classrooms, with respect to digital citizenship education. From our own perspectives, as educators in a Masters of Education program in Educational Technology, we notice that our students rarely enter (or, for that matter, leave) the program with rich and critical conceptions of the definition of digital citizenship, nor do they necessarily leave with pedagogy and practices with which they can teach active, engaged, and justice-oriented critical citizenship.

To that end, we realized that we have several tasks before us. First, we need to determine what the current state of practice is with respect to digital citizenship. How do teachers currently define digital citizenship, and what are they doing to teach for it? Concurrently, we need to engage in some programmatic redesign, if we hope to develop active digital citizenship in our students and in their students. Finally, we wonder about the efficacy of the redesign and pedagogical practices. Does the new emphasis on active and engaged digital citizenship lead to a change in teachers’ pedagogies and in their students’ digital citizenship?

Theoretical Framework

We intentionally chose a framework that moves beyond ISTE’s definition of digital citizenship, because we found their definition still emphasizes the problematic notion that good citizens are well behaved citizens. Instead, we framed our study and our understanding of citizenship using Choi’s (2016) digital citizenship model which identified four categories of digital citizenship: ethics, media and information literacy, participation/engagement, and critical resistance. The first category, ethics, concerns itself with ethical uses of technology, digital awareness, and digital rights and responsibilities. The next category, media and information literacy, addresses issues of digital access, technical skills, and psychological capability. The category of participation and engagement includes notions of political, economic, and cultural engagement, as well as personal participation. Finally, the category of critical resistance encourages political action and critique of existing power structures.

It is important to note that Choi (2016) does not frame the model as a continuum of expertise nor as stages of citizenship development. Instead, each of the four components is integral to the whole, and all are part of digital citizenship. This implies that all parts of the model should be taught and included in curricular design. Choi’s (2016) model provides a framework for what digital citizenship is; however, it does not necessarily offer pedagogies for how to teach digital citizenship.

To address the need for pedagogical grounding, we overlay pedagogical practices onto Choi (2016) in order to examine teaching for digital citizenship. That is, we use Westheimer and Kahne’s (2004) evaluation of citizenship education in order to analyze our own pedagogies for digital citizenship. Westheimer and Kahne (2004) argued that three types of citizenship education existed in US schools. The first, personally responsible citizenship, is the most frequently taught in schools. In these civics education programs, students are taught to be respectful and dutiful citizens who obey laws and follow the mores of the government. The other two types of citizenship education, participatory citizenship and justice-oriented citizenship are rarer in schools. Both of these forms of citizenship help teach skills and dispositions required for the continuation of democracy. Participatory citizenship teaches students to become involved and engaged citizens in order to solve social problems, while justice-oriented citizenship pedagogies help students explore and take an active stance in solving systemic inequalities and addressing inherently unjust social structures.
Methods for Course Redesign

We used the definition of digital citizenship from Choi (2016) and the pedagogical imperatives from Westheimer and Kahne (2004), to examine current practices of digital citizenship in the field, to re-design our own program in order to more effectively teach digital citizenship, and finally, to evaluate the results of our programmatic changes. In a separate and forthcoming paper, we explore the current state of the field. In this chapter, we examine our own program and the programmatic redesign which emphasizes a nuanced and critical understanding of digital citizenship.

Specifically, we examined our program standards, courses, syllabi, and teaching practices. We analyzed this data through the lens of our theoretical framework in order to determine gaps in our program with respect to digital citizenship. We present and examine these gaps in the findings section of the chapter. After identifying the gaps, we re-designed a major assignment in order to emphasize connections between justice-oriented digital citizenship, global education, digital literacy, and Professional Learning Networks (PLNs). We also are redesigning a course in order to focus on digital citizenship and ethics. In the discussion section, we review our findings and discuss the challenges and goals for our new curricula.

Findings

As a faculty, we reviewed our syllabi and key assessments in order to investigate the ways that we taught for and about digital citizenship. It became clear that we did not explicitly address issues of engagement, activism, and justice with respect to digital citizenship. As a program faculty, we agreed that our current conceptualizations of digital citizenship failed to teach how to critically engage with participatory practices in media and technology. We decided to address this issue with some macro- and micro-level changes. On a macro-level, we examined our programmatic standards, goals, and key concepts in order to add a justice-oriented approach to digital citizenship into the structure of our program. This also allowed us to redesign a course in order to better address the new standards. At the micro-level, we began to make changes in our individual syllabi and assignments. In this section, we explore the ways our program made these changes.

Key Concepts

In our masters program, we have developed a set of key concepts (Marcovitz, 2016) that include seventeen key concepts expanded on by thirty-two learning objectives. ISTE Coaching Standards (https://www.iste.org/standards/for-coaches), which had governed our program for accreditation purposes, similarly include six standards with twenty-eight sub-standards. Each of these learning objectives/sub-standards can be unpacked even further (and are within individual courses). Of the three sub-standards for Digital Citizenship, the one most relevant to this chapter is Standard 5.c.: “Model and promote diversity, cultural understanding and global awareness by using digital age communication and collaboration tools to interact locally and globally with students, peers, parents and the larger community.” This is an example of where ISTE’s conception of digital citizenship moves from “personally responsible citizenship” to “participatory citizenship” (Westheimer & Kahne, 2004).

One could imagine fulfilling this sub-standard in a variety of ways, but given that it is one of twenty-eight (and does not even approach “justice-oriented citizenship”), it is unlikely to be the sole focus of an entire course. That tends to lead to the ideas of low-hanging fruit, the 80-20 rule, and checking boxes, not out of a desire to short-change this subject but out of a limited amount of time in the curriculum. It is easiest to teach a few basic concepts (the low-hanging fruit) and simply mention the more difficult concepts, expecting that candidates in our program will see the concepts but probably rarely put them into practice. For example, they will coach other teachers in the basics of being compliant citizens of good character, occasionally in engaging as active participants, but rarely, if ever, in advocating for social justice.

This leads to the question: with so much that goes into teacher education, professional development, and graduate education, how can we make sure that we reach the most important ends and not get stuck reviewing the basics? And how can we do this without denying the importance of the basics? This problem is compounded by the wide range of candidates that enter a master’s program in educational technology.
While the vast majority of our candidates are teachers, they teach at a wide range of grade levels and subject areas and have different levels of understanding of technology, pedagogy, digital literacy, and digital citizenship. With such a wide range of understandings, an approach that starts with the basics and gets, perhaps, 80% through what is important seems to be a reasonable approach. However, as Marcovitz & Janiszewski (2016) suggest in elucidating the key-concepts model to program development, we need to focus on what we think are concepts that graduates of programs must know, or to put it another way, would we be mad if they graduated our program and did not know these certain things.

New Course Emphasizing Social Justice

After reviewing and editing our key concepts, we began to re-align our courses with the new key concepts. One course in particular struck as as ripe for redesign. The course, formerly titled Creativity, Problem Solving, and Educational Change focused on theories of creativity and the change process. Students in our M.Ed. in Curriculum and Instruction (C&I) for Social Justice and students enrolled in our M.Ed. in Educational Technology both took the course. However, it did not fully address the needs of the C&I program, nor did it address the Educational Technology program’s new emphasis on justice-oriented digital citizenship.

A team of faculty is currently rewriting the goals and key assignments for the course. The most significant change is an emphasis on activism and social change. In particular, the students will engage in a “Social Change Project.” The assignment asks students (in-service teachers) to implement a social change through either Participatory or Justice Oriented citizenship. This social change can be conducted through various mediums and it will be up to the instructor and student to explore the various opportunities that the student could use. In this social change, the student should correctly identify the type of citizenship that is being implemented (Participatory or Justice Oriented) and create the necessary materials to implement this change. They should also have started the implementation of this change based on the action steps identified in their Reflection Journal and Project.

Changes in ET630

One of the original courses in the M.Ed. program in Educational Technology at our institution is ET630. Originally (in 1998), it was named Telecommunications in the Classroom, focusing on Web design and telecollaborative projects (see, for example, Harris, 1998). Over the years, it has transformed into Digital Communication in Education, decreasing the emphasis on the skill-based topic of Web design, continuing connecting classrooms with telecollaborative projects, and adding a substantive unit on information literacy. The content of this version of the course is well documented in Marcovitz (2012). As we examined the need for a robust emphasis on digital citizenship, information literacy was retained, telecollaborative projects were expanded to global education (see, for example, Peters, 2009, and Lindsay, 2016), an emphasis was placed on professional learning networks (PLNs), and a new topic of digital citizenship was introduced, framed by Heath (2018) and Choi (2016). Figure 1 shows the conceptual map for the new version of the course.
The question remains: What is the pedagogy that can build a complete praxis of digital citizenship in teachers and in students? By “praxis,” we use the term in the way that Freire (2018) uses it: “reflection and action upon the world in order to transform it” (p. 51). Praxis, in general, is difficult to achieve, and this course is still a work in progress. The emphasis on PLNs supports a number of needs within educational technology and the teaching profession generally, but in this case, the recognition that praxis and democratic citizenship must encompass dialogue with others makes the PLN emphasis even more important. The continued emphasis on digital/information literacy connects nicely with Choi’s (2016) conception of media and information literacy, going beyond simply looking to accept “good” digital information and reject “bad” moving to a concept of building a “domain of knowledge” (Marcovitz, 2012, p. 21) to critically analyze a wide range of viewpoints around a subject. Global education started as a practical way to take advantage of resources (including other classrooms) beyond the walls of the classroom. In the context of digital citizenship, it becomes an imperative to expose teachers and students to different ideas and perspectives.

Finally, digital citizenship, itself, emphasizes the need to encompass the full power of Heath (2018) and Westheimer and Kahne’s (2004) model in which students and teachers learn basic skills of personally responsible citizenship while also becoming participant citizens and participating in a justice-oriented way. The challenge is to work with teachers to help them explore ways to make their classrooms more democratic, recognizing differences among classrooms, not the least of which is that the teachers in our program teach in different grade levels (from K to 12) and different subject areas. Providing a theoretical foundation in digital citizenship, we will explore different ways that different classrooms can incorporate all these concepts. The rest will be dialogue, helping teachers to see what is possible to incorporate democratic ideals of citizenship in their own classrooms.

**Discussion**

It is easy enough to frame the concept of digital citizenship in a way that the concept of “personally-responsible citizenship” is enough or to push into “participatory citizenship.” This can be done with fairly small
changes to any program. That is where the 80-20 rule comes in. If “personally-responsible citizenship” and “participatory citizenship” are 80% of what is needed, that can be done with 20% of the effort.

What we need, however, is to take seriously more advanced concepts of “participatory citizenship” and move toward “justice-oriented citizenship.” Simply framing the problem as a multi-step problem, knowing that we will only get to the first one or two steps almost certainly conceives the battle. If “justice-oriented citizenship” is truly to be one of our key concepts, we must start with being mad that (many of) our candidates never get there, leaving teachers in their schools and their students without any background in key concepts of democracy.

Moving forward, we plan to continue to turn the curriculum on its head and not view digital citizenship as a 3-step process, with responsible citizenship as a prerequisite for active citizenship and participatory citizenship as a prerequisite to justice-oriented citizenship. Instead, we must view them as corequisites, reinforcing each other, with none coming before the other but all happening at the same time. If we do not, we are stuck teaching responsible citizenship over and over again and only hoping to do better. We will continue to review our standards and align our courses and key assessments with our more justice-oriented standards.

Implications for Research and Practice

Further, we are interested in understanding how these revisions impact our students. Specifically, we are curious to find whether our shift in teaching leads to a shift in their conceptualizations of digital citizenship. We also wonder whether there might be a more nuanced shift in our students’ beliefs about justice, social justice, activism, and technology. Certainly, this is one of our aims, and we plan future research that investigates if and how our program might shift beliefs and behaviors. However, to understand if beliefs and practices change, we first must understand the current state of the field with respect to digital citizenship. We plan to investigate how teachers currently define and teach digital citizenship in their P-12 classrooms, so that we may better understand any changes that might occur in their practice. Finally, our ultimate goal is to change the way that P-12 students enact digital citizenship.

We also recognize that changes in our own program have limited influence on P-12 practice. In order to enact broader change, we challenge the societies and consortia that influence and set standards for digital practice in the P-12 communities (e.g. ISTE, Common Sense Media, SITE) to emphasize justice-oriented digital citizenship. While ISTE has begun to speak to the participatory nature of engaged citizenship, we challenge ISTE and others to consider participation as activism and social justice, both of which, we would argue, are necessary to the expansion and preservation of our democratic republic.

In this chapter, we have begun to outline some ways that we can achieve personally-responsible and participatory citizenship without sacrificing justice-oriented citizenship. But moreso, this chapter serves as a call to researchers to find ways to achieve this important goal in new and creative ways to help teachers learn to work with students in important action that furthers democratic ideals, rather than merely re-inscribing historical exclusions and perpetuating normative values of citizenship.

References


Introducing Digital Citizenship to High School Teachers
Using Activities with Information Technologies

Stephen T. Adams
Educational Technology and Media Leadership, College of Education
California State University, Long Beach, USA
stephen.adams@csulb.edu

Lesley S. J. Farmer
Educational Technology and Media Leadership, College of Education
California State University, Long Beach, USA
lesley.farmer@csulb.edu

Fabian Rojas Ramírez
Educational Leadership
California State University, Long Beach, USA
Centro de Investigación y Docencia en Educación
Universidad Nacional, Costa Rica
fabian.rojas.ramirez@una.ac.cr

Abstract: Digital citizenship is a multi-faceted topic that involves the responsible use of technology in a community. This chapter reviews goals and strategies for teaching digital citizenship to teachers, and it presents a study of in-service high school teachers’ video discussions about the topic as part of a graduate course. The study investigates the question, “Which aspects of digital citizenship are of greatest interest to teachers for use in their teaching as evidenced by their video discussions?” An analysis of 17 teachers’ video posts used Ribble’s (2015) nine elements of digital citizenship as a framework. Teachers most frequently expressed interest in aspects of digital citizenship related to security, literacy, and etiquette, and emphasized the importance of these topics to their teaching.

Introduction

Digital citizenship may be defined as the ability to use technology safely, responsibly, critically, productively, and civically. The overarching goal is effective and responsible personal and social engagement with digital resources. While some of the motive is protection and safety, which has resulted in required filtering software and acceptable use policies, there is also a more proactive aspect, for learners to contribute meaningfully to the digital society.

Digital citizenship has roots in work by Weiner (1950), who wrote the first treatise on computer ethics, targeted to computer scientists and philosophers. In the 1980s, with the growth of the Internet and expanded access to it, the need for computer ethics was identified as a public concern (Ess, 2009). Technological advances created new challenges, such as ready access to online pornography, software piracy, and cyberbullying. Being able to respond to such issues is part of digital citizenship, but the topic is broader and multifaceted (Mossberger, Tolbert, & McNeal, 2007).

Digital citizenship is an important topic for teacher educators, and studies of teachers’ responses to the topic are useful to guide efforts to support teacher professional development in this area. This chapter reports on a study of teacher perceptions of digital citizenship that is rooted in a model of digital citizenship proposed by Ribble (2015). As context for the study, we first describe Ribble’s model, and then describe previous work related to teachers and digital citizenship. This includes discussing recommendations for teachers about digital citizenship and previous research regarding teacher perceptions of this topic.
Digital Citizenship Model

The most well-known digital citizenship model was developed by Ribble (2015). He articulated nine elements of digital citizenship, which can be grouped into three umbrella categories, listed below.

- **Category 1. Respect**: Digital access, digital commerce, and digital communication. The items in this category concern promoting equitable access to technology, issues in buying and selling goods online, and online communication, respectively. They involve respecting others in these areas.

- **Category 2. Educate and Connect**: Digital literacy, digital etiquette, and digital law. The items in this category concern learning how to use technology, standards of conduct, and legal implications of technology use, respectively. They involve becoming educated about technology use.

- **Category 3. Protect**: Digital rights / responsibilities, digital health / wellness, and digital security. The items in this category concern rights and responsibilities in a digital world, personal physical and psychological health, and personal safety, respectively. They involve protecting the health of oneself or others.

A proactive aspect of digital citizenship that pertains to using technology to be citizens in a digital community was articulated by Giroux (2005), who asserted that education offers tools for the systematic critique of power and social contexts, and language for creating democratic change in public spaces. Thus, while some aspects of digital citizenship concern protection and avoiding harm, other aspects are proactive and concern civic participation. Along these lines, Handal, Lynch, Watson, Maher, and Hellyer (2016) echoed Giroux, stating that digital literacy helps individuals have a voice about governmental issues, which comes with both rights and responsibilities. Although youth may feel comfortable using technology for entertainment or communicating with friends, such social and recreational uses are negatively related to civic engagement (Kirk & Schill, 2011). Furthermore, youth often do not have academic technical and critical thinking skills or know how to express themselves effectively online in public discourse (Rheingold, 2012).

Teachers and Digital Citizenship: Standards and Recommendations

For youth to understand digital citizenship, it is imperative that teachers are well-grounded in this topic and its many aspects. In the United States, several of the Common Core State Standards (CCSS) support the need for digital citizenship across the curriculum. The CCSS directly support the topic in their advocacy for students to use technology and digital media strategically and capably. They also indirectly support digital citizenship, advocating skills such as responding to the varying demands of audience, task, purpose, and discipline; comprehending and critiquing; valuing evidence; and understanding other perspectives and cultures (Common Core State Standards Initiative, 2010).

Researchers and teacher educators have also articulated the need for teachers to become versed in digital citizenship (Almoosa, 2018; Gleason & von Gillern, 2018; Karal & Bakir, 2016; Kirk & Schill, D, 2011; Sutton, Sutton, & Plants, 2012). The work of Handal et al (2016) states curriculum that is useful for teacher educators should include knowledge, skills, and attitudes. This includes:

- effective societal and global online participation,
- capacities for respecting and protecting themselves and others online,
- compliance with digital-based intellectual property rights, and
- awareness of strategies and resources for teaching digital citizenship.

Pescetta (2011) traced the development of a research-based digital citizenship guide for teachers in international boarding schools. The guide identified competency-based curricula needed by teachers to help students learn how to become good digital citizens. Topics included...
digital communication: rights and responsibilities, netiquette, copyright;
role of culture in using technology at a global academy: usage contracts, cyberbullying;
digital safety, security, and privacy; and
technology wellness and ergonomics.

The need for teachers to be familiar with digital citizenship is recognized by the International Society for Technology in Education (ISTE), whose standards recommend that educators “inspire students to positively contribute to and responsibly participate in the digital world” (ISTA, 2017, “Citizen,” para. 1). ISTE recommends that educators should be able to:

- create experiences for learners to make positive, socially responsible contributions and exhibit empathetic behavior online that build relationships and community.
- establish a learning culture that promotes curiosity and critical examination of online resources and fosters digital literacy and media fluency.
- mentor students in safe, legal and ethical practices with digital tools and the protection of intellectual rights and property.
- model and promote management of personal data and digital identity and protect student data privacy. (ISTA, 2017, “Citizen,” para. 2)

To teach about digital citizenship, teachers can employ a variety of instructional strategies, as illustrated by the following examples:

- Teaching students awareness of digital citizenship issues, engaging students in digital citizenship case studies, having students manipulate information, and giving them opportunities to apply digital citizenship knowledge.
- Creating a safe place for students to share experiences and fears (e.g., cyberbullying).
- Creating an intranet as a kind of walled “garden” for students to explore social media.
- Teaching students what is safe to share online, and what should be private.
- Role-playing digital citizenship behaviors.

In addition, students can make socially proactive digital contributions, for example by: finding a community agency for which they can make web pages, participating in political websites that solicit youth voices, using online tools to address a local community issue, and composing songs about social issues and uploading them online. A compilation of resources about digital citizenship is available under the tab for “civic engagement” of the resource guide at https://tinyurl.com/fakenewsslibguide.

Research studies have also provided useful information about teachers’ views of digital citizenship. Cristol, Choi, and Gimbert (2016) surveyed teachers’ perceptions about digital citizenship, and found significant differences depending on the teachers’ years of work experience, grade level, purpose of Internet usage, and type of digital media sources used to find information. In surveying teachers about their perceptions of digital citizenship, Hollandsworth, Donovan and Welch (2017) found that most teachers were aware or somewhat aware of digital citizenship to about the same extent as reported in a prior parallel survey administered by the researchers (Hollandsworth, Dowdy, & Donovan, 2011). Teachers tended to focus on respectful online behavior, often in response to fears of cyberbullying. Styron, Bonner, Styron, Bridgeforth, and Martin (2016) surveyed teachers about their knowledge of cyberbullying. The researchers discovered that respondents knew about cyberbullying but did not feel prepared to deal with it, nor did they realize the extent that cyberbullying was practiced by their students. Thus, the researchers strongly recommended teacher training about this issue as well as including the topic in general technology training awareness of students’ online behaviors. In these previous studies, key themes regarding digital citizenship included respect for others and avoiding harm. In the present work, we sought to better understand which aspects of digital citizenship were of most interest to teachers.

**Study of Teacher Discussions**
This study pertains to a group of in-service teachers who had been introduced to digital citizenship in a graduate technology course. It addresses the question: “As evidenced by video discussions, which aspects of digital citizenship are of greatest interest to teachers for use in their teaching?” using content analyses of teachers’ video discussions.

**Methods**

In Spring 2017, 18 practicing teachers took an educational technology course as part of a Master's degree program in Curriculum and Instruction at a university in the United States. Of these, 17 agreed to participate in the study per an approved IRB protocol; 14 were women and three were men. All participants had bachelor’s degrees and high school teaching credentials. Their subjects taught included art, business, English, history and social science, Spanish, computer science, mathematics, and science. Their prior teaching experience averaged 8 years, ranging from two to 16 years.

Over the course of three weeks, teachers reviewed a module on digital citizenship. The module included a variety of educational resources including an online unit about digital citizenship by one of the authors (Farmer, 2011) and a website on digital citizenship (Common Sense, n.d.). These web resources provided a broad introduction to the topic of digital citizenship. Further assignments engaged teachers with this material. In one assignment, they developed podcasts on digital citizenship for use in their teaching; these were concise introductions to the topic in the form of an audio file of under three minutes. This assignment served as a way for teachers to synthesize the material and translate it to practical application in their own classrooms. Having teachers create podcasts may potentially help foster a personal connection to the material for the teachers creating them (Forbes, Khoo, & Johnson, 2012) and for their students listening to them (Kay, 2012). An example of such a teacher-created podcast, used with permission by its author Gloria Mayorga, is available at: https://tinyurl.com/dcpodcast5.

In another assignment, teachers used Flipgrid (http://www.flipgrid.com), a tool that creates a kind of electronic discussion board using video segments. Teachers created videos of about 1½ minutes each describing their views of digital citizenship, and then created one or more additional videos to reply to peers. This assignment asked teachers to respond to a prompt to discuss aspects of digital citizenship that seemed most important and pertinent to their teaching. For purposes of the study, the content of teachers’ posts provided an indicator of their perception of important aspects of topics. For instructional purposes, the use of video discussion boards was considered to offer potential advantages compared to text-based discussion boards, especially for a values-laden topic like digital citizenship, in that they capture facial expressions and tone of voice (Mahmoudi, & Gronseth, 2019). The Flipgrid assignment also gave teachers experience using a tool they could use in their own classrooms with their students. An example of a teacher video post, used with permission by its author, is available at: https://tinyurl.com/dcflipgrid6.

The analysis focused on teachers’ Flipgrid discussions. These were transcribed, and using Dedoose software, a content analysis of the Flipgrid posts was conducted using a priori categories based on Ribble’s nine aspects of digital citizenship as a framework. The transcripts were segmented into groupings of multiple sentences expressing a view about digital citizenship. Altogether, 58 segments were identified. Next, these units were coded according to which of Ribble’s nine categories of digital citizenship was being discussed. An initial coding was conducted by one author. Next, two authors reviewed the codes and resolved any differences by consensus.

It is anticipated that the instructional activities influenced teachers’ responses. The purpose of the study was not to investigate teachers’ responses in the absence of such instruction. Instead, it was to investigate their responses after having a general introduction to digital citizenship via the unit.

**Results**

All 58 segments were coded as belonging to at least one category and six were coded as belonging to two categories. Hence, altogether, 58 + 6 = 64 codes were made. In addition, Ribble’s nine categories were grouped into the three “umbrella” categories discussed earlier. Comments related to the category of “Security” were the most frequent, representing 30% of teachers’ comments. An example in this category is listed below:
So one of the things that strikes me as especially important and pertinent is the idea of internet security. So creating strong passwords and making sure that you actually log out of your accounts fully before letting someone else use the computer, that kind of stuff. Because that happens all the time in my classrooms, even if it's not on a computer science class, even my math class, when I see them, they let each other use each other's phones that are already still logged into stuff. So having that conversation, we’ve already have some situations at my school where students have sent other people messages on other people's accounts and stuff like that. I feel like that's one of the big issues right now that needs to be addressed in all of our classrooms.

The second most frequently referred to category pertains to literacy, which was mentioned in 23% of teachers’ comments. An example of a teacher comment in this category is listed below:

What seems especially important to me, is the student's ability to apply what I call the crap test to anything online, really any resource that they're using to decide what truth is, which is why I love <a classmate’s> unit in her senior class right now. The CRAPP Test, is it current? Is it relevant? Is there authority involved? Can you actually trust the people who are publishing it? And there's a little bit more involved in that, but I feel like a lot of them have this misconception that, if it's online, it's true, and that's leading to a lot of the social and political issues that we're seeing today. Teaching them analytical skills and the ability to determine whether or not a source is valid and worth making part of their own personal truth seems highly important to me, especially in today's day of age.

The third most frequently referred to category pertained to etiquette, and had 20% of the codes. An example of a teacher comment related to etiquette is listed below:

So digital citizenship is an extremely important topic to cover with our students for a multitude of reasons. Most importantly, it really reinforces what is appropriate behavior when online, and not just online but overall since we're talking digital citizenship. Online behavior is something that's new to a lot of people especially us adults.

Regardless of the aspect of digital citizenship teachers mentioned, these examples highlight teacher perceptions that digital citizenship is highly important to their teaching. There was only one of Ribble’s nine categories that no teachers mentioned as especially important to them: that of commerce, related to buying and selling goods online. The remaining five categories each had 2% to 8% of the codes. A breakdown of the results is shown below (Table 1), and it is organized into three “umbrella” categories of digital citizenship discussed earlier. Overall, the umbrella category most frequently discussed pertained to “Protect,” with 45% of the codes; the other two umbrella categories had 27% and 28% of the codes. Note that the percentages are rounded to the nearest whole number.

Table 1

<table>
<thead>
<tr>
<th>Category</th>
<th>Protect</th>
<th>Educate/Connect</th>
<th>Respect</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Subcategory</td>
<td>n</td>
</tr>
<tr>
<td>Rights and Responsibilities</td>
<td>5</td>
<td>8%</td>
<td>Literacy</td>
</tr>
<tr>
<td>Security</td>
<td>1</td>
<td>9</td>
<td>Communicatio n</td>
</tr>
<tr>
<td>Health and Wellness</td>
<td>5</td>
<td>8%</td>
<td>Commerce</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>8</td>
<td>%</td>
</tr>
</tbody>
</table>

Note: “n” = number of teacher comments pertaining to a category of digital citizenship. The total number of codes was 64.
Discussion and Implications

Digital citizenship is a multifaceted topic that is timely for teachers and their students. The study we report of teachers’ discussions with Flipgrid serves as an indicator of the aspects of digital citizenship that teachers found most salient for their teaching. Of Ribble’s nine categories of digital citizenship, the categories that were most frequently referenced in teachers’ discussions were matters pertaining to security, literacy, and etiquette, with 30%, 23%, and 20% of the coded comments, respectively. Of the three “umbrella” categories of digital citizenship described, the one most frequently discussed concerned the category “Protect.” In other words, teachers were most interested in aspects of digital citizenship that related to protecting their students from harm. In this way, teachers’ interests aligned with emphases related to avoiding harm that have been emphasized by the prior studies discussed earlier (Hollandsworth, Donovan, & Welch, 2017; Hollandsworth, Dowdy, & Donovan, 2011; Styron et al., 2016).

Further, comments from in-service teachers indicate they view digital citizenship as an important topic to their teaching. These data are limited to a single course and are not necessarily representative of all teachers. The instructional module served to provide students a base of information about digital citizenship, but the study was not intended as an evaluation of instruction per se. The comments are an example of teacher responses after material in a graduate course concerning digital citizenship, and could be expected to be influenced by course materials and by comments of other teachers. Even so, they provide an indicator that could be explored further in subsequent research: that teachers may more readily take interest in aspects of digital citizenship if it is related to avoiding harm. Further research could also systematically explore teachers’ reasons for their interests in different facets of digital citizenship. Further research could also investigate teacher outcomes related to specific educational strategies, including strategies like the ones we describe that use technology. Clearly, supporting teachers in helping their students avoid harm is an important topic for their professional development. We also recommend particular efforts to stimulate teachers’ interests in proactive aspects of digital citizenship involving civic participation.

References


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Pre-service Teachers’ Technological Self-Efficacy – an Irish Perspective

Alison Egan
Marino Institute of Education
Ireland
alison.egan@mie.ie

Ann FitzGibbon
Trinity College Dublin, the University of Dublin
Ireland
aftzgbbn@tcd.ie

Keith Johnston
Trinity College Dublin, the University of Dublin
Ireland
keith.johnston@tcd.ie

Elizabeth Oldham
Trinity College Dublin, the University of Dublin
Ireland
eoldham@tcd.ie

Abstract: This study explores pre-service teachers’ confidence using technology on school placement. Two cohorts of pre-service teachers were surveyed, each over a three-year period, during their college preparation course. The study adopted a sequential explanatory mixed-method design, and the statistical analysis of the survey data is reported here. Personal technological self-efficacy at the time of entering college was not an indicator of use of technology during school placement. The results have wider implications for classroom technology integration in Irish education and elsewhere.

Introduction

Pre-service teachers are typically confident users of personal technologies including their smartphones, laptop and tablet devices. However, this confident use of personal technologies is often not mirrored in professional contexts when pre-service teachers are asked to use technology in a classroom environment. Two groups of pre-service teachers were surveyed, over a three-year period, after their school placement blocks. Composite technological self-efficacy scores were compared to the most frequently used technologies available in school classrooms. Discussion of an apparent technological competence gap that emerged in the data, is the subject of this research chapter. This chapter adds to the literature on technological self-efficacy, and expands on previous research presented at SITE conferences, from Australian colleagues’ research on the Digital Education Revolution and pre-service teacher education (Albion, 1999, 2003, 2007; Redmond & Albion, 2002).

Literature

The literature review focuses on the psychological concepts of self-efficacy, technological self-efficacy, and their application to the use of technology by pre-service teachers. It outlines the high stakes nature of the school
placement classroom environment, and how multiple factors impact on the technological self-efficacy of the pre-service teacher participants in the study.

**Self-Efficacy**

In the context of teachers’ use of technology in the classroom, the psychological concept of self-efficacy is key to understanding their intrinsic motivation to use technology. Self-efficacy is well established in psychological literature as an effective measurement of a person’s confidence in their own ability to achieve a required outcome. Based on the theory of social cognitivism, self-efficacy is defined as “people’s (sic.) beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives” (Bandura, 1977, p. 191). Bandura (1977) expanded this concept further: a strong sense of self-efficacy meant that one approached difficult tasks as challenges to be mastered rather than as “threats to be avoided” (p. 192). He outlined that those who doubt their capabilities shied away from difficult tasks and often viewed them as personal threats; “to realize their aims, people try to exercise control over the events that affect their lives, they have a stronger incentive to act if they believe control is possible, that their actions will be effective” (Bandura, 1977, p. 214). Thus, a pre-service teacher in a classroom on school placement is unlikely to use technology if they are not confident in their own abilities to do so. To put it plainly, when faced with obstacles and failure, people who doubt their capabilities give up quickly, whereas those with strong self-efficacy respond to challenges by persevering and exerting greater effort (Bandura, 1997). Recent research into the area of self-efficacy has focused on the domains of motivation and commitment of pre-service teachers to use technology (Chesnut, 2017) and the relationship between pedagogical knowledge and self-efficacy (Depaepe & König, 2018).

**Computer Self-Efficacy**

Computer self-efficacy was explored by Compeau and Higgins (1995) when discussing the role of an individual’s belief about their ability to use a computer competently. A group of managers and professionals (n=2000) were questioned to assess their computer self-efficacy and a ten-item instrument for measurement of computer self-efficacy was devised. This ten-item instrument looked at variables such as encouragement by others, others’ use of technology, support of others, self-efficacy, outcome expectations, affect, anxiety, and use. Their findings suggested that “individuals in this study with high self-efficacy used computers more, derived more enjoyment from their use, and experienced less computer anxiety” (p. 203). This ten-item instrument was germane for the current study.

In Australia, a Queensland government initiative, Digital Education Revolution, required that all pre-service teachers integrate technology into all aspects of their teaching (Albion, 1999) and this research has been discussed at previous SITE conferences. By applying the concept of self-efficacy as described by Bandura (1994) to his work, Albion established that “teachers’ beliefs in their capacity to work effectively with technology are a significant factor in determining patterns of classroom use” (Albion, 1999, p. 2). Albion also noted that “student teachers who report strong belief in their personal capacity to work with computers are more likely to report feelings of self-efficacy for teaching with computers” (p. 1353) and found this concept of self-efficacy to be an enabler for the integration of technology by those participants. In subsequent research on this topic, Albion (2007) questioned the ability of millennial learners to integrate technology at all, and concluded that “first year university students while reporting high levels of confidence (self-efficacy) when using the internet, do not necessarily manifest matching levels of competence” (p.1244).

In a further evaluation of the Australian Digital Education Revolution (DER) initiative, Albion (2011) contended that “students should graduate with relevant knowledge and skills for using ICT, and that ICT should be integrated to improve student learning” (p. 74). Having researched a sample of first years from a variety of education courses, in three different Australian universities, he found that 50.5% felt confident to a great extent about using ICT and a further 17% were confident to a very great extent (pp. 76-77). However, when participants were queried further about their specific skills (e.g. managing digital photos or working with audio and video), the responses reflected lower confidence levels. He concluded that “Australia’s Digital Education Revolution (DER) is still in its early stages and it is not entirely clear what it will mean in the typical classroom” (p. 80). Yet, “their experiences and resulting skills appear to be balanced more towards consumption of digital content than creation” (p. 80) and as such, the first years’ skills using technology remained limited. However, technological self-efficacy of pre-service teacher educators
has a continued relevance, and recent literature (Instefjord & Munthe, 2017; Tondeur, van Braak, Siddiq, & Scherer, 2016) has noted that often confidence using technology has not equated to competent use of technology. Hence, the literature suggests a possible technological self-efficacy competence gap, and as such, forms the basis for this chapter.

**School Placement**

The importance of school placement—also known as teaching practicum, teaching practice and field placement—as an integral element of pre-service teacher education is acknowledged in the literature. Huberman’s (1989) *model of teacher development* (p. 32) was applicable to the current study, as the pre-service teacher participants were in the first phase of their teaching life cycle. During this first phase a pre-service teacher’s main concern is one of *survivability* and *discovery* (p. 34); survival and the pre-service teacher’s own discovery about how a classroom operates were relevant to this research. In line with a model of cognitive apprenticeship, Brown, Collins, and Duguid (1989) and Darling-Hammond (1987) outlined the importance of placement as being an authentic assessment of teaching; the context of teaching should not be underestimated. Thus, as Darling-Hammond (2006) stated, “no amount of course-work can, by itself, counteract the powerful experiential lessons that shape what teachers actually do” (p. 308); the school placement experience shaped pre-service teachers’ beliefs about what it was to be a good teacher. Hence, what professional technologies were used by the research participants in such a high stakes placement environment was also important for the study.

**Methodology**

This chapter reports on one element of a larger research study, which used a sequential explanatory design (Creswell, 2009, p. 211). The larger study was based on three phases of data collection for each of two cohorts of pre-service teachers attending their undergraduate college course. The first and second phases focused on quantitative data collection and the third phase on qualitative data, using semi-structured interviews. In the first phase, at the beginning of their pre-service teacher education course, participants were given a questionnaire in which they were asked to self-report their levels of technological self-efficacy using Compeau & Higgins’ (1995) instrument (survey I, section II).

In the second research phase, frequency of use of technologies for professional purposes was measured. Items of relevance to this chapter were drawn from a questionnaire on technologies used in European classrooms (EU Commission, 2013), and referred to items such as data projectors, laptops, desktop computers, internet connections, digital cameras, cloud storage and curriculum software packages. It should be noted that some technologies, such as laptops and desktop computers, are likely to be alternatives, so the items are not expected to constitute a scale or to provide a useful total score. Participants were asked to rate how frequently they used each item. Frequency of use ranged from ‘never’ to ‘very often’ (or many times a day) (survey II and survey III).

The ten technological self-efficacy statements commenced with an introductory phrase ‘I am able to’, which led into various self-efficacy statements about using technology. Participants’ levels of agreement were measured on a five-point Likert-type scale, from *Strongly Agree* to *Strongly Disagree* (coded from 5 to 1). Statements such as ‘I am able to integrate technology in my college work effectively’, ‘I am able to navigate the contents of a computer’ and ‘I am able to use technology if there are user manuals available’ were used (Compeau & Higgins, 1995; McCoy, 2010). The Cronbach alpha scores demonstrated that these ten statements were a reliable measure of technological self-efficacy for each cohort (Cohort 1 α .773 and Cohort 2 α .823).

Before statistical analysis on the technological self-efficacy items (survey I) commenced, the data were checked to see if they followed normal distribution patterns. From using a Shapiro-Wilk test in SPSS on the technological self-efficacy items, the results indicated the survey data was sufficiently normally distributed. Then, by using the same test on the ‘professional’ use items (survey II and survey III), it was found that these data did not follow a normal distribution. This was anticipated, as the items listed represented alternative technologies, rather than cumulative use of a particular piece of technology, as indicated above. As such, parametric and non-parametric analyses were required, and the results for each cohort are now reported.
Results

Quantitative analysis of the survey items included descriptive statistics and frequency counts for the ten technological self-efficacy statements from survey I, for each cohort, (Table 1) as these data were normally distributed. Pearson product-moment correlation analysis was used to check for any differences or similarities between technological self-efficacy composite scores in survey I, with use frequencies from survey II and survey III, while on school placement, for each cohort (Table 2). Finally, paired t-tests were then used to calculate any difference in response patterns by respondents from either cohort, and whether one cohort had a higher technological self-efficacy score than the other (Table 3).

Table 1

<table>
<thead>
<tr>
<th>Technological self-efficacy statements – descriptive statistics</th>
<th>Cohort one survey I</th>
<th>Cohort two survey I</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Complete a job or task using technology if shown how to first</td>
<td>80</td>
<td>4.26</td>
</tr>
<tr>
<td>Complete a job or task using technology</td>
<td>80</td>
<td>4.08</td>
</tr>
<tr>
<td>Navigate the contents of a computer</td>
<td>79</td>
<td>3.85</td>
</tr>
<tr>
<td>Use technology if there are user manuals available</td>
<td>80</td>
<td>3.79</td>
</tr>
<tr>
<td>Adopt and adapt technology resources for assignments</td>
<td>80</td>
<td>3.68</td>
</tr>
<tr>
<td>Integrate technology in my college work creatively</td>
<td>80</td>
<td>3.66</td>
</tr>
<tr>
<td>Search, evaluate and select appropriate technology resources</td>
<td>79</td>
<td>3.63</td>
</tr>
<tr>
<td>Integrate technology in my college work with minimal help</td>
<td>80</td>
<td>3.58</td>
</tr>
<tr>
<td>Use technology without needing to be told how it works</td>
<td>77</td>
<td>3.52</td>
</tr>
<tr>
<td>Use my knowledge of technology to help my classmates</td>
<td>79</td>
<td>3.46</td>
</tr>
</tbody>
</table>

Table 2 demonstrates that pre-service teachers in both cohorts either strongly agreed or agreed that they could ‘complete a job or task using technology’ (Cohort one, survey I Mean 4.08 SD .76 and Cohort two, survey I Mean 4.08, SD .60), and even more so, if ‘shown how to do it first’ (Cohort one, survey I Mean 4.26 SD .82 and Cohort two, survey I Mean 4.35 SD .75). There was little variance in the responses to either of these statements (Cohort one, survey I SD .82, Cohort two, survey I SD .75 and Cohort one, survey I SD .76 and Cohort two, survey I SD .60) for either cohort. The mean scores for ‘if shown how to first’ (Cohort one, survey I Mean 4.26 and Cohort two, survey I Mean 4.35) showed higher levels of agreement than for having to complete the task on their own. Small differences in mean scores began to emerge for the statement ‘navigate the contents of a computer’ where cohort one’s mean scores were marginally lower than cohort two’s results (Cohort one, survey I Mean 3.85 SD 1.06 and Cohort two, survey I Mean 4.07 SD .70). Further, both cohorts reported some level of agreement with being able to use technology if ‘there were manuals available’ and there was little difference in the mean scores (Cohort one, survey I Mean 3.79 SD 1.03 and Cohort two, survey I Mean 3.95 SD .89); again, cohort two’s responses showed marginally more agreement with this statement. Of note was that the lowest level of agreement was with the statement ‘I am able to use my knowledge of technology to help my classmates’ (Cohort one, survey I Mean 3.46 SD .87 and Cohort two, survey I, Mean 3.61 SD .94). However, this data was from the first survey administered to each cohort as they started
their Bachelor in Education course, and thus they may not have thought of helping their colleagues at this early juncture. Furthermore, for each cohort, there were no significant correlations present between their responses to survey instrument II and their responses to survey instrument III, for any of the most frequently used technologies.

**Composite Technological Self-Efficacy Scores**

A composite score for technological self-efficacy (TSE) was then calculated in SPSS, by creating a new variable that calculated the mean of the ten technological self-efficacy items for each participant. Correlational analysis, using Pearson’s r, was conducted for each cohort, testing whether there was any association between a respondent’s composite technological self-efficacy score on entry to college and their extent of use of the most frequently used professional technologies while on school placement. It was not possible to calculate a composite score for professional use generally, as these items (e.g. desktop computer and/or laptop) represented alternatives rather than a cumulative use of technology, as noted earlier. Thus, the most frequently used technologies are listed separately. For each one, the Pearson product-moment coefficient between respondents’ technological self-efficacy scores and their ratings for frequency of use of that technology (Table 2) are reported. As such, higher technological self-efficacy composite scores did not indicate an increased use, on placement, of any of the technologies listed. It is also interesting to note the negative correlation for use of Google by members of Cohort one, but not Cohort two, in their responses to survey III.

### Table 2

*Pearson correlations between technological self-efficacy scores and extent of reported use of most frequently used technologies*

<table>
<thead>
<tr>
<th></th>
<th>Cohort one Survey II</th>
<th>Cohort one Survey III</th>
<th>Cohort two Survey II</th>
<th>Cohort two Survey III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Projector</td>
<td>-.018</td>
<td>-.272</td>
<td>.152</td>
<td>-.245</td>
</tr>
<tr>
<td>Laptop</td>
<td>-.169</td>
<td>-.235</td>
<td>.130</td>
<td>.199</td>
</tr>
<tr>
<td>Internet</td>
<td>.028</td>
<td>-.233</td>
<td>.078</td>
<td>-.169</td>
</tr>
<tr>
<td>IWB</td>
<td>.047</td>
<td>-.164</td>
<td>-.214</td>
<td>-.256</td>
</tr>
<tr>
<td>MS PowerPoint</td>
<td>.103</td>
<td>-.041</td>
<td>.010</td>
<td>.091</td>
</tr>
<tr>
<td>Google</td>
<td>.213</td>
<td>-.322</td>
<td>.089</td>
<td>.259</td>
</tr>
</tbody>
</table>

### T-Tests

Paired sample t-tests were conducted on the survey data to check for similarities or differences between each cohort’s composite technological self-efficacy score. There was a difference, narrowly missing significance, in the composite technological self-efficacy scores between cohort one (Cohort one, survey I $M=3.75$, $SD=.591$) and cohort two (Cohort two, survey I $M=3.89$, $SD=.467$); $t(77)=1.88$, $p=0.06$), where cohort two demonstrated a higher composite score for technological self-efficacy than cohort one (Table 3).

### Table 3

*Results from t-tests between cohort differences for composite technological self-efficacy scores*

<table>
<thead>
<tr>
<th>Paired Sample</th>
<th>Composite Score</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort 1 * Cohort 2</td>
<td>Technological Self-Efficacy (TSE)</td>
<td>1.883</td>
<td>77</td>
<td>.063</td>
</tr>
</tbody>
</table>
**Discussion**

This section explores the themes of confidence and competence using technology, and how these two psychological constructs were evident in the data gathered in the study. These constructs are then discussed in light of research on the social cognitive theory of self-efficacy (Bandura, 1977, 1994, 1997), and the associated theory of technological self-efficacy (Compeau & Higgins, 1995), where often confidence using technology did not equate to competent use of technology for participants in the study. In the current research, the expectation based on previous literature was that those who had reported higher personal technological self-efficacy scores in first year (survey I) would exert a greater effort to overcome technological obstacles that they may have faced while using technology in the classroom during school placement (Albion, 1999, 2003, 2007, 2011; Hammond, Reynolds, & Ingram, 2011).

However, expectations around confident use of technology were not matched in the school placement environment. The results are therefore of interest given the current debate on the nature of use of technology by the millennial generation (Akçayır, Dündar, & Akçayır, 2016; Barak, 2018; Šorgo, Bartol, Dolničar, & Podgornik, 2017) where the notion of an innate ability to use technology has recently been refuted. Kirschner & De Bruyckere (2017) contend “there is no such thing as a digital native who is information-skilled simply because (s)he has never known a world that was not digital” (p. 135) and the current research study would support their findings.

**Technological Competence**

Where technological self-efficacy was present it was limited to personal use of the Internet, social media, YouTube, pre-service teachers’ own laptops, and smartphone/mobile devices, akin to the recent similar conclusions of Drabowicz (2017), Kirschner and De Bruyckere (2017) and Lau, Hung, and Jong (2016). Lack of technological competence was also evident in the research findings, echoing Albion’s (2007) earlier research where students had experienced problems searching for information on the Internet.

A competence gap has been reported more recently by Gross and Latham (2012), where “students [are] coming to higher education without needed information literacy skills” (p. 581), and the issue is still the subject of frequent debate in the literature (Hartnett, 2017; Lai & Hong, 2015; Senkbeil & Ihme, 2017; Wang, Hsu, Campbell, Coster, & Longhurst, 2014). Thus, a technological skills gap was evident in the results, where confident use of personal technologies was not translating into competent use of professional technologies available in a school placement classroom. As noted earlier, there were no significant correlations present for either survey instrument (II and III), for either cohort, for any of the most frequently used classroom technologies. The t-test results demonstrated similar response patterns from both pre-service teacher cohorts, indicating similar lack of use of professional technologies.

Hence, these results were comparable to Kruger and Dunning’s (1999) seminal analysis that “skills that engender confidence are often the same skills you need to evaluate your competence in that particular domain” (p. 1121) where Kruger and Dunning suggested that often confidence did not necessarily equate to competence, in a particular field. Mahmood (2016) evaluated the Dunning-Kruger effect with information technology literacy skills, and the findings of the current study demonstrated similar results where “there was no match between self-efficacy and actual performance [using IT]” (p. 205). Indeed, this was evident where, in relation to the composite self-efficacy items, there were no significant correlations between these and scores for frequency of use of many professional technologies, as noted in Table 2. Similarly, Maderick, Zhang, Hartley, and Marchand’s (2016) recent research demonstrated pre-service teachers in their study were

either not aware of how much they do not know about the technologies that they will need to carry to their perspective classrooms or they are indeed, cognizant of their gap in knowledge without having an accurate understanding of its magnitude (p. 342).

Hence, Maslow’s (1962) early model of learning competencies has continued relevance for the current research where participants in the study had moved from the unconscious incompetence to the conscious incompetence stage of learning, and an awareness of their own technological skills gap was reported by these pre-service teachers.

To try to improve pre-service teachers’ skills using technology, recent literature has advocated an approach whereby they should be equipped with strategies to use a wide range of technologies during their college preparation course (Banas & York, 2014; Celik & Yildirim, 2016; Roy, Giraldo-Garcia, Mathew, Matias, & Bommisetty, 2016). However, such strategies are but one approach; there are many others advocated in the literature, where exposure to
technology during the college preparation course is merely a first step. As technology is constantly changing, familiarity with sound pedagogical underpinnings that are not technology dependent, such as SAMR (Puentedura, 2010) and TPACK (Mishra & Koehler, 2006), would build on pre-service teachers’ apparent confidence to use technology in their future classrooms. In the context of the current chapter it is worth noting the significance of school placement being perceived and experienced by pre-service teachers as a pressurized assessment environment. This perception, along with factors relating to the particular placement school context (amongst other issues experienced), may have influenced the levels of technological use reported, in spite of the reported levels of technological self-efficacy for members of each cohort.

**Conclusion**

The research findings have implications for pre-service teacher education in particular. For example, there is an evident transfer gap with respect to how pre-service teachers transfer their personal knowledge and competence using technology to a professional context (i.e. in the classroom). It is suggested that more accomplished mentoring in the school placement context may help pre-service teachers develop their technological self-efficacy, which in turn would lead to greater levels of technology integration in classrooms.

Other countries have already identified the significance of modelling and mentoring based approaches to support technology use by beginning teachers. For example, the recent introduction of Teacher Educator Technology Competencies (TETCs), in a US context, is designed to support “the redesign of teaching in teacher education programs so that ALL teacher educators are prepared to model and integrate technology in their teaching” (p.413). Furthermore, in a European context, the Digital Action Plan (2018) has noted the need for joined up thinking encompassing teacher educators to support technology integration:

> Innovation in education and training depends greatly on empowering and connecting educators…to bring innovation and technology to the classroom, educators need the right environment, infrastructure, devices and leadership support…and requires an approach that combines teacher training, curricula and educational materials that are fit for digitally supported teaching models. (p. 5)

This has been acknowledged in the recent Irish Action Plan for Education (DES, 2017) where “a step change in the use of ICT in teaching, learning and assessment at all levels of the education and training system, so that learners are equipped with the skills to live in an increasingly digitally connected world” (p. 16) is required. How this will happen in each individual pre-service teacher education environment remains unclear in an Irish context, but some initial steps have been taken. Near the end of 2018, a Digital Learning Framework (DLF) pilot study began in 50 Irish schools. One of the main priorities was to “facilitate a whole school approach to understanding what it means to embed digital technologies using constructivist principles for teaching and learning” (p. 3). We await the results of the pilot study and look forward to its application to all schools involved in school placement, for pre-service teacher educators.

**References**


Obstacles, Travails, and Barriers, Oh My! Educators’ Perspectives on Challenges in Professional Social Media Use

Jeffrey P. Carpenter
Elon University
United States
jcarpenter13@elon.edu

Stephen Harvey
Ohio University
United States
harveys3@ohio.edu

Abstract: Social media such as Facebook, Twitter, and Instagram have become important venues for self-directed professional activity for some educators. Although these professional learning and networking activities are generally voluntary in nature and thus are assumed to provide some benefits and/or gratification to participating educators, social media use for professional purposes is not without its drawbacks. In this chapter, we present challenges described by a sample of educators who had actively used social media professionally over an extended period of time. We draw upon data from 48 educators who participated in semi-structured individual and focus group interviews. We identify four types of challenges experienced by the participants: intrapersonal, interpersonal, school community, and online educator community challenges. Finally, we consider implications of our findings for educators, teacher educators, and education researchers.

Introduction

Professional development (PD) has long been critiqued by educators, researchers, and policymakers who see it as failing to sufficiently impact teaching and learning (e.g., Timperley & Alton-Lee, 2008; The New Teacher Project, 2015). Because school-mandated PD often relies upon one-size-fits-all approaches, it frequently suffers from a lack of alignment with individual educators’ perceived interests and needs. Due to such perceived shortcomings, many educators have pursued self-directed professional learning beyond the official PD programs required by their schools (Carpenter, 2016). In particular, it has become common in recent years for educators to turn to social media platforms such as Twitter (Greenhalgh & Koehler, 2017) Facebook (Lantz-Andersson, Peterson, Hillman, Lundin, & Rensfeldt, 2017), Instagram (Carpenter, Morrison, Craft, & Lee, 2019), Pinterest (Hu, Torphy, Opperman, Jansen, & Lo, 2018), and Reddit (Staudt Willet & Carpenter, 2019) for professional purposes.

Research on educators’ professional social media use has defined multiple possible benefits to such activities. For instance, educators can use social media to collaborate with a broader pool of colleagues from beyond their individual schools (Carpenter & Green, 2017). Social media can mitigate the isolation that has historically harmed teachers (e.g., Carpenter & Krutka, 2015; Holmes, Preston, Shaw, & Buchanan, 2013; Smith Risser, 2013). Additionally, social media can provide a convenient means for teachers to find, share, amplify, and discuss instructional materials and resources. For example, many education-focused Facebook groups play host to discussions of topics ranging from academic content, to pedagogy, and to assessment (e.g., Lantz-Andersson et al., 2017), while Pinterest has proven to be a popular tool for curating curriculum materials and as a space for some educators to engage in entrepreneurial activities (e.g., Carpenter, Cassaday, & Monti, 2018; Hu et al., 2018).

Despite such reported benefits, it seems logical educators may also experience some challenges as they make professional use of tools that were not explicitly designed for those purposes. In some cases educators have lost their jobs because of ill-advised social media posts (e.g., Warnick, Bitters, Falk, & Falk, 2016), but there are also more mundane obstacles that educators encounter as they use social media. For example, teachers may struggle to manage boundaries between their personal and professional worlds (Fox & Bird, 2017). However, the knowledge base regarding such challenges remains underdeveloped (Owen, Fox, & Bird, 2015). This study thus contributes to the field
by exploring the challenges reported in interviews with 48 educators who had actively used social media for professional purposes for an extended period of time.

**Conceptual Framework**

Our understanding of the challenges educators experience with professional social media use is framed by a social-ecological model. Social-ecological models seek to explain the relationship between individuals and the settings and contexts in which they are involved. Bronfenbrenner (1979) suggested that humans are influenced by “a set of nested structures, each inside the next, like a set of Russian dolls” (1979, p. 22), and this notion of a nested set of influences impacting human behaviors has been previously applied to schools (e.g., Felner, Seitsinger, Brand, Burns, & Bolton, 2007) and in particular to educators’ professionalism and professional activities (e.g., Dalli, Miller, & Urban, 2012). The benefits and challenges educators experience in their use of social media cannot be fully understood without consideration of the multiple levels of influence on the adoption and maintenance of human activities. Educator professionalism is, after all, “embedded in local contexts, visible in relational interactions, ethical and political in nature, and involving multiple layers of knowledge, judgement, and influences from the broader societal context” (Dalli et al., 2012, p. 8).

In our adaptation of the social ecological model, the educator is at the center of a series of concentric circles, which represent contexts that have influences on the educator. Such a model accommodates a range of proximal and distal factors that shape educators’ professional actions and their perceptions of those actions. First, educators’ individual characteristics can shape their social media experiences, and thus intrapersonal challenges are at the center of our model. Second, educators may also experience challenges related to their dyadic interactions with other individual educators; we refer to such as interpersonal challenges. Third, social media can create challenges for educators related to the school community, including stakeholders such as administrators, families, students, and local tax payers. Fourth, educators can encounter challenges associated with the larger community of educators they encounter when using social media. We acknowledge that the borders between these different levels of influence can at times be difficult to precisely delineate.

**Literature Review**

Large numbers of educators leverage the affordances of digital tools in order to collaborate with peers from beyond their schools (Lantz-Andersson, Lundin, & Selwyn, 2018), and a growing body of research focuses on the potential for different social media to support educator professional learning (e.g., Carpenter & Green, 2017; Greenhalgh, & Koehler, 2017; Xing & Gao, 2018). Prior research on teacher learning in online spaces has tended to focus on experiences with a single community, network, or site (e.g., Carpenter et al., 2018; Lantz-Andersson et al., 2017) and has produced more findings regarding the affordances and benefits of professional social media activities (e.g., Carpenter & Krutka, 2015; Greenhalgh & Koehler, 2017) than findings related to barriers and obstacles.

Some challenges associated with educators’ professional uses of individual social media tools have been previously identified. The relative absence of traditional information gatekeepers on social media can create issues with the quality of content being shared. For example, Hertel and Wessman-Enzinger (2017) analyzed 176 teaching resources shared on Pinterest related to the teaching of negative integers and found that roughly one-third included mathematical errors. Teachers may also confront ethical dilemmas in their use of social media. For instance, Thunman and Persson’s (2018) research described cases in which teachers’ use of Facebook with their students resulted in their becoming aware of student behaviors that they were uncertain how to respond to. Educators may also face identity-related challenges as they can feel pressured to present themselves in idealized or fragmented forms on social media (Carpenter, Kimmons, Short, Clements, & Staples, 2019; Kimmons & Veletsiansos, 2014, Robson, 2018).

Educators’ online activities can also be impacted by context collapse (Marwick & boyd, 2011). While social media tools can present opportunities for users to connect across geographic, temporal, hierarchical, and institutional boundaries, they also can create context collapse. Individuals commonly communicate with an intended audience in mind, but the open nature of social media means that this imagined audience can differ from the audiences a post reaches. A social media user might tweet intending to communicate in a particular context – for example, with a group of friends – but other users may see and interact with the post as well. In face-to-face settings, individuals typically seek to adjust their presentation to fit the particular context, but the collapse of contexts online can eliminate such adjustments. This increases the risks associated with content posted online being interpreted in ways that the poster may not have intended or anticipated. Context collapse is particularly relevant for educators due to their professional responsibilities to multiple audiences, including students, families, and their communities. Given social media’s
pervasiveness, educators’ personal and private behaviors that might not be considered acceptable by some members of their school communities may now be more likely to become public knowledge (Warnick et al., 2016). Furthermore, as educators interact with colleagues from outsider their own school contexts, they may experience challenges in judging the credibility and expertise of their online interlocutors.

In addition to such specific challenges, social media could also generally contribute to the intensification of educators work by requiring them to learn new skills and be more available to students and families outside of the school day (Selwyn, Nemorin, & Johnson, 2017). While the prior literature illustrates some challenges associated with educators’ professional uses of social media, many studies have focused on a single social media tool and/or a single type of challenge. The data set in this research draws upon the experiences of 48 educators who had all used social media professionally for an extended period of time, and who overwhelmingly have experience with professional uses of two or more social media platforms.

Methods

This chapter addresses the following research question: What challenges do educators identify in their uses of social media for professional purposes? As part of a study that followed-up on a survey conducted by Harvey and Hyndman (2018), we interviewed physical education and health (PEH) educators about their uses of professional media. The interviews were semi-structured in nature and occurred via videoconference. We drafted an initial list of 25 prompts for the interview protocol, which we discussed, and revised down to a list of twelve prompts. We then solicited expert review from five scholars familiar with professional uses of social media. We made edits to existing items based on these educators’ feedback. The final interview protocol included 10 prompts, and 14 probes which were utilized only when participant responses were particularly brief or vague. The researchers co-conducted three of the first four focus groups in order to establish a consistent interview approach. Focus groups lasted approximately 60-75 minutes, while individual interviews lasted approximately 25-45 minutes.

This chapter relies upon participant responses to one prompt that directly inquired about any challenges they had experienced in their use of social media for professional purposes, as well as drawing upon responses to three other prompts that ended up eliciting relevant data related to challenges: What can’t you say on social media? What influences you to unfollow someone [on social media]? What makes you join or leave a group [on social media]? Initial analyses of the interview transcripts suggested the presence of rich data related to challenges, and the data related to these four items were thus separated from the full data set for more focused analysis. Thematic analysis as defined by Braun and Clarke’s (2006) was the approach to data analysis being employed in this research. After initial open coding of the data, and discussion of the emergent codes by the research team, we aligned the results with a social ecological model.

Sample

The online survey used in Harvey and Hyndman’s (2018) study of PE and health education professionals’ Twitter use included an item that asked respondents to leave an email address if they were willing to participate in a follow-up interview at a later date. Of the original 251 survey respondents, 171 individuals left their emails. Of that group, 65 subsequently consented to be interviewed, and we were able to schedule and execute interviews with 48 of those individuals. Fourteen participants were individually interviewed, and 34 participants took part in one of 10 focus groups. Nineteen of the participants were female (39.6%) while 29 (60.4%) were males. Thirty-five of the participants (72.9%) were K-12 classroom teachers, 10 (20.8%) were in higher education settings as professors of teacher education in physical education and health or graduate students preparing to become teacher educators in physical education and health, and three (6.3%) were in other roles related to K-12 physical health and education. The sample included 27 participants teaching in the US (56.3%), six teaching in Canada (12.5%), two each teaching in New Zealand, South Korea, China, and the UK, and individuals teaching in an additional seven countries. All participants were assigned pseudonyms which are used in the results section below. As the sample was drawn from respondents to a survey on professional Twitter use, 100% of the participants reported they used Twitter professionally. A review of the participants’ profiles in November 2018 indicated that the participants on average had been using Twitter for 72 months (6 years), and the mean numbers of Twitter users they followed was 1082, while 2719 other Twitter users followed them, and they had sent on average 7912 tweets. In terms of other social media, 46 participants (95.8%) mentioned at least two social media they used professionally. Thirty-
five participants described professional use of Voozer (72.9%), 24 Facebook (50%), 6 Instagram (12.5%), 5 LinkedIn (10.4%), and 3 Pinterest (6.3%). In sum, the sample was composed of participants who appeared to have engaged quite substantially with Twitter as a professional tool over an extended period of time, and who tended to use at least one other social media professionally.

Results

Participants all had some positive things to say about their professional social media use, with 93.1% attributing improvements in their teaching to social media facilitated learning, and 58.3% identifying impact on their students’ learning. Most of the respondents described themselves as, on the whole, advocates for the professional use of social media by educators. However, 47 of the respondents (97.9%) also identified challenges they experienced in their professional use of social media. In what follows, we present those challenges according to whether they primarily existed at the intrapersonal, interpersonal, school community, or online community levels.

Intrapersonal Challenges

Participants described various challenges that we interpreted to be primarily intrapersonal in nature. Twenty-nine participants (60.4%) mentioned grappling with such issues. The most common challenge, identified by just over half of participants (52.1%), related to various ways in which they experienced social media to be overwhelming. Some form of the word “overwhelm” was directly used by eleven participants to describe their feelings about at least one aspect of social media. While the participants saw various benefits to their social media activities, many commented on struggling to find an appropriate balance regarding how much they used social media. For instance, Ali, a high school Physical Education teacher, described social media as “overwhelming because you want to try to catch up with everything and there's no way you can do that.” Alana, a teacher educator in physical education, spoke of what she perceived as the elusive nature of finding balance regarding social media: “It's almost like I have to either do it all the time or not do it at all.” Multiple participants alluded to the risks of becoming “addicted” to social media. Olivia, a with a large Twitter following, noted that she was “recovering” from what she considered a period of overuse of social media: “I'm more aware now that ‘Hey, it's time shut it off,’ or get it out of sight. I try not to not use my phone in the bedroom ever.” Nate described reaching a point where the number of followers he had acquired on social media began to make him more self-conscious about how he posted:

I felt a bit overwhelmed, with a lot of responsibility of what I say, when I say, what I do. I started to think about a little more carefully about what I say, what I do, and what kind of mentor or teacher I want to be. Because I found myself, from just being in a classroom in front of 15-20 students, to sharing my experiences ... it kind of changed everything quickly for me, the weight of what I post.

Some participants also mentioned challenges that arose from comparing themselves to other educators they saw posting to social media. For example, Winston, an elementary school Physical Education teacher said of some other users: “It seems like they don't sleep, and they produce something pretty amazing almost on a daily basis. And that can start to get to be like, ‘Well, why am I not doing that?’” Another participant made a similar comment:

[Educators] devote hours a day to creating new things, and it's really easy to get caught up thinking ‘I have to be like them’ instead of finding your own path. So that's one of the things that in social media has really been something that I've had to watch because I don't want to. I want to learn from people, but sometimes trying to copy what they do is not my path, and that's something that has detracted me from social media.

A handful of participants noted the presence on social media of directly or indirectly self-promotional posts, and opined that such use of social media was at times problematic. Amber, who was a consultant, indicated that she was regularly conscious of such posts: “There are a lot of comments about shameless self-promotion … so I’m very careful that I don’t look like I’m promoting myself.” Some educators use social media in part to market products that they sell on lesson marketplaces such as TeachersPayTeachers.com. A participant with an active account on one such lesson marketplace described struggling to negotiate multiple motives for using social media: “I’m always struggling with that balance … I’m a person, I’m a teacher, and I’m also a businessman and how do I work all of those 3 things together.”

Another type of internal conflict voiced by multiple participants related to their roles as leaders, or at least responsible members of their profession. For example, Annabelle, an elementary school physical education teacher, commented, “People are still playing dodge ball; it's not a good practice. SHAPE America [the national organization for health and PE in the USA] has documents saying don't play it and people are still promoting games that are similar.
It's almost made me want to stop using social media because of that. But I feel like it's part of my responsibility to get best practice out there also.” One participant spoke of spending time in a large Facebook group in order to respond to questions from other teachers, rather than to advance his own learning. These individuals felt some sense of obligation to be present on social media to mentor, disseminate effective teaching practices, and/or to combat ineffective practices, not simply to learn for their own sake. However, some participants struggled with feeling that such service to their profession was taking a toll upon them and detracting from their overall experiences of professional social media.

**Interpersonal Challenges**

A second set of challenges described by participants related to interpersonal interactions with other individual educators. Thirty-five of the participants (72.9%) noted grappling with one or more such issues. These challenges tended to relate to content posted by and/or discourse with other educators. Participants described being conflicted or frustrated about various kinds of posts from other educators. As previously noted, for a handful of participants the commercial nature of social media created intrapersonal challenges. However, it was more common that respondents (18.8%) alluded to challenges related to the commercial nature of posts by some other educators. Although a few of these participants referenced the commercial nature of the platforms themselves, and associated ads or promoted content, many more participants’ critiques related to directly or indirectly commercial posts from their fellow educators. Various participants did not appreciate the presence of such overtly self-promotional content. For example, Linda commented, “I think some people do use it as a commercial tool to sell their product … which I have a bit of a problem with.” Another participant lamented the presence of other users “ peddling things a little bit … they’ve taken a new job working for a specific company or something, where before some of their posts were kinda helpful, and now everything is geared towards, use this, use this, this is why you have to use this.” A third individual, Elizabeth, mentioned unfollowing users who “are just self-promoting, sort of without providing for the community and so I will unfollow them … I also unfollow people that are trying to sell me anything.”

Another group of participants (n=15, 31.3%) expressed frustrations around problematic teaching practices advocated by other social media users. For instance, Emma mentioned feeling “disillusioned at some of the points by the number of people that put out practices that long ago were listed by SHAPE as inappropriate practice, developmentally inappropriate.” Some participants also questioned whether educators were using content shared via social media in an appropriate manner. Stuart critiqued other educators’ implementation of trendy teaching activities without connection to curriculum or particular pedagogical purposes:

> What is professional for a teacher? Is professional taking a game from online and putting it into your class or is professional following the curriculum that’s assigned and all of that? … How people use the information that they’re accessing online, the validity of that information I think is really a challenge for everybody.

Twenty-one participants (43.8%) mentioned their disapproval of some the content that other educators posted because they did not consider it professional in nature. For example, 33.3% of participants (n=16) did not consider it appropriate when other educators posted content that was too political in nature. Some respondents also indicated that they did not value when educators posted too much content related to their personal lives (n=14, 29.2%) or were at times too negative in their posting (n=13, 27.1%). For instance, one participant said of negative posts, “There’s a difference between being critical, constructive criticism let’s call it that, versus just outright mean spirited comments back to the individual.”

**School Community**

Twenty-three of the participants (47.9%) mentioned challenges associated with their social media use that existed because of school community level factors or considerations. In a few instances, participants noted cases of colleagues failing to appreciate or understand why the participants would utilize social media. For example, Michael commented, “Administration does not see Twitter, Voxer and other forms of social media as a valued professional development tool. They just don’t get it … try to explain it to them and they look at you like what in the world are you talking about. I think the moniker is still social media is a leisure activity. It is something for kids.” Various participants noted ways in which context collapse presented challenges to their social media use. For example, a handful of participants commented on how their use of social media made them aware of student actions that put the educators in ethically ambiguous situations regarding whether they needed to report or take action. One teacher explained, “When the students follow you, you can actually see their feed and dealing with teenagers, in generally, sometimes you see things you don't want to see, so I've tried to change the settings so that it's just me sharing, not
However, it was more common that participants expressed reservations regarding how content they themselves posted might be perceived or misconstrued. Isaac commented, “You always gotta worry about parents and administrators from your district. You know, are they seeing what you’re doing out there. What if they disagree with you? Are you breaking confidentiality?” Another individual explained,

There are also some parents of students that I teach that follow me on Twitter, which it all great, but it makes it a little bit more difficult for me to be as critical as some of the other people are on Twitter, so I always need to make sure that whatever comes out of my mouth on Twitter, that I stand for that also when I face these parents in the hallway.

Online Educator Community

Challenges also arose because of limitations associated with online communications. For instance, Yannick felt that the Twitter communities in which he participated were too activity focused:

[Twitter]’s very activity heavy … Activities that loses the concept and the theory and the practice behind it. What the hell is the teacher doing that they can just drop everything that they had planned to do this one tag game with a noodle? --- It's just an example of how people are posting things on Twitter with no pedagogical purpose explained.

Multiple participants described challenges associated with the nature of discourse in educator social media spaces. One educator commented, “There is no personal relationship established” between users, and as a result, when one user offer critiques, “it is always taken in a very … defensive way.” Nadia asserted that, “There's not enough of listening to somebody else's perspective and entertaining their opinion and engaging with it before interacting.” A pedagogy coach explained that, “If you're getting in there, and you're diving in there with a probing question … their immediate response is to justify why it is they did what they did rather than open up a dialogue. So, one of the challenges is that it’s very hard to have dialogue. Genuine dialogue.” Nash commented, “We have to open a discourse and talk about things” but that this was difficult because “there’s no referee on social media.”

Participants also mentioned the tendency of some online educator communities to avoid certain types of conversations. For example, several participants mentioned the curated nature of self-presentation on Twitter. One teacher commented, “I don’t share on Twitter if I totally bomb a lesson,” while Winston pointed out problems with such avoidance of more authentic sharing:

We don't like to share the bad things that happen as a teacher ... we all go through classroom management issues, but we don't want to share that on social media because people might think of you less. So, that's kind of a drawback is it feels like we only can share the good things instead of coming together. I think that if we get to the point where we can actually share some of those bad things, it's really actually even more helpful than sharing the good things that happen to us.

A number of participants were also concerned that educators could be using social media in ways that created somewhat of an “echo chamber” and therefore limited their exposure to diverse ideas and/or perspectives. For example, one teacher commented, “I think over time you figure out sort of who your trusted sources are as well but then there’s they the other challenge of that is that potentially the reason I listen to those people more is because they agree with me and then becomes sort of an echo chamber type situation and that’s not necessarily good.” Harold spoke of the risks that educators “can end up finding a comfortable group that all agrees with each other, and doesn't challenge each other. And that seems like a great thing but really then that’s where the growth stops.”

Respondents infrequently focused on challenges that they explicitly linked to the technical features of different platforms, such as whether a service featured threaded conversations. One respondent did note limitations associated with Twitter’s brevity: “The challenge of Twitter is that it doesn't give you enough context or background of why it's being used … to get to those deeper levels of professional growth you've got to take it to the next level.” Nash noted how Twitter users can purchase batches of followers and thus deceive other users: “So all you have to have is a computer and pay some company to get you a bunch of followers and all of the sudden you’re the expert.”

Discussion

In recent years, a steadily growing body of research has documented various benefits and affordances of social media for educators. However, our findings contribute to the literature by adding to the limited empirical evidence regarding the challenges educators experience in their social media activities. Our participants described challenges that were diverse in nature, and which we organized via a social ecological model (Bronfenbrenner, 1979). Also, these findings are unique in that they draw upon the experiences of educators who had engaged with social
media over an extended period of time, and the identified challenges are thus not simply those proposed by Luddites or individuals who have shallow understandings of these social media (cf. Biddolph & Curwood, 2016). Admittedly, this strength of our data set is simultaneously a limitation of sorts, as our sample does not include the perspectives of educators who have tried to utilize a social media professionally and found the experience so negative that they entirely ceased their use.

Our findings on educators’ social media experiences are consistent with research on social media more generally in terms of the salience of context collapse (Marwick & boyd, 2011). Educators are public figures whose personal behaviors can be the subject of scrutiny by members of their local communities. Social media can render users almost constantly visible to others, and such persistent visibility can detract from open communication and expression (Hampton, 2016). Because of the risks of context collapse, teachers may worry that their every online interaction could fall afoul of some community members’ standards for educators. Such pressures can lead educators to try to present themselves in ways that may be limited or at least fragmented (Kimmons & Veletsianos, 2014; Robson, 2018). Similar to the educators in Fox and Bird’s (2017) work, some of the participants in this research also identified tensions between personal and professional uses of social media.

Eraut (2004) has suggested that for informal professional learning contexts, there is often a relationship between challenge, support, and confidence, and this three-part relationship may well be an important dynamic in understanding educators’ social media uses. While the participants overwhelmingly identified challenges related to their social media activities, they had nonetheless continued those activities, and generally indicated plans to continue doing so in the future. Some educators may simply have enough pre-existing support and confidence that they are comfortable navigating the challenges they encounter on social media. And for some educators, the same social media that can present them with certain obstacles, it may also provide various forms of support—in terms of access to both informational and relational resources – that help educators feel confident that they can navigate those and other challenges (e.g., Carpenter & Green, 2018).

Many of the challenges the participants identified were not obviously related to their specific content area, and we thus anticipate that our findings could be useful to educators and teacher educators associated with any academic content areas. However, we acknowledge that our sample was composed of PEH teachers who can encounter professional dynamics associated with the perceived lower status of their content area within the academic hierarchy. Because of common accountability pressures around subjects such as math, literacy, science, and history, many schools and districts may opt to invest only very limited amounts of their PD resources into professional activities for PEH teachers. This could mean that some PEH teachers might be more open to and motivated to persist with informal and self-directed learning activities such as those available via social media.

This chapter has implications for researchers, organizers, and facilitators of various types of educator professional learning. While school policies related to social media have become somewhat more attuned to educators’ professional uses of these media (Warnick, Bitters, Falk, & Kim, 2016), nuanced policies and regulations that could both support positive uses of and limit the challenges of social media are still lacking in many places. Given how common it is today for educators to engage in professional activities online, school districts and administrators should consider how to help educators negotiate online professionalism. For example, school leaders might identify steps they could take to protect educators who are engaged in face-to-face activities for the majority of the working day from undue pressure to connect for professional purposes outside of the school day (Fox & Bird, 2017). If social media is to be an important part of teacher learning, educators need opportunities to openly talk about the associated challenges and reflect upon ways to address, remedy, or avoid them.

Teacher preparation programs should contemplate how they might prepare pre-service teachers to manage the challenges of professional engagement with social media. As social media is an increasingly common part of modern life, pre-service teachers (PSTs) will likely consider making at least some professional use of these media. Despite PSTs possible preexisting familiarity with personal uses of social media, professional uses may be unfamiliar and even intimidating for many of them (e.g., Carpenter, 2015; Carpenter, Tur, & Marin, 2016; Hsieh, 2017; Krutka, Nowell, & Whittlock, 2017). The next generation of teachers could benefit from guidance in recognizing the affordances and constraints of particular social media, and understanding how to maximize the opportunities and mitigate the challenges associated with these media. PSTs who are prepared to effectively navigate professional social media activities could potentially tap more sources of mentorship and support during their critical transition into the profession (Carpenter, 2015; Carpenter, Cook, Morrison, & Sams, 2017; Carpenter & Morrison, 2018; Smith Risser, 2013).

Although this study suggests various types of issues educators can encounter in their professional social media activities, much remains to be learned about the challenges associated with the social media use in education. For example, ways in which educators’ entrepreneurial activities (Shelton & Archambault, 2018) and spam content complicate social media spaces for educators (Carpenter, Koehler, Staudt Willet, & Greenhalgh, 2019) merit further
investigation. Each social media likely presents different challenges when used for professional purposes, and greater understanding of the similarities and differences between social media tools could benefit the field and perhaps inform understanding of how such tools might be effectively used in combination. Furthermore, research that captures the perspectives of educators who have mostly or completely withdrawn or given up on professional social media uses would expand the knowledge base on the challenges of educator learning in digital spaces. Researchers could build on our findings by exploring the degree to which the issues reported by our sample of P.E. and health educators are similar and different to the challenges educators in other content areas experience. Furthermore, while our participants did not tend to focus on challenges associated with particular features of the technologies themselves, future research could explore the extent to which the features of certain platforms limit or exacerbate educator concerns around matters such as context collapse and the nature of discussion in online spaces.

Conclusion

Many educators have taken to social media tools for professional purposes because of how these technologies provide them avenues to engage in a variety of self-directed professional activities with other educators. Given that these activities are typically voluntary, it is logical that educators who participate in them often report benefits or positive outcomes they believe are associated with their social media use. However, educators can experience benefits from their social media use while also encountering significant and thorny challenges. We have sought in this chapter to contribute to the field by identifying such challenges. Awareness of these challenges can help teachers, administrators, policymakers, and teacher educators consider how social media might best be incorporated into educators’ professional practice and what limitations there may be upon what we can reasonably expect as outcomes of professional social media endeavors. While extreme boom and gloom narratives often proliferate in discussions of educational technologies, our findings can be part of a more measured and pragmatic consideration of both the opportunities and challenges associated with social media use by educators.

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Educators on the Front Page of the Internet: Teacher Learning in Four Subreddits

K. Bret Staudt Willet
Michigan State University, United States
staudtwi@msu.edu

Jeffrey P. Carpenter
Elon University, United States
jcarpenter13@elon.edu

Abstract: Accessing and contributing to online spaces have become regular parts of many educators’ professional activities. However, the popular discussion forum website Reddit has received little attention from educational researchers despite the presence of multiple education-related subreddits that have tens of thousands of subscribers and feature thousands of threaded conversations per year. To address this gap in the literature, we gathered data related to one year of activity on four education-related subreddits. Comparative analysis revealed substantial differences among the four subreddits in terms of levels of engagement, sentiment, and network characteristics. Reddit appears to host multiple online spaces that are diverse in nature and might meet or respond to different educator needs. We discuss these findings in relation to the extant literature and consider implications for future research and teacher education practice.

Introduction

A robust body of research has described educators’ professional use of social media—including Facebook (e.g., Kelly & Antonio, 2016) and Twitter (e.g., Rehm & Notten, 2016), but also numerous other platforms—for a variety of professional purposes such as collaborating, experimenting, idea exchange, learning in interaction, combating isolation, professional improvement, reading, and reflecting. Against this backdrop, the platform Reddit has been under-researched—in fact, almost entirely unstudied by educational researchers. Reddit, which bills itself as “the front page of the Internet,” is a website that largely follows the format of Internet message boards and forums. Reddit is a significant presence among social media platforms, with more than 330 million average monthly active users contributing 14 billion average screen views per month, and supporting more than 138,000 active communities, as of November 2017 (Reddit Inc., 2019). Reddit’s features might create unique affordances and constraints for learning spaces and influence the nature of discourse among users in subreddits. The platform’s discussion-forum infrastructure creates threaded conversations of posts (i.e., “parent” comments) and responses, or “children” comments (Hogan, 2017). The further structuring of threaded conversations into subreddits—which the Reddit describes as communities gathered around a topic, but practically are distinct discussion forums hosted on the platform—provides an additional layer of organization that contrasts with a platform like Twitter’s fluid and informal hashtag conversations. The content within subreddits is ordered by popularity, as measured by a scoring system where other users can vote with a +1 (i.e., upvoting) or -1 (i.e., downvoting), based on their evaluation of the contribution.

This study seeks to explore a single research question: What kind of learning spaces can be found on the social media platform Reddit? More specifically, we investigate several education-related subreddits. We build upon and follow recommendations made in earlier research conducted by Carpenter, McCade, and Childers (2018) on a single education-related subreddit: we expand the scope of study to compare and contrast different education-related subreddits—there are numerous ones that have tens of thousands of subscribers and feature thousands of threaded conversations per year—and include additional methods of analysis. More specifically, Carpenter and colleagues’ earlier research used Reddit data spanning 20 days, from which the top 25 posts and top responses to each were analyzed with human-coded content analysis. Here, we seek to establish a broader foundation of educational research on Reddit, so we extend the scope of inquiry to a full year of Reddit data and analyze all contributions (i.e., both posts and responses) to four different education-related subreddits.
Background

Understanding Educators’ Professional Learning in Social Media

Research on educators’ professional growth has often focused on learning that occurs as a result of participation in formal professional development (PD) activities such as district-provided workshops and university-based coursework (Macià & García, 2016). However, professional learning has many forms and purposes (Lieberman & Pointer Mace, 2010), and informal learning activities have long been a part of educator professional growth, even if these have received relatively less attention in the literature. More recently, the rise of social media has created new opportunities for educators to personalize their learning beyond PD encouraged or required by their schools, districts, and licensure regulations (e.g., Carpenter & Krutka, 2014, 2015). A variety of popular social media are used by educators to reach outside their individual schools and districts to share resources, connect, and collaborate with a wider set of colleagues (Carpenter & Green, 2017; Hu, Torphy, Opperman, Jansen, & Lo, 2018; Robson, 2018). In contrast to offline modes of educator informal learning which can prove challenging for researchers to explore, many professional activities that occur via social media also leave digital traces that researchers can study.

Exploring Educators’ Uses of Reddit

Despite the existence of many education-related subreddits, Reddit has received scant attention from researchers in comparison to the literature on educators’ professional uses of other social media such as Facebook and Twitter. Reddit has a number of features that would seem to create unique affordances and constraints for users and influence the nature of discourse in subreddits. For example, Reddit’s infrastructure is that of an online discussion forum, hosting a number of separate, stable, ongoing conversations through the various subreddits. This contrasts Twitter’s more fluid and informal hashtag conversations. In addition, the content within subreddits is ordered by popularity, as measured by a scoring system where other users can vote with a +1 (i.e., upvoting) or -1 (i.e., downvoting), based on their evaluation of the contribution. Finally, Reddit offers anonymity to any user who desires it, and the norm of the platform is for usernames to not be readily identifiable with real people. Potts and Harrison (2013) described the interface of Reddit as a kind of “rhetorical construction” where its features “all work towards building a distinct culture of sharing information” (p. 144). Because of these unique features and the resulting culture of the platform, it seems likely that educators’ activities on Reddit may differ in important ways from their uses of other social media.

Although Chang-Kredl and Colannino (2017) studied how teachers were portrayed on Reddit, only limited investigation of the use of Reddit by educators has been published. Carpenter and colleagues (2018) conducted a qualitative analysis of the top posts and responses to the r/Teachers subreddit, which at the time was the education-related subreddit with the second largest number of subscribers. Analysis suggested that individuals who posted to r/Teachers most frequently engaged in seeking and giving advice related to both technical and emotional aspects of teaching, while top-rated responses sometimes provided advice in line with the nature of the original advice-seeking post, and at other times provided emotional support or advice that reframed the original post. Of note for teacher educators was the presence of pre-service teachers (PSTs) on r/Teachers seeking and receiving various kinds of advice related to teaching and the teaching profession. The limitations of this single study of one education-related subreddit mean that much remains to be understood about what use educators make of the platform and the nature of the learning spaces Reddit supports.

Affinity Spaces as a Framework for Educators’ Uses of Reddit

Researchers have conceptualized educator professional learning via social media in various ways, including the frames of communities of practice (e.g., Wesely, 2013) and professional learning networks (e.g., Trust, 2012). However, because of the particular features of Reddit described in the previous section (e.g., the anonymity offered to users), Carpenter and colleagues (2018) preferred an affinity spaces framework to other lenses. Reddit has described itself as a place where, “every day, millions of people around the world post, vote, and comment in communities organized around their interests” (Reddit Inc., 2019); this would seem to match Gee’s (2004) conception of an affinity space as defined primarily by a common goal, endeavor, or interest. The shared affinity is expressed through the content of the space, and of interest are how users interact directly with that content as well as with each other around
the content (Staudt Willet, Koehler, & Greenhalgh, 2017). Thus we are interested in how educators interact with the content of different education-related subreddits and with each other within these subreddits.

**Method**

Following the precedent of the scant earlier educational research studies on Reddit (e.g., Carpenter et al., 2018; Chang-Kredl & Colamanno, 2017), we used digital traces—that is, those durable and machine-readable records of social life resulting from electronic transactions with social media (Welser, Smith, Fisher, & Gleave, 2008)—to examine educators’ uses of Reddit. We collected these digital trace data using the BigQuery web service (Google Cloud, 2018). In total, we collected 351,301 contributions—114,524 posts and 236,777 responses to those posts—to four different education-related subreddits—r/education, r/Teachers, r/teaching, and r/teachingresources—between July 1, 2017 and June 30, 2018. For this initial exploratory study, we want to examine education-related subreddits that included substantial activity levels and potentially demonstrated different approaches to conversations about education. We chose r/education and r/Teachers because at the time of data collection, they were the education-related subreddits with the most subscribers; r/teaching and r/teachingresources also appeared on Internet lists of top education-related subreddits, although they had significantly fewer subscribers.

Digital traces are a form of observational data and, as a result, are limited in terms of the depth of interpretation they offer. We used R, a “free software environment for statistical computing and graphics” (R Core Team, 2018), to analyze the collected data with a variety of methods to vary our perspective on what we were able to see and thus “thicken” our descriptions of the data (Latzko-Toth, Bonneau, & Millette, 2017). First, we calculated descriptive statistics for contributions and contributors. Second, we used the sentiment R package (Rinker, 2018), with the Jockers-Rinker dictionary of positive and negative words, to calculate a text-polarity sentiment score for each response. Third, we created word clouds of the 100 most common words in each of the four subreddits, after removing numbers and English stop words (i.e., the most common words in a language, such as “the” and “of”). Fourth, we used the igraph R package (Csárdi, 2018) to conduct social network analysis of how contributors responded to each other within a subreddit.

**Results**

Through calculating descriptive statistics for overall contributions to the four subreddits, we found an active percentage which represented the number of contributors to a subreddit in the past year divided by the number of subscribers to that subreddit, as of September 2018. We also found an engagement score which represented the number of responses to questions in a subreddit in the past year divided by the number of threads, or clustered conversations, in that subreddit during the same span of time (Table 1). The data suggest that a large number of subscribers is not necessarily associated with the most active contributors; for example, r/education and r/Teachers had nearly identical number of subscribers, but r/Teachers had more than three times as many contributors in the past year. Similarly, r/teaching had less than half as many subscribers as r/education but almost the same number of contributors. Engagement scores tell a similar story; for instance, the threads of conversation in r/Teachers had on average three and a half times as many responses as those in r/education and r/teachingresources. These findings suggest that those users subscribed to r/Teachers and r/teaching were much more actively involved (i.e., not just watching the subreddit but willing to contribute) than those subscribed to r/education and r/teachingresources.

<table>
<thead>
<tr>
<th>Subreddit</th>
<th>Contributors</th>
<th>Subscribers</th>
<th>Active</th>
<th>Responses</th>
<th>Threads</th>
<th>Engagement</th>
</tr>
</thead>
<tbody>
<tr>
<td>r/education</td>
<td>6,129</td>
<td>70,900</td>
<td>8.64%</td>
<td>23,299</td>
<td>6,258</td>
<td>3.72</td>
</tr>
<tr>
<td>r/Teachers</td>
<td>19,366</td>
<td>71,600</td>
<td>27.05%</td>
<td>190,335</td>
<td>13,739</td>
<td>13.85</td>
</tr>
<tr>
<td>r/teaching</td>
<td>5,436</td>
<td>30,800</td>
<td>17.65%</td>
<td>22,309</td>
<td>2,330</td>
<td>9.57</td>
</tr>
<tr>
<td>r/teachingresources</td>
<td>549</td>
<td>11,500</td>
<td>4.77%</td>
<td>834</td>
<td>294</td>
<td>2.84</td>
</tr>
</tbody>
</table>
Because we wanted to describe what would be considered normal or typical behavior within these different subreddits, we also calculated descriptive statistics related to responses-per-responder (Table 2). Examination of these statistics reinforces our observations from Table 1—the typical user in r/Teachers does indeed contribute more than an average user in the other subreddits, as measured both by mean and median.

### Table 2

**Descriptive Statistics of Responses per Responder**

<table>
<thead>
<tr>
<th>Subreddit</th>
<th>Mean</th>
<th>SD</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>r/education</td>
<td>4.21</td>
<td>13.95</td>
<td></td>
<td>1</td>
<td>488</td>
</tr>
<tr>
<td>r/Teachers</td>
<td>10.80</td>
<td>49.65</td>
<td>2</td>
<td>1</td>
<td>3,170</td>
</tr>
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<td>r/teaching</td>
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<td>8.22</td>
<td>2</td>
<td>1</td>
<td>146</td>
</tr>
<tr>
<td>r/teachingresources</td>
<td>1.82</td>
<td>2.21</td>
<td>1</td>
<td>1</td>
<td>30</td>
</tr>
</tbody>
</table>

We calculated a text-polarity sentiment score for every response to each of the four subreddits. This allowed us to create scatterplots (Figure 1) of the voting score (i.e., the sum of all upvotes and downvotes) of each response (the y-axis) by the sentiment score (the x-axis). Although each subreddit had a range of sentiment scores, r/Teachers had the greatest diversity of voting scores and r/teachingresources had very little; these findings reinforce the theme that r/Teachers had the most active and engaged participants, and r/teachingresources had the least.
We calculated the means and standard deviations of the sentiment scores and voting scores for every response in each subreddit (Table 3). With these statistics, we notice that the average text-polarity sentiment score of responses in all four subreddits are positive and similar to each other, although r/teaching and r/teachingresources are slightly more positive. We also notice that the average voting score of contributions in each subreddit was positive; contributions in r/Teachers had the highest average voting score, r/teaching and r/education were fairly similar, and r/teachingresources were lowest on average. In addition, the large standard deviation for voting scores in r/Teachers suggests that some threads in that subreddit garnered quite a bit of attention in terms of responses.

### Table 3

<table>
<thead>
<tr>
<th>Subreddit</th>
<th>Sentiment Scores</th>
<th>Voting Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>r/education</td>
<td>0.28</td>
<td>0.83</td>
</tr>
<tr>
<td>r/Teachers</td>
<td>0.31</td>
<td>0.75</td>
</tr>
<tr>
<td>r/teaching</td>
<td>0.43</td>
<td>0.83</td>
</tr>
<tr>
<td>r/teachingresources</td>
<td>0.45</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Comparing the word clouds (Figure 2) of the most common words in each of the subreddits (not including numbers or stop words), we notice that many of these words are obviously relevant to conversations about education—for example, “students” and “teachers.” The word “education” appeared frequently in r/education contributions, but surprisingly did not feature prominently in any of the other subreddits. On the other hand, all the subreddits had a high occurrence of “school,” except for r/teachingresources. These differences could suggest that r/education does include more broad conversations about the field of education and that r/teachingresources has more attention paid to the resources themselves rather than what takes place in schools.
Finally, we conducted network analysis of how contributors responded to each other within a subreddit, and we created the network graphs shown in Figure 3 below. We depicted each subreddit contributor with a node (i.e., a dot) and each interaction between two contributors with an edge (i.e., a line). Following Csárdi, Nepusz, and Airoldi’s (2016) recommendation for determining the layout of very large (i.e., more than 1,000 nodes) and disconnected networks, we used the distributed recursive (graph) layout (DrL) algorithm to create the network visualization. We only included contributors who had connected with other contributors in these visualizations, so even nodes that appeared to be isolated dots were in fact connected with an edge. In these cases, what appears to be a dot is two nodes plotted very close together. The centrality of nodes on the plot represents the number of other users interacted with, which means the nodes around the periphery were minimally connected.

The r/Teachers network had a very dense core: more than three times as many nodes as r/teaching and r/education were plotted close together, with several thick spokes coming out to additional node clusters, and very few nodes around the periphery. This could indicate that there were several notable conversation clusters occurring in r/Teachers, where contributors tended to respond to each other with higher frequency within that cluster than with those in other clusters. Because of the lower rate of contributors connected to others in r/education, r/teaching had more nodes depicted in Figure 2 in a denser network core with fewer nodes around the periphery. Finally, the r/teachingresources network had a sparse core, with many nodes around the periphery—users who did not connect to the core and only rarely connected to each other. Thus the visualizations in Figure 3 align with findings reported above indicating that the interaction level was highest in r/Teachers, then r/teaching, then r/education, and lowest in r/teachingresources.
Discussion

Our analysis of four education-related subreddits suggests that Reddit hosts a variety of learning spaces. These subreddits demonstrated characteristics—to varying degrees—of both networks and communities, consistent with Macià and García’s (2016) review of educational research on how educators pursue PD in informal online spaces. Networks provide access to a wide range of useful information, but participation in networks can be spontaneous and unpredictable (Macià & García, 2016). On the other hand, communities are more stable, but access to content can be complicated by interpersonal relations. For example, the r/teachingresources subreddit was characterized by more network qualities, showing lower levels of engagement by a number of different measures, meaning this subreddit may be more focused on the sharing of teaching and learning materials than on discussion of those resources. In contrast, the r/Teachers subreddit seemed to have more community qualities, featuring a high level of interaction in terms of responses, vote scores, and peripheral users’ connections to central conversations—suggesting more active discussion threads. By signaling collective values, Reddit’s voting mechanism may contribute to the development of community because of how it helps build a shared identity around a topic (Wenger, 1998). However, we temper any application of a “community” framework to these subreddits, because while communities are characterized by the commitment of members to each other, Reddit’s anonymity may undermine that commitment in some cases.

Implications for Practice

Our findings have various potential implications for educators and teacher educators at various levels. Despite their anonymity, it may still be the case that some educators derive social and emotional benefits from their Reddit activities. Educators who opt to invest time in education-focused subreddits could feel they can receive useful support from these online spaces, or that they can offer meaningful contributions to their profession through their posts and responses. Furthermore, Reddit’s anonymity might encourage educators to make visible aspects of their practice in ways that benefit other educators (Lieberman & Pointer Mace, 2010).

Teacher educators might benefit from learning the kinds of questions PSTs ask in subreddits, as these questions could reflect practical and pragmatic concerns that teacher education courses and formal PD opportunities neglect. In addition, the power dynamics present between teachers and administrators in charge of PD, PSTs, and teacher educators may mean that there are certain kinds of discussions and content that educators prefer to address in more anonymous contexts—like Reddit—rather than face-to-face settings. For instance, teachers may find Reddit to
be a helpful place to get outside perspectives on internal school politics (Carpenter et al., 2018). Even if the PD and initial preparation available to them were in many ways effective, there may be value and safety in interacting with colleagues from outside one’s immediate professional environment when discussing certain topics. As another example, Carpenter and colleagues (2018) reported on instances in which PSTs queried the r/Teachers subreddit regarding complex matters such as how their identities as PSTs who were transgender or had learning disabilities would impact their interactions with students and school communities. Teacher educators could explore the advice PSTs seek and receive on the r/Teachers and r/teaching subreddits as well as the kinds of materials that are being shared on r/teachingresources.

Additionally, teacher educators could make PSTs aware of education subreddits—either specific subreddits, or education subreddits generally—and the professional affordances and constraints they may present, particularly in comparison to learning in other online affinity spaces. For example, a teacher educator who specializes in preparing secondary English teachers might explore the r/ELATeachers subreddit with their PSTs and compare and contrast the nature of that space to the #nctechat Twitter hashtag space that is facilitated by the National Council of Teachers for English (NCTE). Teacher educators could help PSTs develop critical dispositions toward the advice and materials they encounter on different education subreddits such that they are not unduly influenced by ill-founded ideas or popular but pedagogically unsound teaching materials (cf. Hertel & Wessman-Enzinger, 2017). Teacher educators who become conversant with various education subreddits might be able to offer specific recommendations to PSTs regarding which subreddits to avoid or visit, based on their particular needs. For example, PSTs seeking to gather curriculum materials could be pointed toward r/teachingresources, while those interested in more dialogue or community-like qualities could be recommended r/Teachers. Teacher educators could also make PSTs aware that the r/education subreddit, although including a large number of posts, features comparatively low levels of interaction—especially in terms of response rate to initial posts—and thus may not be a space in which to seek advice.

For educators initiating their own professional learning, these subreddits offer both active and passive forms of engagement in online spaces (Robson, 2018). Educators might find r/Teachers and r/teaching a better fit for connecting with other educators and participating in longer threads of conversation that could offer greater nuance and depth. However, educators who are more focused on finding resources or prefer more passive modes of participation in online spaces could find r/education or r/teachingresources to be compelling despite their different activity patterns. Collaborative processes of knowledge sharing via Reddit may be quite useful to educators, even if they attract fewer responses or votes. Educators bring diverse purposes and motivations to their online professional activities (e.g., Carpenter & Krutka, 2014, 2015), and it may be that different education subreddits can accommodate these disparate needs and interests. The varied nature of the subreddits we studied does raise the question of how educators are to find the online spaces best suited to them. While some educators may be persistent in searching out and testing various online spaces to identify those which are most helpful to them, others might give up on professional social media activities if they do not quickly find the spaces that meet their needs.

**Limitations and Future Research**

With the methods we use in this study, we are unable to fully discuss the content of the contributions to these subreddits. Ranking the top word frequencies and creating word clouds is imprecise and limiting, although a worthwhile inclusion for this introductory study. As a next step, we suggest that future research could implement a structural topic modeling or supervised machine learning approach (see Xing & Gao, 2018); establishing these more robust computational methods would also allow researchers to examine and compare a greater number of additional education-related subreddits. Future research could also combine such content analyses with surveys or interviews that allow educators to explain their purposes for participating in particular subreddits and how Reddit use relates to their other professional learning activities.

**Conclusion**

Reddit is a potentially rich source of informal learning and professional development for both pre-service and in-service teachers that should be of interest to teacher educators. Many PSTs could benefit from guidance regarding how to take advantage of the opportunities and limit the challenges associated with professional use of social media platforms such as Reddit. Teacher education coursework could include activities that help PSTs analyze how different social media might best be used professionally (e.g., Carpenter, 2015; Damico & Krutka, 2017). In the specific case of Reddit, certain subreddits may be more or less hospitable spaces for novice teachers. The challenges
that early-career educators face are well documented, and potential additional sources of online mentoring that could support persistence should be of interest to teacher educators. This exploratory study has built off the existing literature on education-related uses of Reddit, provides teacher educators with considerations for directing PSTs to different subreddits, and offers clear on-ramps to potentially fruitful next waves of research.

**References**


