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FOREWORD

The chapters presented here in the 2020 edition of Research Highlights in Technology and Teacher Education represent some of the finest research from our SITE 2020 Annual Conference. Each paper here has undergone several rounds of rigorous review, and we are pleased to share them with you in this twelfth edition.

These chapters, focused on themes curriculum studies, educator development, and student learning, demonstrate the wide scope of SITE researchers, as well as give evidence of the international representation that can be found within the SITE community. SITE is a society of experts on technology and teacher education, and it is more important than ever to share our expertise with the wider world as we work to improve the preparation of teachers; this year, the world has seen how important it is to prepare educators to be able to teach in blended and online environments.

When SITE had to suddenly pivot to an online conference in April, we missed seeing each other, not only in presentations, but also in the hallways, during beverage breaks, or at the end of the conference day. But if SITE, with the support from AACE, can’t successfully pull off an online conference, I don’t know who can! Building on this success, we hope to finally achieve a goal we have had for years – design events that will keep the SITE members connected in-between the annual spring conferences. SITE Interactive represents this new initiative, and will give us a platform to explore and have rich discussions around the critical topics that need our attention – from emergency remote teaching to the digital inequities that are being even further exposed during the pandemic. The new SITE Interactive event is slated for October 2020 and our annual SITE conference in April 2021.

Finally, we wish to extend thanks to the SITE members who have generously given their time to review, select, and give feedback on these high-quality papers, and to our senior book editors, David Gibson and Marilyn N. Ochoa, who have done so much of the heavy lifting on this project to guide this volume to completion. Enjoy reading this twelfth edition of the Research Highlights in Technology and Teacher Education!

Elizabeth Langran
SITE President
Research Highlights in Technology and Teacher Education 2020

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 fifteen chapters are organized into three themes: (a) Curriculum Studies, (b) Educator Development, and (c) Student Learning.

CURRICULUM STUDIES

This year, four chapters focus on the intersection of technology and curriculum studies.

In 2018, the Netherlands developed a new curriculum framework for primary and secondary education, which included Digital Literacy, defined as a combination of ICT skills, media literacy, information literacy and computational thinking. In “Authentic integration of Digital Literacy in education: development of a new curriculum and assessment tool” authors Petra Fisser, Maaike Heitink and Allard Strijker describe the redesign the national curriculum for digital literacy and the development of a related authentic assessment instrument that can give insight into students’ acquisition and application of digital literacy skills in authentic tasks.

Authors Brian Delaney, Mark Petrovich Jr. and Mikhail Miller discuss the methodological contributions and evaluation findings of a syllabus content analysis for an accreditation self-study report in their chapter “A Content Analysis of Syllabi for Educator Licensure Programs: Tracking Themes for CAEP Accreditation.” The team examined diversity and technology content themes across 143 syllabi in licensure-granting programs. Recommendations and implications for both evaluation and methodological findings are discussed.

In “The Hashtag-Thread Mashup: How Educators Talk to Each Other in Twitter #Edchat,” author K. Bret Staudt Willet explores the social dimension to learning in the nature of Twitter #Edchat conversations given Twitter’s technological features. Through analysis of over a million #Edchat tweets collected over eight months, the author finds evidence of how social interactions in Twitter #Edchat differ in two of the affinity space’s portals, hashtag replies and upstream replies. The implications for educators’ practice and educational research are discussed.

In the theoretically based chapter “TPACK’s Arc of Technology Transparency and Teachers’ Ethical Obligations: Understanding The Digital as the New Materia Medica of Pedagogy” Catherine Adams examines the technoethical obligations for today’s teachers from a perspective in which T-PCK (when a technology is “present-at-hand” or obstinately apparent) to PCK (when a technology has become “ready-to-hand” or transparently integrated into ones teaching and learning practice). The author asserts that teachers are well positioned to critically assess and ethically weigh the benefits and risks of adding a new digital technology to the already complex media ecologies of their students’ lives.

EDUCATOR DEVELOPMENT

Chapters in this section focus on educator development in both humanities and STEM areas.

In “Digital Storytelling through Authoring Simulations with Teacher Moments” authors Garron Hillaire, Laura Larke and Justin Reich discuss their co-design workshop with 12 teacher educators from nine U.S. states as a source of insights for supporting educators authoring digital clinical simulations. They report on how authors set context, select content, and engage in the simulation authoring process to gain insight into supporting teacher educators as digital storytellers.
In “Humanizing Digital Mentorship: Using Video-based Remote Supervision for Student-teachers Abroad” authors Jennifer Rider and Di Ryter examine the use of video-based remote supervision of three student-teachers conducting their 16-week internship in Costa Rica. Three main findings from this study: Iris Connect hardware and software was user-friendly and met the needs for this project; the technology allowed for self-reflection by the student-teachers; and the technology helped student-teachers feel more comfortable receiving and reflecting on constructive criticism from faculty supervisors from their teacher education program.

Steven Chesnut, Daniel Mourlam, Gabrielle Strouse and Lisa Newland write about self-efficacy in “An Investigation into Teacher Candidate Self-Efficacy as a Result of a STEM Professional Development School Program.” The program engages candidates in planning, teaching, and evaluating integrated STEM lessons to elementary students throughout the semester. Data were collected from PDS and non-PDS candidates enrolled in different sections of the same course. A teaching self-efficacy survey was used to measure candidate self-efficacy at the beginning and end of the semester. Data were analyzed using descriptive and inferential statistics. Findings indicated statistically significant increases over time with medium effect sizes for both PDS and non-PDS candidates, however, only PDS candidates experienced a calibration of their beliefs.

In their chapter “Developing Pre-service Elementary Teacher’s Computational Thinking Knowledge Through Coding and Mathematics Pedagogy” Cory Gleasman and ChanMin Kim examine impacts of a course entitled “Block-Based Coding and Computational Thinking for Conceptual Mathematics.” The course aimed to help early childhood and elementary education preservice teachers learn and apply computational thinking concepts to their elementary mathematics teaching. This convergent mixed-methods study of a cohort of 10 participants documents how their computational thinking knowledge changed as a result of the course.

Amanda Thomas and Amy Sokoll Bauer examined perceptions of coding and robotics of 20 preservice teachers in an undergraduate elementary certification program. In their chapter “Robotics and Coding within Integrated STEM Coursework for Elementary Pre-service Teachers” they examined qualitative analysis of written reflections, combined with participant-researcher observations and artifacts of classwork. Findings suggest that the two-pronged approach of integrating coursework and infusing coding and robotics within elementary teacher preparation can lead to positive outcomes.

**STUDENT LEARNING**

Chapters in this section focus on technology-enhanced student learning.

Mark Petrovich Jr., Chris Fornaro, Amanda Barany and Aroutis Foster present a qualitative deductive approach utilizing the Playing Research Method to analyze a player-researcher’s experience in “Game Design Features for Facilitating Identity Exploration: An Exploration of Minecraft EE Chemistry Lab.” They discuss a number of game mechanics with potential for influencing change across players’ knowledge, interests and valuing, regulated actions, self-perceptions and self-definitions.

The theoretical chapter by Katherine L. Walters, Theodore J. Kopcha, Christopher R. Lawton entitled “History Comes Alive”: Implications for Teacher Professional Development on Place-Based Local History” advocates for historical inquiry and the importance of social dynamics and individual perspectives in influencing the stories people tell about the past. Historical inquiry, according to the authors, engages students in thinking and reasoning like an academic historian, offering an approach to history that promotes organizing facts and information to explain the causes and consequences of historical events.

In “Growing up mobile: How do today’s preservice teachers feel about integrating mobile phones in their classrooms?” authors Kevin Thomas, Michael Hylen, and Beth Carter examine the perceptions of 183 preservice teachers in Kentucky and North Carolina to determine their support for the use of mobile phones in the classroom, and their perceptions of phone features useful for school-related work. They identified access to the Internet, use of educational applications, and use of a calendar as the most beneficial. The researchers also found that age and school policy affected participants’ perceptions.
In “Instructional Design and Formative Assessment - Strategies and a Case Study of Teaching Elementary Students Abstract Computational Concepts at Elementary Level,” author Karen H. Jin presents a case study of a weeklong robotic program for grades 3-5 students to illustrate how instructional design and formative assessment strategies are applied to help students learn the computing concept of loops. The report includes information about a novel game-based formative assessment method used to gain insights into students’ learning in a playful and low-stake setting.

Amanda Barany and Aroutis Foster report findings from their research to test and refine Projective Reflection (PR) as a theoretical and methodological framework for facilitating learning in virtual learning environments. In the chapter, “Mapping Identity Exploration of Science Careers using Epistemic Networks,” Epistemic Network Analysis was used to visualize different processes found in three sessions of Virtual City Planning, a play-based course that supported the exploration of environmental science identities mediated by a virtual learning environment (Philadelphia Land Science), and supportive classroom experiences. Results develop theoretical knowledge and illustrate the value of epistemic networks for illustrating identity exploration processes over time.

September, 2020
Senior Book Editors
David C. Gibson
Marilyn N. Ochoa
SITE BOOK REVIEWERS 2020

Youngkyun Baek, Boise State University, United States
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Jana Willis, University of Houston-Clear Lake, United States
Hong Zhan, Embry-Riddle Aeronautical University, United States
Authentic Integration of Digital Literacy in Education: Development of a New Curriculum and Assessment Tool

Allard Strijker  
National Institute for Curriculum Development, The Netherlands  
a.strijker@slo.nl

Maaike Heitink  
Department of Research Methodology, Measurement and Data Analysis  
University of Twente, The Netherlands  
m.c.heitink@utwente.nl

Petra Fisser  
National Institute for Curriculum Development, The Netherlands  
p.fisser@slo.nl

Abstract: The Netherlands started the development of a new curriculum framework for primary and secondary education in 2018. One of the new themes in this curriculum is Digital Literacy, which is defined as a combination of ICT skills, media literacy, information literacy and computational thinking. A teacher design team developed a vision and elaborated this into eight themes. Based on these themes learning trajectories were designed. These learning trajectories describe what students should learn in primary and lower secondary education. For effective instruction that is focused on the improvement of students’ digital literacy skills, measuring or mapping of these skills is necessary. Therefore, this paper describes both the re-design of the new Dutch national curriculum for digital literacy, and the development of an authentic assessment instrument that can give insight into students’ digital literacy skills through the application of these skills in authentic tasks.

Introduction

Many daily activities at home, at school and at work require the use of digital technology and assume the presence of skills that are necessary to be able to participate in today’s society (Kozma, 2008; Voogt & Pareja Roblin, 2012, Fraillon et al., 2014). Although the power of technology in teaching and learning is acknowledged, the appropriate use of technology is not obvious, with much room for improvement in students’ technological skills (e.g., Aesaert & van Braak, 2015; Fraillon et al., 2014; van Deursen & van Diepen, 2013). Hence, many researchers have emphasized the importance of the development of these skills (e.g., Frerejean, van Strien, Kirschner, & Brand-Gruwel, 2016; Van Deursen & van Diepen, 2013), and in many countries formal expectations and standards regarding technology-related skills for students are now formulated in the curricula (Aesaert & van Braak, 2018; Thomas & Knezek, 2008). The Netherlands started the development of a new curriculum framework for primary and secondary education in 2018. One of the new themes in this curriculum is Digital Literacy, which is defined as a combination of ICT skills, media literacy, information literacy and computational thinking. Together with the other subjects (Dutch, Arithmetic/mathematics, English/modern foreign languages, Citizenship, Exercise & Sport, Art & Culture, Human & Nature, Human & Society), Digital Literacy will be part of the new curriculum.

For effective instruction that is focused on the improvement of students’ digital literacy skills, measuring or mapping of these skills is necessary. Assessment of students’ digital literacy skills can provide insight into the extent to which students possess such skills, which in turn can serve as a foundation for teachers and policymakers to make informed decisions about their education. However, research into measuring the actual digital literacy skills of students is still limited (cf. Aesaert & van Braak, 2018; Christensen & Knezek, 2018). Existing assessment instruments are often based on self-perception. Self-perception can result in a biased representation of students’ skills, as the accuracy of these measures depends on the extent to which students are capable of assessing their own skills (Aesaert, Voogt, Kuiper, & van Braak, 2017; Siddiq, Hatlevik, Olsen, Thronsd, & Scherer, 2016). Much research has shown that there are often large differences between students’ self-reported skills and their actual skills (e.g., Allayar, 2011; Hakkaraite et al., 2000; Merrit, Smith, & Renzo, 2005; Siddiqi et al., 2016). Another way in which online information literacy skills are assessed is through traditional paper and pencil tests. These tests also often cause validity problems.
through their lack of authenticity, as it can be confusing to measure ICT literacy through queries on paper (e.g., searching for information on the Internet, opening a website). Measuring the actual skills students need in online information literacy thus requires a different approach.

Therefore, the focus of this paper is twofold: first it will describe the way the Dutch national curriculum was re-designed to include digital literacy, and second it focusses on the assessment of these digital literacy skills, through an assessment instrument in which students need to apply their actual skills in authentic tasks.

Conceptual Framework

Digital Literacy

Although digital literacy is acknowledged as one of the most important 21st century skills, scientific literature does not seem to agree on the definition of these skills. Different terms that refer to different meanings and skills are used interchangeably. What all definition do have in common is that digital literacy is a complex competence with a layered structure (Aesaert & van Braak, 2018; Voogt, Godaert, Aesaert, & van Braak, 2019). Only being able to operate a device is not enough to be digital literate; higher order skills are needed to be able to use technology in daily live. Ferrari (2013) even describes digital literacy as a transversal key competence that is needed to acquire other key competences (e.g. math, literacy, creativity, learning to learn).

Because the context of this study is The Netherlands, the re-design of the Dutch national curriculum and the authentic assessment tool were based on the framework for digital literacy that was developed by Thijs, Fisser & van der Hoeven (2014) at the National Institute for Curriculum Development (SLO). This framework was developed based on an exploration of recent national and international literature, combined with a consultation with experts in the field, teachers, administrators, and policy makers.. The domains for digital literacy that are described in this framework match well with well-known international frameworks for digital literacy, for example DigComp 2.1 (Carretero, Vuorikari & Punie, 2017).

Digital Literacy was defined as a skill that relates to using ICT effectively, efficiently and responsibly. It involves a combination of (basic) ICT skills, computational thinking, media literacy and information literacy, as shown in Figure 1:

![Figure 1. The four components of digital literacy (Fisser & Strijker, 2019)](image)
The four components were described as (SLO, 2020):
- ICT basic skills (IB) includes the knowledge of basic concepts and functions of computers, the ability to identify, connect and operate hardware, the ability to deal with standard office applications (word processors, spreadsheets and presentation software), the ability to deal with software programs on mobile devices, the ability to use the internet (browsers, e-mail), and to be aware of and deal with security and privacy issues.
- Computational thinking (CT) is about using think processes that involve problem identification, and the organization, representation and analysis of data that are used for finding solutions for problems while using ICT techniques and tools.
- Media literacy (ML) is about the knowledge, skills and attitudes necessary for conscious, critical and actively working with media. Next to the ability to understand how media work and how they influence what we see, it is about the ability to create content, participate in social networks, and to reflect on your own media use.
- Information literacy (IL) is the ability to identify and analyze a need for information and based on this to be able to search, select, process, use, and present relevant information.

The Development of the New Dutch Curriculum

In November 2014, the State Secretary for Education, Culture and Science of the Netherlands officially launched an online country-wide consultation about the future of primary and secondary education. Everyone in the Netherlands had the opportunity to take part: students, teachers, parents, researchers, educational scientists, representatives of the business community, etc. Using social media and the hashtag #onderwijs2032 [education2032], over 16,000 people contributed their ideas on what the young students of today should learn if they are to be productive members of society in the year 2032. In January 2016 an independent committee presented the final version of the report to the State Secretary of Education, Culture and Science. Next to the importance of specific content domains such as Language, Science, Numeracy and Social Studies they concluded that Citizenship and Digital Literacy should also be part of the formal curriculum (Platform Onderwijs2032, 2016).

It took a year to discuss the report with several stakeholders and for parliament to make decisions about the way to proceed, but in 2018 the process to develop a new curriculum for primary and secondary education started. It was decided that the new curriculum will consist of nine subjects: Dutch, Arithmetic/mathematics, English/modern foreign languages, Exercise & Sport, Art & Culture, Human & Nature, Human & Society, Citizenship, and Digital Literacy. All stakeholders agreed that a feeling of ownership is needed to make the eventual implementation of the new curriculum successful. For that reason, the new curriculum was not designed by the Ministry of Education and curriculum experts only, but for the development process 125 teachers, 18 school leaders and over 80 schools were recruited to work on the corner stones for the new curriculum. For each subject a teacher design team was formed to work on a subject. The nine teacher design teams worked together in eight three-day sessions to create a vision for each subject, design big ideas and corresponding learning trajectories for the big ideas1.

For Digital Literacy a teacher design team (TDT) of 12 teachers and 4 school leaders were recruited from primary, secondary and special needs education. The team was guided by a member of the national institute for curriculum development and a process leader. Next to this five schools for primary education, five schools for secondary education and one institute for teacher training were recruited to give feedback on the work of the TDT. The feedback focused on the usability of the products and was gathered from teachers, parents and students.

1 It is important to note that this is still work in progress. The learning objectives and learning trajectories are still concept versions.
Vision and Position

The first step for the TDT was to develop a vision on Digital Literacy. They adopted the framework for digital literacy developed by Thijs, Fisser & van der Hoeven (2014) and indicated that Digital Literacy is the combination and whole of ICT-basic skills, media literacy, information literacy and computational thinking. The TDT stated that students are digitally literate if they can use digital technology, digital media and other technologies required to access information in a conscious, critical, and creative way, in order to take actively part in the contemporary and future (knowledge) society (Ontwikkelteam Digitale Geletterdheid, 2019).

This raised the question where Digital Literacy should be situated in the curriculum. Should it be a separate subject? Or should it be integrated into the other subject domains? The TDT concluded that Digital Literacy should be both a separate subject and a cross-curricular subject. Similar to the fact that digital technology is embedded in day to day life, Digital Literacy should be embedded in the different subjects at school, because these subjects provide the context in which students live and learn. But next to the integrative part students need a sound knowledge base, basic skills, and mastery of specific skills. Therefore, the TDT concluded that special attention for Digital Literacy in a separate subject is needed, as are specialized teachers to teach this relative new subject (Ontwikkelteam Digitale Geletterdheid, 2019).

From Vision to Big Ideas

Big ideas are broad statements that frame what students will learn (Government of Alberta, 2019). Based on literature on Digital Literacy, examples of foreign curricula, and consultations with a number of experts six big ideas were described by the TDT as examples of the essence of the learning area of Digital Literacy: (1) data and information, (2) security and privacy in the digital world, (3) the operation and use of digital technology, (4) digital communication and collaboration, (5) digital citizenship and (6) digital economy.

For each of the big ideas, descriptions are given. For instance, within the first big idea "data and information", the importance of the growing volume of data, storage and digital access is described. Students need to learn how to collect relevant information based on their own information need. They have to learn to use suitable (combinations of) digital applications, but they also have to know how to filter the large amount of available data, and to interpret that information in order to create new knowledge. Important to note is that all big ideas are equal to each other, there is no priority or order. However, it could be that while keeping the stage of development of the students in mind (age, primary or secondary education, regular or special needs education) one big idea will get more attention in one phase of the curriculum and the other big idea in another phase of the curriculum.

From Big Ideas to Learning Objectives

For each of the big ideas a set of learning objectives was defined for primary education (PE) and lower secondary education (SE) (Curriculum.nu, 2020):

<table>
<thead>
<tr>
<th>Data and information (IB, ML, IL, CT).</th>
</tr>
</thead>
<tbody>
<tr>
<td>From data to information</td>
</tr>
<tr>
<td>PE: students learn how to search for information, selecting and presenting with the use of digital technologies. They learn how to formulate questions that computers can understand.</td>
</tr>
<tr>
<td>SE: students learn to make a conscious choice from available digital resources to search, select and present information, they also learn about copyright.</td>
</tr>
<tr>
<td>Digital data</td>
</tr>
<tr>
<td>PE: students learn what is digital data, what the importance is of data, how digital technology uses data and how they themselves can deal with digital data.</td>
</tr>
<tr>
<td>SE: students learn how digital technology can help them dealing with large amounts of data and the value of data for use in society and the economy.</td>
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<tr>
<td>Security and privacy in the digital world (IB, ML, CT).</td>
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<tr>
<td>Security</td>
</tr>
<tr>
<td>PE: students learn that their personal data are stored in different places, they learn how they can ensure that their data is safe and what to do if something goes wrong.</td>
</tr>
<tr>
<td>SE: students learn how abuse of data can occur through uncareful behavior and security, they learn that companies and institutions can have security issues.</td>
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<tr>
<td><strong>Privacy</strong></td>
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<tr>
<td>---</td>
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<tr>
<td><strong>The operation and use of digital technology (IB, ML, CT).</strong></td>
</tr>
<tr>
<td>Controlling and creation PE: students learn that people use digital technology, they learn the basics of programming and use applications to solve problem. SE: students learn programming in order to solve complex problems they meet with ai and robotics and learn to think about the value of technology for their personal lives and society.</td>
</tr>
<tr>
<td><strong>Digital communication and collaboration (IB, ML, IL, CT).</strong></td>
</tr>
<tr>
<td>Communication PE: students learn how digital communication works and use it effectively with others to communicate, they learn to deal responsibly with social media. SE: students learn the importance of digitally communicate for themselves, others and society, they learn to have an eye for the interests of individuals and of society.</td>
</tr>
<tr>
<td>Collaboration PE: students learn how to work together with the support of digital technology, they also collaborate remotely or asynchronous, they learn to work with collaborative applications. SE: students learn what the importance of digital work means for themselves, others and the society. They learn that collaborate devices can work together and what the added value can be.</td>
</tr>
<tr>
<td><strong>Digital citizenship (IB, ML, IL).</strong></td>
</tr>
<tr>
<td>Digital identity PE: students learn that the way someone presents online is not required to match with reality and how they can handle that, they learn to present themselves online. SE: students learn that a good online presentation offers opportunities in the social and professional field. They learn to exploit opportunities and deal with the risks of unwise use.</td>
</tr>
<tr>
<td><strong>Digital economy (IB, ML, IL, CT).</strong></td>
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<tr>
<td>Digital marketing PE: students learn how digital marketing works, what possibilities does this and what disadvantages may entail. SE: students learn to recognize techniques and revenue models of digital marketing. they learn to think about the impact of digital marketing on their own identity and how they see society.</td>
</tr>
</tbody>
</table>

**Table 1. Learning Objectives**
From Learning Objectives to Learning Trajectories

In order to help teachers from primary and secondary education to teach the concepts of Digital Literacy key stages or learning trajectories have to be designed. Learning trajectories are defined as "a reasoned structured set of intermediate objectives and content leading to a certain core objective" (Strijker, 2010, p. 10). Learning trajectories not only give clarity about the core objective, but it also gives the opportunity to personalize learning by adjusting learning goals and related learning activities to the possibilities of the learners. For primary education two levels were defined to design intermediate objectives for: Stage 1 (age 4-8) and Stage 2 (age 9-12). This continues into lower secondary education with Stage 3 (age 12-14) and higher secondary education Stage 4 (age 15-18). This means that the learning trajectory for Digital Literacy contains four stages of learning objectives that all cover a specific period of ages. To give an impression of how such a learning trajectory looks like, we give an overview of the learning trajectory "data and information":

<table>
<thead>
<tr>
<th>Stage 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children explore the (digital) world around them and learn how they can use their curiosity in the search for information that can help them further in understanding the world. The students learn:</td>
</tr>
<tr>
<td>- to make explicit what they want to know;</td>
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<tr>
<td>- to think of useful questions to extend their knowledge;</td>
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<tr>
<td>- to deal with (digital) resources and several types of media messages and their purposes such as advertising, information, and amusement in a safe environment;</td>
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<tr>
<td>- to use and search within (digital) resources and media to find answers for their questions;</td>
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<tr>
<td>- to represent the information they found;</td>
</tr>
<tr>
<td>- to evaluate the process of searching and findings and explicit their learnings.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage 2</th>
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</thead>
<tbody>
<tr>
<td>Building on Stage 1 the students learn to deal with more general information. They learn that the information gathering is a process with several steps. The complexity increases and the digital component is more important. Media is used as a digital resource. Students will focus on target groups and the possibilities for presentation offered by digital technologies. Students learn:</td>
</tr>
<tr>
<td>- to identify their need for information and to formulate relevant questions;</td>
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<tr>
<td>- to identify the (digital) information resources that are relevant to use for answering questions;</td>
</tr>
<tr>
<td>- to formulate, select, combine relevant terms for searching information;</td>
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<tr>
<td>- to collect and evaluate information from several digital tools and resources and decide if the found information is useful and reliable;</td>
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<tr>
<td>- to recognize facts and meanings from media messages, and how messages can be affected by using specific words, visualization or audio messages;</td>
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<tr>
<td>- to select information and systematically save the information in a digital environment;</td>
</tr>
<tr>
<td>- that information is owned by someone and may not be used freely by everyone;</td>
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<tr>
<td>- to present information with digital technologies, taking into account the public for which the presentation is intended and making use of the possibilities of digital technology;</td>
</tr>
<tr>
<td>- to evaluate the process of information acquisition, processing and presentation and to review the end-product based on a number of criteria and reflect on the entire process;</td>
</tr>
<tr>
<td>- to see the relationship between concepts from digital information processing and computational thinking.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage 3</th>
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<tbody>
<tr>
<td>Stage 3 builds upon stage 2 and students learn more about the possibilities of digital technology and about the creative use of these technologies in the process of information acquisition, processing and representing. They also learn to deal with the limitations of technologies. The topics that they learn will become more abstract and are more and more related to study, profession or social developments. Students learn:</td>
</tr>
<tr>
<td>- to explore and articulate the information needs of others;</td>
</tr>
<tr>
<td>- to choose a different search strategy, should the chosen strategy give no or insufficient results;</td>
</tr>
<tr>
<td>- how digital search technology works and continues to innovate by exploiting the characteristics of search technology, and they learn how to cope with the possibilities and limitations of digital search technology;</td>
</tr>
<tr>
<td>- how to interpret, analyze, and summarize information, and to explain their reasoning in relation to the way they answer the information need;</td>
</tr>
<tr>
<td>- how to manage the sources they found (give references, ask permission), and that there are legal conditions for using sources of others;</td>
</tr>
<tr>
<td>- to choose an appropriate form of presentation, using the strength of different types of media;</td>
</tr>
</tbody>
</table>
to formulate and apply criteria in order to assess the form of presentation on relevance, usability and reliability;
- to apply concepts from computational thinking in the process of acquiring digital information;
- to evaluate their own process of acquiring digital information and that of others and relate this to their future study and profession;
- to reflect on the role of information acquisition, processing and representing and its role in society, businesses and professions.

**Stage 4**

Stage 4 is the part of education in which students do their exams in upper secondary education. The complexity of renewing the national exam documents and procedures without explicitly knowing how Digital Literacy will be part of the new curriculum (that still has to be implemented!) was a problem that could not be solved in the current development process. The TDT decided to give recommendations instead on how to continue working on the skills and knowledge from Stages 1 to 3. The TDT recommends that Digital Literacy
- should be part of the official (legal) final terms of secondary education;
- should be integrated in the subjects to contextualize and apply Digital Literacy in the different domains;
- should be integrated in the subjects to make sure that the students can deepen and widen their knowledge and skills, so they can become advanced users of digital technology, with as ultimate goal that all students are digitally literate and are prepared for their follow-up study and (future) job;
- should be part of computer science, an optional course in Dutch upper secondary education, to enable students to learn more expert knowledge and skills.

**Table 2. Four Stages Learning Trajectory**

**The Development of an Authentic Assessment for Digital Literacy**

The preliminary learning trajectories and corresponding learning objectives were used to develop an authentic assessment tool. The design and development process were derived from a framework for designing and developing multimedia-based performance assessments (De Klerk, Eggen, & Veldkamp, 2015) and a four-step procedure for designing ability tests (Roid, 2006). The design of the digital environment consisted of the following stages: (1) defining assessment criteria, (2) conceptualization and operationalization of online information literacy, (3) design of authentic assessment tasks and the assessment environment, (4) determining assessment output and scoring, (5) small pilot, (6) development of final prototype. The development of the environment was carried out simultaneously with the design. This means that the software developer was involved from the beginning, in order to have the opportunity to review parts of the assessment environment (with their expected functionalities) and the design of the corresponding database in their early stages and to make sure the developed ideas were feasible. Teacher educators co-designed assessment tasks. An assessment expert reviewed the tasks and, when necessary, the resulting tasks were adjusted to satisfy criteria for effective item design (Haladyna, Downing, & Rodriguez, 2002; Welch, 2006) for the specific target audience. Furthermore, reviews by experts, teachers, mini try outs by students and revisions were carried out after each stage in order to foster the validity and practicality of the assessment, resulting in changes to the assessment environment throughout the process.

This resulted in an authentic assessment environment which included different contexts in which students had to apply their digital literacy skills in authentic tasks. As is inevitable with generic and complex constructs like digital literacy, all domains are connected because they overlap at some points or include skills that refer to other domains. Likewise, in practice students use the skills described in the separate domains in an integrated way. This makes students’ technological skills dependent on the context and content, implicitly situated in the knowledge and attitudes that underlie students’ actions in day-to-day situations (cf. Heitink, 2018). Therefore, the assessments focused on performing tasks in a specific context. One context focused on creating a digital product (help with creating a website about Bolivia, see Heitink, 2018 for an elaborate description and results) and one context focused on applying digital literacy skills in social media (this assessment was called Spacebook, publication in preparation). The results of Spacebook will be shortly described here. Specific tasks related to safety and privacy, collecting and evaluating digital information, processing and presenting digital information, and computational thinking. Spacebook included, among others, the following elements: create a social media account, think about how to protect your personal information, search for information on the internet, create a photo story, think about which information you would like to share and with whom, solve a problem by using digital technology.

A notification system was used to administer the assessment tasks to the test-taker through a plausible narrative. During the assessment, students were able to search the web for information. Since digital literacy is
assessed in a digital environment, also information extracted from the process of responding to the items was logged. The environment can provide us with information about how fast the candidates responded, whether their strategy was accurate, if they changed their responses often, and so on.

Spacebook was piloted by 746 Dutch students (373 boys and 373 girls, mean age = 12, SD = 1.04) from 16 upper primary and lower secondary schools that responded to a national open call. Table 1 shows an overview of the participating students for every educational level.

<table>
<thead>
<tr>
<th>Educational level</th>
<th>Primary education Grade 5</th>
<th>Primary education Grade 6</th>
<th>Pre-vocational education</th>
<th>Pre-university education</th>
</tr>
</thead>
<tbody>
<tr>
<td>N students</td>
<td>121</td>
<td>281</td>
<td>182</td>
<td>162</td>
</tr>
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</table>

Table 3. Participating Students per Educational Level

Trained assessment leaders went into the schools to administer the assessment. These leaders brought all necessary materials with them to make sure all students were assessed in the same way. The study was approved by the Ethics board of the University of Twente. Spacebook included 18 tasks for digital literacy with an acceptable reliability ($\alpha = 0.67$). All students finished the assessment and students experienced the assessment predominantly as fun and user friendly. IRT analysis indicated that one task hardly discriminated between low scoring and high scoring students. Therefore, this task was excluded for analysis. To be able to compare Grade 5-6 students from primary education with the pre-vocational students and pre-university students from secondary education, the advice of the teacher regarding the educational level for secondary education was used. In this advice the teacher gives a prognosis on the estimated educational level in secondary education.

This study showed that students from different educational levels differed in their digital literacy skills. Students from pre-university education scored significantly higher than students from other educational levels (14.1 points out of 17, SD = 2.06). Grade 6 students scored 12.6 points (SD = 2.79), which was significantly higher than Grade 5 students (11.9 points, SD = 2.48). Pre-vocational education students scored 12.1 points (SD = 2.64), which did not significantly differ from the scores of Grade 5 and Grade 6 students. However, looking more closely to the data reveals large differences between students’ performances within educational levels. Figure 2 shows how the educational levels of students are distributed through four quartiles. In this figure, Quartile 1 represents the 25% of students that scored the least and quartile 4 represents 25% of the students that scored best.

![Figure 3. Distribution of educational level per quartile of total sample. Quartile 1 represents the 25% of students that scored the least and quartile 4 represents 25% of the students that scored best.](image)

This figure shows that the 1st and 2nd quartile (least skilled students) mostly consist of pre-vocational education students and primary education students with a pre-vocational education advice. Pre-university education students are mostly represented in the 3rd and 4th quartile (most skilled students). Additionally, the figure shows that
all educational levels are present in every quartile. This means that there are students from Grade 5, Grade 6, pre-vocational education and pre-university education that belong to the weakest students and that at the same time all these educational levels also hold high scoring students. This illustrates that there is a large spread of digital literacy skills within educational levels. Therefore, we looked into the specific tasks that were done predominantly correct by students that scored within different score ranges. This showed that students in the lower scoring groups only scored relatively well on tasks related to finding online communities and sharing personal information. Only high scoring students scored well on tasks that were related to finding the right information on the internet, evaluating the reliability of online information, safety (e.g. making a strong password), ethics and computational thinking. An overview of this is shown in Figure 4.

![Figure 4. Levels for digital literacy based on predominantly correct performed tasks.](image)

The digital assessment environments proved to be a valuable approach to determining students’ digital literacy skills. The way data that was gathered is a first step towards identifying weak skill domains for students, which can ultimately be used to inform teachers and students about students’ online information literacy, and the assessment can be integrated with teachers’ instruction and students’ learning processes. The results of this study suggest that it is important to obtain detailed insights into the various skill domains of students’ digital literacy skills to prevent a possible digital divide between students from different educational levels. However, to be able to generalize the results it would be desirable to further extend the assessment to be able to study the use of digital literacy skills in other contexts as well, and pilot this with a representative sample. Additionally, follow-up research should also pay attention to in what way students have the opportunity to learn digital literacy (curriculum, how much time, at what age). Another step forward is to study the extent to which log-data adds to measuring digital literacy and how this data can be taken into account in a scoring model.

When we consider the test score as indicative for the initial situation that teachers encounter when introducing digital literacy, these results show that students can differ greatly in their prior knowledge and skills that relate to digital literacy. These differences between students occur in each of the educational levels studied. Based on these findings, we conclude that teachers can encounter an extremely complex initial situation with a large range of differences in students’ skills when introducing digital literacy. When considering students’ digital literacy skills, we should be aware of the rapidly changing nature of the digital world. Technological innovations often offer new possibilities for teaching and learning in the classroom, with the consequence that some skills disappear, and new skills are required (ACARA, 2017). To offer relevant educational experiences for their students with technology, teachers should be able to respond to these changes in society. This is important from the perspective of teaching with technology as well as teaching about technology.
References


A Content Analysis of Syllabi for Educator Licensure Programs: Tracking Themes for CAEP Accreditation

Brian Delaney
Mark Petrovich Jr.
Mikhail Miller
Drexel University School of Education, United States
bcd48@drexel.edu
mep64@drexel.edu
mm4879@drexel.edu

Abstract: This paper communicates the methodological contributions and evaluation findings of a syllabus content analysis aimed at strengthening one school of education’s self-study report for first-time CAEP accreditation. In a compressed time frame, the evaluators identified the presence or absence of two cross-cutting themes, diversity and technology, across 143 syllabi in licensure-granting programs. Inconsistent levels of diversity and technology-as-content were found, and efforts to increase validity and reliability are documented. Recommendations and implications for both evaluation and methodological findings are discussed.

Introduction

This paper conveys the methodological process, rationale, and findings for a content analysis of syllabi for licensure-granting teacher education programs in a school of education housed within a large, private, urban four-year institution of higher education in the Mid-Atlantic United States. This evaluation report was commissioned to help the evaluand — the school of education — prepare to submit a self-study report (SSR) in winter 2020 as part of the Council for Accreditation of Educator Preparation (CAEP) accreditation process. A CAEP Steering Committee comprised of administrators, faculty, and staff was created to conduct the accreditation preparation work. Following a review of CAEP standards and requirements for technology and diversity within educator preparation programs (EPPs), the steering committee identified a gap in evidence concerning how these themes are addressed and assessed in the preparation and learning progression of initial and advanced candidates in school of education programs (Foster, 2019; Lewis Grant, 2019). In gathering evidence to support alignment with CAEP standards for the cross-cutting themes of diversity and technology, the CAEP Steering Committee recommended a syllabi analysis to uncover the extent to which the themes were addressed and assessed.

The purpose of this report is to identify and evaluate evidence pertaining to the cross-cutting themes of diversity and technology across syllabi in three licensure programs. This report discusses the methods utilized in a compressed timeframe to analyze syllabi at the course and program levels for evidence related to candidate learning and completer preparedness in diversity and technology. The resulting outcomes of this study will aid school leaders in developing a comprehensive understanding of the varying degrees of presence of diversity and technology in their licensure-granting degree programs. This paper will also inform peer EPP institutions in three specific ways: first, it will offer a rigorous design for conducting a large content analysis in a compressed time frame (eight weeks); second, it will highlight how technology can be both present and absent from syllabi in obscure ways; and third, it will detail how schools can enact quality assurance and continuous improvement methods with regards to curricular improvement.

Diversity and Technology Themes in Syllabi

The evaluand serves over 1,300 students across face-to-face, blended, and online programs at the undergraduate, masters, and doctoral levels. As part of its mission, it seeks to develop students into organizational leaders that can educate diverse populations (About Us: Drexel University School of Education, n.d.). The broader scope of this mission seeks to extend high-quality education, as a result of continuous teacher education and
improvement, to children within the surrounding metropolitan area and beyond to ensure deep and lasting impacts within schools nationwide.

Multiculturalism, Community Teachers, and Teacher Education Programs

Culture directly influences learning environments both inside and outside of schools, and thus uniquely impacts the developmental arc of students at the individual level (National Academies of Sciences, Engineering, and Medicine, 2018). Students’ ethnic, racial, religious, linguistic, physical, cognitive, and socioeconomic diversities contribute to their knowledge acquisition and meaning making processes. Teacher education accreditation organizations have responded to this dynamic by emphasizing diversity to their membership schools in multiple ways: one, through multicultural courses; two, by embedding multicultural content throughout their curriculum; three, through adding diverse administrators, faculty members, and staff; and four, by increasing community-school relations (Yuan, 2018). Teacher education scholars have encouraged a community teacher framework, in which teachers engage in the communities of their students to deepen their cultural and community understandings in ways that can inform pedagogy (Murrell, 2001; Yuan, 2018; Zeichner & Payne, 2013). A study (Cherng & Davis, 2019) of 2,500 preservice teachers found that Black and Latinx candidates reported greater multicultural awareness than white preservice teachers, while higher multicultural awareness was “tied to candidates’ competence in creating nurturing classroom environments” (p. 219). Teacher education candidates must unite multicultural and community knowledge with an understanding of education technologies, their potential classroom fit, and their student’s ability to access them.

The Importance of Technology in Course Syllabi

The rapid development of technologies has necessitated an ongoing change in education. Students must become digitally literate citizens capable of adapting to an ever-changing society in preparation for jobs that may not currently exist (Fraillon et al., 2014). As a result, schools and instructors are all but required to meaningfully include technology within teaching and learning curricula (Siddiq et al., 2016). Despite this, questions still remain regarding the extent to which technology education is successfully integrated into courses broadly. Mishra & Koehler (2006) address some of these issues as they suggest technology integration in the classroom is a complex, multifaceted, and situated issue of teacher knowledge (i.e. technological knowledge, pedagogical knowledge, and content knowledge) (Koehler & Mishra, 2009). Arballo and colleagues (2019) highlight the importance of teachers’ technical and professional skills in addition to generic digital technology skills required to understand and adopt technologies. In lieu of these technological requirements, course syllabi and curricula have traditionally offered a guide in which teachers may follow to achieve predetermined goals. In addition, it’s been noted in policy-based research that course syllabi provide a basis for drawing inferences from supplementary instructional materials, course intentions, and curricula (Tekir & Akar, 2019). As such, the presence or absence of technological elements in the course syllabi under examination in this study provide perspective on the extent to which technology is being integrated into courses and curricula within this School of Education.

Content Analysis for Syllabi Evaluation

The course syllabus is a valuable source of data that provides detailed descriptions of the course content and teaching methods (Brown et al., 2013). It introduces students to courses typically during a time when they need to decide whether to add, drop or remain in those courses (Savaria & Monteiro, 2017). It also acts as an academic contract between the course instructor and the students, is a permanent record of academic history and may be used as a learning tool to facilitate student success (Harnish & Bridges, 2011; Parkes & Harris, 2002; Savaria & Monteiro, 2017). An effective syllabus uses language that clearly shows the required academic components that contribute to the overall grade in a course, motivates and engages students and allows students to incorporate their ideas into course activities (Harris, 1993; Popov et al., 2012; Savaria & Monteiro, 2017). When analyzed at the program level, course syllabi reveal the contents and arc of a curriculum that culminates in a credential. In the era of accreditation, it has become common practice for educators to conduct a content analysis of syllabi at the discipline, program, department, or university levels in order to better understand the scope of teaching and learning taking place (Brown, Charlier, Rynes, & Hosmanek, 2013; Griffith, Domenech Rodriguez, & Anderson, 2014). This report highlights areas in the school of education course syllabi for selected programs where themes of diversity and technology are prevalent or lacking.
Content analysis is a method for identifying trends and patterns in syllabi (Stemler, 2001). Numerous studies have demonstrated its usefulness as a research method for identifying themes in syllabi (Eberly, Newton, & Wiggins, 2001; Ezzy, 2002; Griffith et al., 2014; Pugach & Blanton, 2012). It was these examples of syllabi content analyses, among others, that provided evidence that a content analysis approach would best identify the presence or absence of diversity and technology.

Research Questions

In order to identify evidence to support candidate preparation through the cross-cutting themes of diversity and technology, several research questions were posed:

RQ1. How are diversity and technology conveyed in syllabi across EDAM, EDEX, and EDUC programs within the evaluand?

RQ2. How is diversity conveyed in syllabi in specific programs (e.g. EDUC, EDAM, and EDEX) within the evaluand?

RQ3. How is technology conveyed in syllabi in specific programs (e.g. EDUC, EDAM, and EDEX) within the evaluand?

Methods

The evaluand operates on the quarter term system, offering 10-week courses across two dozen programs during the Fall, Winter, Spring, and Summer quarters via face-to-face, blended, and online modalities. Three researchers conducted a multi-method content analysis of syllabi from three education programs: Educational Administration (EDAM), Special Education (EDEX), and Teacher Education (EDUC). Educational Administration is a graduate degree program, while Special Education and Teacher Education both offer degrees at undergraduate and graduate levels. Each syllabus was pulled from its master course shell. A total of 143 syllabi were analyzed across the three programs: EDAM (n=23), EDEX (n=41), and EDUC (n=79). The three selected programs deliver outcomes resulting in licensure for graduates.

Manifest content analysis informed the research design. It is a method of “analyzing text by counting the frequency of words or phrases” (Roessger, 2017, p. 214; McBurney & White, 2010). This study’s content analysis counted the presence or absence of two cross-cutting themes — diversity and technology — across 14 common sections in 143 syllabi. The design was constructed in consultation with the evaluand’s Director for Assessment and Accreditation to best address the research questions.

The 14 common syllabus sections were course description, course learning objectives, course materials, course assignments, and (10) weekly course schedules. The research team reviewed each section in each syllabus to identify the presence or absence of diversity and technology. Researchers added one technology subcode for discussion boards. This was created because the majority of SOE courses are delivered online, which meant technology was inherently present in each course. Separating discussion boards from non-discussion board themes helped the researchers gauge a deeper understanding of technology’s utility and relevance within school of education licensure programs. Researchers looked for exemplars that aligned with the CAEP Steering Committee’s definitions for diversity and technology (Appendix A). Exemplars were either explicit (“diverse classrooms”) or implicit references (“inclusive classrooms”) to those themes.

Coding Protocol

Coding protocol was straightforward. If a theme was identified in one of the 14 sections of a syllabus, it received a coding of 1. If a section did not contain a cross-cutting theme, it was coded 0. If the category did not exist in that particular syllabus, it was coded 99. The presence or absence of codes were based not just on keywords (e.g. diversity, technology), but also the content contained within course materials, assignments, and additional syllabi sections. The coding protocol emphasized rater agreement to better achieve construct validity. In the context of a content analysis, construct validity is the degree to which codes accurately capture the intended phenomenon (Potter & Levine-Donnerstein, 1999). A common approach to strengthening validity is creating a systematic protocol for verifying codes. Such a process was used in this study. A visual summary of this process can be viewed in Figure 1. The 143 syllabi were split into three blocks, one per researcher. Each researcher then conducted a Round 1 coding
The R1 coding was conducted directly in each syllabus document using text highlighter and comment functions. When the R1 coding was complete, the researchers rotated to a subsequent block of syllabi to review their colleague’s R1 codes. This initiated a second round of coding (R2), during which each researcher reviewed R1 codes for agreement or potential omissions. Any disagreements or omissions were logged in a separate document. The researchers then met one-on-one to discuss those discrepancies in search of consensus. If consensus was not achieved, the third researcher made the final decision. Dozens of initial disagreements were settled through one-on-one discussion without requiring input from the third researcher. Once R2 coding was complete, the researchers logged the confirmed codes into a spreadsheet, then verified the accuracy of the spreadsheet data. If necessary, a third round of coding was utilized to address disagreements between two R2 coders. A third coder was asked to provide insight to the disagreement which would inform the final decision. This occurred only once over a total of 10,010 coded sections across the syllabi. The final spreadsheet was then uploaded into SPSS for analysis. Analyses were conducted across and within the three programs, and by theme. The researchers also discussed qualitative observations from the coding process and established agreement on emerging themes that necessitate further examination.

Due to the compressed time frame (8 weeks) in which the research team had to complete this evaluation, the above coding protocol was utilized as a replacement for more traditional interrater reliability protocols. Whereas traditional interrater reliability would require that both reviewer 1 and 2 review the entirety of the 46 syllabi in the R1 phase, reviewer 2 was instead asked to check reviewer 1’s existing codes and address any perceived discrepancies or omissions. This adaptation enabled a shortened coding period and quicker movement to data analysis and construction of the final report, while ensuring the integrity of a rigorous coding process.

Figure 1: Coding protocol utilized in identifying themes of diversity and technology in course syllabi (n=143).
Findings

RQ1: Findings Across Programs

A total of 143 syllabi were analyzed for their cumulative occurrences of diversity, technology, and discussion boards across Educational Administration (n=23), Special Education (n=41), and Teacher Education (n=79) programs. This section will address the first research question:

How are diversity and technology conveyed in syllabi across programs within the evaluand?

Syllabi from undergraduate level syllabi accounted for about a third of the total (n=52), while graduate level syllabi accounted for the remaining two-thirds (n=91). Occurrences of diversity and technology were tracked across the major syllabus sections (e.g. course descriptions, learning objectives, course materials, assignments/assessments, and weekly course objectives).

Overall, roughly a quarter (n=38) of the 143 syllabi lacked a single occurrence of diversity throughout four primary syllabus sections. Alternatively, about a tenth of syllabi (n=15) demonstrated a diversity occurrence through the four primary sections. Within the primary sections, diversity was most prevalent in course learning objectives (n=93), while occurring least in course materials (n=50) and assignments/assessments (n=55) (Fig. 2). These results indicate that diversity was often present in the early sections of syllabi (e.g. course descriptions/learning objectives) but did not manifest as frequently in required course materials or assignments/assessments.

Technology was present in over 80% (n=116) of syllabi in the assignments/assessments section. Despite a large technology presence in that section, technology was present in just 40% to 50% of syllabi in the course descriptions (n=59), learning objectives (n=63), and materials (n=69) respectively. Though the results indicate a higher incidence of technology in later sections of course syllabi (e.g. assignments/assessments), qualitative analysis revealed that technology in these sections often referred to usage of electronic resources (e.g. course readings available electronically, wiki posts, Zoom meetings, VoiceThread interaction) as opposed to explicit instruction in how to integrate technologies into everyday teaching and practice.

Following analysis of the individual cross-cutting themes, summative analysis indicated that diversity occurred in just under 47% of all potential syllabi locations, whereas technology was present in 54%. Technology presence is atypically present across assignments/assessments sections, an explanation for which has been previously discussed in the technology-centric section prior.

Figure 2: Presence of diversity, technology, and discussion boards in four primary sections of syllabi (n=143).
RQ2: Diversity findings

EDAM

Diversity presence was limited in the Educational Administration program. It was present in 2 of 23 course descriptions (8.7%), 9 of 23 course learning objectives (39.1%), zero course materials (0%), and 1 of 22 course assignment sections (4.3%). Cumulatively, 12 of 23 syllabi (52.2%) had zero diversity presence across all 14 sections. In the weekly course calendar, nine out of 10 weeks showed diversity presence in two syllabi or less. Week 8 showed diversity presence in four of 23 syllabi (17.4%). Data from the course learning objectives and assignments sections suggest misalignment may exist within multiple syllabi. Courses that identify diversity themes in their learning objectives should have corresponding assignments that assess mastery of those objectives.

EDEX

Diversity presence was prominent in the Special Education program, which offers 41 total courses between undergraduate and graduate degree programs. Elements of diversity were identified in 82.9% (n=34) of course descriptions, 80.5% (n=33) of course learning objectives, 63.4% (n=26) of course materials, and 75.6% (n=31) of course assignments. Diversity presence was consistent in the weekly course calendar, as more than half of Special Education syllabi had elements of diversity in eight out of 10 weeks. Cumulatively, nearly 25% (n=10) of Special Education syllabi had diversity presence in all 14 sections; five syllabi had no diversity presence. Diversity themes were inherent throughout much of the Special Education curriculum, which prepares teachers, researchers, and behavioral analysts to work with students with disabilities. Coded language included emphasis on inclusive environments, strategies that accommodate diverse learners, content on the Universal Design for Learning framework, and working with exceptional children, among others. These themes aligned specifically with descriptors like “life experiences” and “ability” from the diversity definition.

EDUC

Diversity presence was captured in 44.3% (n=35) of course descriptions, 63.3% (n=50) of course learning objectives, 30.4% (n=24) of course materials, and 29.1% (n=23) of course assignments. These findings suggest misalignment between diversity presence in course objectives and course assessment. Across 10 weeks in the weekly

Figure 3: The presence of diversity in four primary sections of EDAM, EDEX, and EDUC syllabi.
course schedule, Week 8 saw the highest percentage of diversity presence with 35.4% (n=28) of syllabi. The other nine weeks ranged from 19% (n=15) to 30.4% (n=24) of diversity presence.

RQ3: Technology findings

**EDAM**

The presence of technology in Educational Administration was mixed across different sections of the syllabi. For example, 39.1 percent (n=9) course descriptions and course learning objectives showed the presence of technology. The course materials and course assignments however, had higher occurrences of technology. The use of technology in the course materials was identified in 69.6 percent (n=16) of syllabi, and it was present in 82.6 percent (n=19) of course assignments. The weekly learning objectives were more closely aligned with the percentages shown in the course materials and course assignments sections of education administration syllabi. This suggests that the majority of the weekly technology-related activities were due to course assignments and use of technology-related course materials such as websites and online journals.

**EDEX**

Technology was featured in 51.2 percent (n=21) of course descriptions in Special Education syllabi. Technology was mentioned in 56.1 percent (n=23) of the course learning outcomes, 43.9 percent (n=18) of the course materials and 97.6 percent (n=40) of course assignments. The weekly schedules for the EDEX syllabi show how technology is distributed throughout each course. These represent the highest and lowest number of syllabi that mention technology throughout the 10 weeks. The high prevalence of technology in the weekly course schedule suggests alignment with the course learning objectives and course assignments. The incorporation of technology into the course as stated in the course learning objectives have been reflected in the course assignments, which showed that 97.6 percent of assignments utilized technology.

**EDUC**

In Teacher Education syllabi, 36.7 percent (n=29) exhibited technology presence in the course description, 39.2 percent (n=31) in the course learning outcomes, 44.3 percent (n=35) in the course materials and 72.2 percent (n=57) in the course assignments. The potential for misalignment exists between course learning objectives and course assignments, suggesting that technology assumed the role of deliverable rather than subject matter. The analysis found no technology-centric courses among EDUC offerings at the undergraduate level.
Discussion and Implications

The evaluand is preparing for its first CAEP accreditation in the 2020-2021 academic year. This report was commissioned to provide the CAEP steering committee with a deeper understanding of how elements of diversity and technology are built into the curriculum at the course level of three licensure-granting programs: Educational Administration, Special Education, and Teacher Education. It is apparent that considerable efforts have been made to embed diversity and technology into the School of Education curriculum. The school counts social justice and equity and diversity among its five core values (The School of Education Strategic Plan, 2016). At the program level, diversity was largely absent from Educational Administration syllabi. Teacher Education syllabi lacked substantive technology presence, particularly at the undergraduate level, and indicated possible misalignment between course objectives and course assignments. Findings indicate that, specifically in Educational Administration and Teacher Education programs, technology was present in one of three primary ways: (a) as a mode of delivery for evidence of comprehension, analysis, or synthesis of content knowledge; (b) as an external host for content materials; or (c) as an internal host of course materials (LMS functions). These findings can inform educators of the importance of instituting rigorous program-level analyses that can ascertain the presence and makeup of department or school priorities.

The research design for this evaluation builds upon similar syllabi analyses designs in the evaluation literature (Beuoy & Boss, 2019; Eberly & Wiggins, 2001; Griffith et al., 2014; Pezzoli & Howe, 2001). The evaluators contribute to the literature with a coding protocol that emphasized forms of inter-rater reliability and construct validity despite a compressed project time frame of eight weeks. All 143 syllabi were reviewed twice across 14 sections for the presence or absence of diversity, technology, and discussion boards. The R2 review examined the R1 codes for agreement, disagreement, or omissions. Later, the evaluator dyads discussed disagreements for each occurrence in order to reach agreement. A similar system of validation was utilized to enter data accurately into an Excel spreadsheet for analysis in SPSS. Both teachers and administrators can adopt this protocol to conduct reliable and valid content analyses of syllabi for the purposes of course or program improvement, or accreditation.
Limitations

Although the literature verifies that content analysis of syllabi can be an effective component in program evaluation, the process is not without limitations. First, each syllabus is notably different from the next. Many syllabi reviewed for this report lacked descriptive detail in multiple sections that may have otherwise clarified the presence or absence of cross-cutting themes. The coding system to identify the presence of diversity and technology within syllabi may exclude the possibility of implicit or embedded representations of those themes. The coding system may not capture the intentionality of the assignment and does not capture the potential for students to customize their learning according to those themes. Time was a limitation. The research team had eight weeks to code 143 syllabi, analyze findings, and write a comprehensive report. This study was quantitative in nature and as such, only presented the frequency with which diversity and technology occurred for each program. Although some exemplars were noted qualitatively, this was not systematically done. As such, it is possible that the themes of diversity and technology do present themselves in ways that are not represented on the syllabi.

Recommendations

Upon analysis and reflection of this evaluation project’s findings, the evaluators made the following recommendations:

● **Review findings at program level.** Specifically, evaluand leadership should review the lack of diversity presence within the Educational Administration program, and inconsistent presence of technology in the Teacher Education program.

● **Review curricular alignments with cross-cutting themes.** Program leaders should review alignment for crosscutting themes among course learning objectives, course assignments, and course assignment descriptions at the individual syllabus level. This report’s findings revealed potential misalignment for diversity in both Educational Administration and Teacher Education. Specifically, diversity presence was notably higher at the course learning objective level than the course assignment / assignment description level. These two programs had nearly three times as much diversity presence in course learning objectives as they had in course assignments. These two sections should be more closely aligned to ensure students can provide evidence of meeting course outcomes.

● **Pedagogical knowledge and technology.** Due largely to the breadth of classes offered in either online or hybrid formats by the evaluand, technology presence was noted consistently throughout the three programs. Through researcher observation, we agree that the overwhelming majority of codes captured technology first as a tool for assignment delivery (e.g. PowerPoint, discussion forums, papers submitted as word documents), and second as host of a content resource (e.g. digital resources, journal articles, YouTube videos). Technology was noticeably less present in relation to issues of teaching with technology. This was particularly apparent at the Teacher Education undergraduate level, where technology presence was found in less than 30% of course descriptions, learning objectives, and course materials.

● **Build in layers of checks.** Syllabi analysis can be monotonous, time-consuming work. A compressed time frame increases the potential for mistakes. The evaluators found that systems of rigorous doublechecks at the data collection, data entry, and data analysis stages proved critical to addressing significant levels of human error. It is recommended that teams of evaluators conduct systematic analyses to ensure rigor.

References

About us: Drexel University School of Education. (n.d.). Retrieved September 11, 2019, from https://drexel.edu/soe/about/overview/


Appendix

The evaluand’s CAEP Steering Committee adopted the following definitions for diversity and technology. Coding protocol utilized these definitions to identify exemplars of each across 14 sections of 143 syllabi for three licensure-granting programs.

**Diversity:** (The evaluand embraces) the ideological, intellectual, economic, gender, ability, gender identity, religious, age, racial, cultural, ethnic, national and all differences of our students, faculty, staff, and alumni and value their contributions in shaping the transformation that (the evaluand) has embarked upon, as a global education leader (Diversity at Drexel, n.d.)

**Technology:** The tools and techniques available through computers, the Internet, telecommunications, and multimedia that are used by educator preparation providers (EPPs) for instruction and the input, storing, processing, and analyzing of data in quality assurance systems. Educator candidates should be able to demonstrate that they use technology to work effectively with students to support student learning (Glossary, n.d.)
Abstract: Research has described a social dimension to learning, which is likely complicated by technology. This paper explores what differences, if any, are evident in the nature of Twitter #Edchat conversations when taking into account Twitter’s technological features. Twitter contains a mashup of features, such as indexing with hashtags and bringing conversational coherence by threading replies together. Following past Twitter studies, this work is framed by the affinity space concept, but expands a spatial understanding by considering reply threads connected to tweets containing a hashtag, #Edchat. More than one million #Edchat tweets were collected, spanning eight months. Reply tweets were selected, and then additional “upstream” replies were collected as well. Two research questions were addressed: How common are hashtag replies versus upstream replies? How different, if at all, are hashtag replies and upstream replies? Finally, implications for educators’ practice and educational research were discussed.

Introduction

Much educational research has described a social dimension to learning. That is, there are important benefits for learning that stem from people interacting with one another. This has been shown to be true for K-12 students in formal classroom settings as well as for educators’ professional learning in more informal settings.

It is likely that technology complicates the social dimension of learning. However, this has not yet been fully explored, particularly with respect to educators’ professional learning. In contrast, there is an extensive body of literature related to educators’ knowledge required to teach with educational technologies—that is, their technological pedagogical content knowledge (TPACK). One of the foundational arguments for TPACK is that technology is not just an add-on to be applied in teaching with a simple new dimension of teacher knowledge. Rather, teaching with technology requires a new synthesized knowledge in dynamic interplay with subject-matter and pedagogy (Mishra & Koehler, 2006). Similarly, it may be the case that technology is not merely an additional tool to be used by educators for ongoing professional development but opens up new avenues for and types of professional learning. There is a growing body of literature related to how educators use social media for professional learning, but rarely has this research taken into account how particular features of social media platforms may complicate how people use these tools—for instance, how they talk to each other.

This paper seeks to highlight such technology-related complications through exploration of one long-term, ongoing education-related conversation on Twitter: #Edchat, one of the oldest and most used educational hashtags. This paper aims to increase understanding of how technology complicates the social dimension of educators’ professional learning by specifically considering how Twitter’s features may be related to how users talk to each other. Thus, the purpose of this study is to explore what differences, if any, are evident in the nature of Twitter #Edchat conversations when taking into account Twitter’s various technological features.

Twitter Background

Because this paper explores differences in Twitter conversations when taking into account Twitter’s features, a more detailed background on several of these features is warranted. Twitter was not specifically designed to support educational pursuits. Instead, it developed as what Jenkins (2004) termed a media convergence, a place where existing technologies, markets, and audiences came together in a new way. This was not a clean or linear process but more of a kludge, a “jerry-rigged relationship between different media technologies” (Jenkins, 2004, p. 34). The result is that Twitter is composed of a mashup of features. That is, Twitter’s platform is made up of an odd collection of functions. Humphreys (2016) observed that Twitter does not fit neatly into the various different types of social media platforms, but instead combines features of distinct social media genres. Twitter combines (a) a news feed where users see content
created by others, (b) social networking to create profiles and connect with other users, and (c) microblogging, or user-generated content in the form of very short posts (Humphreys, 2016).

Twitter users have often developed their own practices (i.e., conventions) to make the platform function in ways they found more beneficial. These user-defined practices have included adding hashtags to tweets to index topics and using addressivity to direct responses to specific individual accounts. Twitter, in turn, has formalized some of these conventions into platform-supported features. For instance, hashtags are now hypertext, and replies are threaded together. In the following sections, I describe four Twitter features essential to this current study.

First, the basic building block of Twitter are tweets, the brief posts that Twitter users contribute. Twitter limits each tweet to a maximum of 280 text characters but does allow the inclusion of images, videos, and hyperlinks. These multimedia possibilities allow for more complex ideas to be presented even within the constraints of these necessarily brief posts.

A second key Twitter feature is the hashtag. A hashtag is simply text preceded by the “#” symbol. However, this simple literary device can be used in complex ways. Hashtags were originally developed as a user-defined practice presumably to index, group, and structure ideas and conversations. After hashtags had become an established practice by users, Twitter formally adopted the hashtag as an official feature, automatically converting hashtags into hypertext to streamline the search for other messages containing the same hashtag keyword. Twitter users have created and used hundreds of different hashtags for education-related conversations, such as #Edchat for general educational conversation (Staudt Willet, 2019; Xing & Gao, 2018), #sschat for social studies teachers (Kerr & Schmeichel, 2018), and #michED for those interested in educational issues in the U.S. state of Michigan (Rosenberg et al., 2016).

A third key Twitter feature is addressivity, which is the inclusion of text in the form of “@username” at the beginning of a tweet to signal that the tweet is a message intended for a specific user account. As Honeycutt and Herring (2009) described: “In this noisy environment, use of the @ sign is a useful strategy for relating one tweet to another and, indeed, for making coherent exchanges possible” (p. 4). As with hashtags, once it became a common convention for users to include the “@” symbol in tweets to tag others into a comment or direct a message to someone specific, Twitter formally adopted the practice as a feature. A reply button was placed at the bottom of every tweet to make responding simpler, and “@username” text was automatically converted to hypertext, linking to the @username account’s Twitter profile page.

In addition, Twitter’s platform began to link replies together into threads of potentially unlimited length (Figure 1). Although a single tweet must be 280 text characters or less, tweets can be connected together endlessly. Twitter users take advantage of this feature to compose longer messages by threading together a series of self-replies (i.e., extended posts; Staudt Willet, 2019). Similarly, hashtag participants can reply back and forth together without limit, and Twitter will bundle these exchanges into a thread as well. Finally, when a user clicks to view a single reply tweet, the entire thread of replies is also displayed, giving the appearance of a coherent conversation.

Finally, a fourth key Twitter feature reflects Twitter’s kludge-like nature: the mashup of two previous features, hashtags and addressivity, which I call the hashtag-thread mashup. This mashup can be understood as the synthesis of two disparate functions into a new whole. Researchers have conceptualized education-related conversations on Twitter as the collection of all tweets containing a hashtag keyword (e.g., #Edchat, #sschat, #michED). However, the conversation, as experienced by participants, may be much larger than this. That is, the hashtag-thread mashup can potentially contain many more tweets than just those tweets with the hashtag. For instance, a long thread of replies might not contain any hashtags until someone adds #Edchat to a final tweet. Because of how Twitter threads replies, an educator searching for #Edchat would not just find the one final tweet. Clicking on that one tweet would open up the whole thread of earlier (i.e., upstream, or pre-conversation context) posts and replies. On the other hand, a group of teachers might have a robust discussion in which all the tweets contain the #Edchat hashtag, until someone accidentally forgets to include the hashtag in a reply, and then subsequent replies also neglect to include the hashtag. In this case, again, an educator following #Edchat could click on any one of the #Edchat tweets and view the whole thread, even those later (i.e., downstream, or post-conversation context) replies. This is illustrated in Figure 1 when the “#hashtags” hashtag is dropped from later tweets in the thread. Finally, for various reasons, some responses to the #Edchat conversation may occur privately, through Twitter’s direct messages which would not be observable to general users or researchers.
In sum, how participants talk to each other within the larger #Edchat conversation may be understood as a hashtag-thread mashup composed of four different types of replies. These include: (a) hashtag replies (i.e., replies that contain the keyword text #Edchat), (b) upstream replies (i.e., replies that do not contain the keyword text #Edchat but occur earlier in a thread where #Edchat appears in a later tweet), (c) downstream replies (i.e., replies that do not contain the keyword text #Edchat but occur later in a thread where #Edchat appears in an earlier tweet), and (d) private replies (i.e., replies that occur through direct messages).

**Educators’ Online Professional Learning**

The literature has described numerous professional benefits from educators’ Twitter use, including exchanging resources (Carpenter & Krutka, 2014), developing social capital (Rehm & Notten, 2016), and offering emotional support (Carpenter & Krutka, 2014). Contributors add new content easily, and others access a continually updated stream of information, meaning that Twitter offers a form of on-demand and just-in-time professional development (Greenhalgh & Koehler, 2017).

Many studies have described learning opportunities related to a social dimension, or a “people orientation” (Prestridge, 2019) toward social media. Xing and Gao (2018) concluded that collaboration was an important factor in educators’ ongoing participation in Twitter #Edchat, possibly because users “valued tweets that focused on generating and co-constructing ideas” (p. 395). Davis (2015) described educators’ knowledge-sharing on Twitter as a social endeavor, a type of collaborative inquiry and information filtering, and they reported a sense of belonging that teachers nurtured through Twitter. Chen (2011) also reported a sense of “informal camaraderie” (p. 759) resulting from Twitter use, and other researchers have concluded that educators’ experiences of professional isolation can potentially be
alleviated through participation on Twitter (e.g., Carpenter & Krutka, 2014). Educators’ use of social media has also been characterized as seeking and finding a “professional refuge” (Trust et al., 2016, p. 31). Rehm and Notten (2016) found that educators continued to form new social ties as they spent more time on Twitter. Finally, educators’ professional learning through social media can be understood as participation in an online “community.” Even minimal participation may be considered a form of legitimate peripheral participation, a way of learning what it means to be part of, or an apprentice in, a community of practice (Lave & Wenger, 1991).

There are new challenges associated with educators’ social media use. For instance, the ability to bypass time and geographical constraints also blurs the lines between teachers’ professional and personal lives, creating an expectation that teachers are—or should be—available and accessible to students, parents, and colleagues outside regular school-day hours (Selwyn et al., 2017). In addition, with so many interpersonal connections, self-serving behaviors are prevalent. Prestridge (2019) defined two such types of social media users: the info-consumer and the self-seeking contributor. The latter user type mirrored a major category of tweet purposes in Twitter #Edchat: almost half of the original content in that hashtag points back to the tweeter rather than highlighting the work of others or inviting dialogue (Staudt Willet, 2019). This means that more connections through social media are not inherently beneficial. Rather, the nature and quality of those connections must be examined.

Framework and Research Questions

The purpose of this study is to explore what differences, if any, are evident in the nature of Twitter #Edchat conversations when taking into account Twitter’s various technological features. The affinity space concept (Gee, 2004) offers a compelling framework through which to pursue this purpose, for several reasons. First, affinity spaces are becoming a popular approach for understanding educators’ use of Twitter (e.g., Carpenter & Krutka, 2014; Greenhalgh & Koehler, 2017; Greenhalgh et al., 2020; Rosenberg et al., 2016; Staudt Willet, 2019). Of particular note is how these studies have conceptualized a Twitter hashtag as an affinity space—that is, a place in which participants can interact around a common topic or shared interest denoted by the hashtag.

Second, this framing is useful because Twitter users tweet with hashtags for a variety of purposes, whether highlighting the work of others, seeking collaboration, or promoting themselves (Staudt Willet, 2019). This is reminiscent of how Gee (2013) described students’ various modes of participation in classrooms—students engage for different purposes, such as a “school-science community of practice vs. ‘doing school’ community of practice” (p. 88). That is, some learners want to become apprentices in a discipline and subsequently bond together over this identity. Others want to earn a certain grade or credential, which is the extent of their interest. With these varying forms of participation in mind, Gee (2004) conceptualized affinity spaces as a more open and fluid alternative to earlier conceptions of communities of practice (e.g., Lave & Wenger, 1991; Wenger, 1998). Rather than focusing on community features such as the development of shared identity or mutual engagement (see Wenger, 1998), affinity spaces foreground interactions. Affinity spaces are made up of content interactions between participants and shared content (e.g., searching for and reading tweets containing a specific hashtag keyword), as well as social interactions amongst users around the shared content (Gee, 2004)—for instance, replying to someone else’s tweet.

Third, affinity spaces are simple in structure. The only key markers for affinity spaces are a generator that produces the content of the space and portals through which users access that content and interact (Gee, 2004). This structure of generator and portals suggests helpful directions for research questions in alignment with a study’s purpose (e.g., Greenhalgh et al., 2020). A few examples will make these concepts more concrete. First, an affinity space only requires a purpose for teachers to gather (i.e., a generator) and a way for them to do so (i.e., a portal). In the case of a fan website (e.g., Lammers, 2013) or an online discussion forum (e.g., Staudt Willet & Carpenter, 2020), generators may be understood as discussion board topics and portals as the overall website design that provides a clear and structured means of responding to discussion board posts. Twitter hashtags can also serve as helpful affinity-space generators. For instance, although #mathchat and #sschat may overlap somewhat in topic, the hashtags themselves suggest spaces for conversations about math as opposed to social studies, and vice versa. Portals to these hashtag affinity spaces can be confusing due to Twitter’s high volume of short posts and lack of overall organizing structure. For instance, educators may tweet using a common hashtag (e.g., #Edchat) in a variety of modes (e.g., weekly synchronous chats versus asynchronous, when-convenient tweeting), with a variety of tweet types (e.g., original posts, self-retweets, peer-retweets, and replies), and for a variety of purposes—such as to benefit oneself versus to benefit others (Staudt Willet, 2019).

In sum, framing this study with an affinity spaces lens follows a recent trend in the literature, leaves open the scope of inquiry regarding what and how #Edchat users are participating, and suggests several directions for research questions related to the affinity space concepts of generator and portal. That is, with this framing, the purpose of this
study—to explore what differences, if any, are evident in the nature of Twitter #Edchat conversations when taking into account Twitter’s various technological features—can be restated. In affinity space terms, the purpose of this study is to explore what differences, if any, are evident between social interactions within the affinity space (i.e., the hashtag-thread mashup) defined by the #Edchat generator, when taking into account the space’s various portals (e.g., different types of reply tweets).

Past research may have missed important social interactions because of how affinity spaces were defined and bounded. That is, a limited conception of affinity space portals (e.g., studying hashtag replies but not considering other reply types) may have led to overly narrow results. Therefore, in this exploration of the Twitter #Edchat affinity space, I explore an expanded conception of what constitutes a Twitter “space” by comparing social interactions through two affinity space portals related to #Edchat: hashtag replies and upstream replies. I seek to answer two research questions regarding social interactions in the Twitter #Edchat affinity space (i.e., the #Edchat hashtag-thread mashup):

RQ1. How common are hashtag replies versus upstream replies?
RQ2. How different, if at all, are hashtag replies and upstream replies?

Method

This exploration of social interactions in the Twitter #Edchat affinity space (i.e., the hashtag-thread mashup) employed an unobtrusive form of Internet-mediated research (Hewson, 2017) by collecting digital traces from social media use (Lazer et al., 2009). In addition, data were analyzed using both machine and human analyses; in this way, results will be triangulated to increase the trustworthiness and persuasiveness of the findings.

I began with #Edchat tweets collected during an earlier study (Staudt Willet, 2019). There, I used a series of Twitter Archiving Google Sheets (Hawksey, 2014) to collect 1,228,506 unique tweets containing the keyword text “#edchat” from 196,263 distinct tweeters between October 1, 2017 and June 5, 2018. I then pulled additional information (i.e., metadata) associated with these tweets from the Twitter API using the rtweet package (Kearney, 2018) for the statistical-computing environment R (https://www.R-project.org/). In the process of collecting metadata, I removed tweets from the dataset that had been deleted or marked as protected since the time of my original data collection; 1,111,643 unique tweets from 175,474 distinct tweeters remained in the tweet corpus for the present study. Using the additional metadata, I retrieved the upstream replies for #Edchat, that is, all replies with the hashtag #Edchat plus earlier tweets either outside my collection timeframe or without the hashtag but connected with reply threads. This resulted in a corpus of 13,176 unique reply tweets associated with #Edchat from 3,672 distinct tweeters. Note that I was unable to retrieve downstream replies for #Edchat because of limitations with the metadata reported by the Twitter API nor the private replies because these are not publicly available.

To answer the first research question, I calculated the percentage of tweets in the #Edchat hashtag-reply mashup containing the keyword text “#edchat”—that is, the percentage of tweets that were hashtag replies. I also calculated the percentage of contributors to the #Edchat hashtag-reply mashup who only composed hashtag replies, those who only composed upstream replies, and those who composed both hashtag and upstream replies.

To answer the second research question, I constructed a table (Table 1) to compare hashtag replies and upstream replies in the #Edchat hashtag-thread mashup. I calculated (a) the percentage of synchronous tweets (i.e., tweets occurring during, one hour before, or one hour after #Edchat’s planned weekly, hour-long synchronous chat on Tuesdays) and (b) the percentage of replies that are self-replies. I also calculated mean values for (c) words per tweet, (d) characters per tweet, (e) text-polarity sentiment score per tweet (using the sentimentr R package [Rinker, 2018] and the default Jockers-Rinker dictionary), (f) hashtags per tweet, (g) hyperlinks per tweet, and the number of times the tweet was (h) liked, (i) retweeted, or (j) replied to. I human-coded random samples of hashtag replies (n = 100) and upstream replies (n = 100), using categories of tweet purposes (i.e., self, others, mutual, and miscellaneous) validated by Staudt Willet (2019) and tweet discourses (i.e., cognitive, interactive, and social) validated by Xing and Gao (2018). I created bar plots comparing purposes and discourses for hashtag replies and upstream replies. Finally, I used the software Gephi (https://gephi.org/) to create a visualization of the #Edchat hashtag-thread mashup, depicting tweeters as black dots, hashtag replies as blue lines, and upstream replies as red lines.

Results

In answering the first research question regarding the commonality of hashtag replies versus upstream replies, I found that social interactions in the reconstructed #Edchat hashtag-thread mashup were made up of 13,176 reply
tweets from 3,672 tweeters; 79.18% of these tweets were hashtag replies, meaning they contained the keyword text “#edchat.” Of the tweeters who contributed replies, 2,364 (64.38%) composed hashtag replies only (i.e., they always included the #Edchat hashtag in their replies), 822 (22.39%) contributors composed upstream replies only, and 486 (13.24%) contributors composed both hashtag and upstream replies.

To answer the second research question regarding differences between hashtag replies and upstream replies, I compared tweets in the hashtag-thread mashup (Table 1) and noticed that a larger percentage of hashtag replies occurred during the Tuesday synchronous chat than upstream replies. Hashtag replies (i.e., replies with #Edchat) were more likely to contain additional hashtags as well. On the other hand, upstream replies were twice as likely to be self-replies and received more response in the form of likes, retweets, and replies. This could mean that hashtag replies were often meant to both contribute to #Edchat’s synchronous weekly conversations as well as create intersections with other hashtags, whereas upstream replies tended to link together self-replies to create extended posts in which lengthier and potentially more complex ideas could be expressed.

<table>
<thead>
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<th></th>
<th>Sync</th>
<th>Self-reply</th>
<th>Words</th>
<th>Chars</th>
<th>Sentiment</th>
<th>Hashtags</th>
<th>Links</th>
<th>Likes</th>
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<td>0.24</td>
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<td>0.48</td>
<td>0.27</td>
</tr>
<tr>
<td>Upstream Replies</td>
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<td>29.20%</td>
<td>27.90</td>
<td>201.87</td>
<td>0.25</td>
<td>0.57</td>
<td>0.22</td>
<td>26.25</td>
<td>3.66</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Table 1. Comparison of Tweets in the #Edchat Hashtag-Thread Mashup

From human-coded content analysis, I found that hashtag replies were almost entirely on topic, with the miscellaneous purposes category (Figure 2) mostly including didactic arguments in the form of self-reply threads (e.g., “Social media are about the human connections, not the tech tools! I’ll explain why in this series of tweets…”). Numerous hashtag replies were for sharing resources, both resources from others as well as expressing gratitude for someone else sharing the tweeter’s own work. There were discussions of grading, education policy and reform, student-centered learning, and teacher professional development, as well as more contested subjects such as and the presence of guns in schools and Elon Musk’s views of learning. Hashtag replies were more likely to demonstrate mutual purposes (e.g., asking for advice, seeking collaboration) than upstream replies. Upstream replies had a notable number of off-topic (i.e., not related to education) threads. One very long reply thread was just a series of references to popular movies, at the end of which someone replied with a tweet containing #Edchat. As with hashtag replies, in the upstream replies sample, there were a number of long didactic threads of self-replies. In this case, it seemed as if the tweeter made their argument and then tacked on #Edchat at the end to gain the attention of Twitter users watching that specific hashtag. Several long threads of upstream replies appeared to be conversations in other education-related affinity spaces—for example, #hacklearning and #ditchbook—covering topics such as student portfolios. Again, like hashtag replies, there were discussions of grading as well as resources being exchanged.

![Figure 2. Percentage of Tweet Purposes by Type of Reply](image-url)
In terms of tweet discourse (Figure 3), hashtag replies were more likely to exhibit an *interactive* dimension, such as expressing agreement or building upon an existing tweet (Xing & Gao, 2018). This overlaps somewhat with the *mutual purposes* category in Figure 2, which may mean that tweeters included the #Edchat hashtag in replies with hopes of receiving a response. In contrast, upstream replies were more likely to exhibit a *cognitive* dimension, such as stating a personal opinion or prompting a new topic of discussion (Xing & Gao, 2018). This would seem to align with the earlier finding that upstream replies were more likely to be self-replies, creating threads of extended posts.

![Figure 3. Percentage of Tweet Discourses by Type of Reply](image)

The visualization of social interactions in the #Edchat affinity space (i.e., the hashtag-thread mashup) depicts how contributors are connected to each other through reply tweets (Figure 4). Although there are some visible clusters of participants who reply to each other frequently (i.e., nodes the layout algorithm placed close together), it also appears that blue lines (i.e., hashtag replies) and red lines (i.e., upstream replies) are distributed throughout the network without a clear pattern. At a glance, this may seem to suggest that hashtag replies and upstream replies are similar. However, the results from other analyses suggest the opposite: there are noticeable differences between hashtag replies and upstream replies, despite the interconnectedness of those who compose them.
Discussion

These results provide evidence of how social interactions in Twitter #Edchat differ in two of the affinity space’s portals, hashtag replies and upstream replies. In the following paragraphs, I discuss how these differences have implications for educators’ practice and educational research.

First, there are several implications for educational practice. Because a single affinity space like Twitter #Edchat can simultaneously host a variety of conversation styles and topics, as Greenhalgh et al. (2020) also demonstrated, educators must be mindful to develop the new forms of knowledge necessary to maximize the professional learning opportunities afforded by this social media platform. Although Jenkins (2004) described a media convergence as a kludge when the design process resulted in a mashup of features—which is apparent in Twitter’s case—Potts and Jones (2011) used the term kludge to describe the content of Twitter. They described Twitter as an “unruly mass of content connected in ways and reasons that are difficult, if not impossible, to fully explain” (p. 339). Twitter’s dual kludge of features and content necessitate increased digital literacy by those educators seeking professional learning on this platform. Research related to digital literacies must extend beyond the current focus on K-12 students’ practices to describe various ways educators must pursue digital literacy as a foundation for professional learning. The need for educators’ digital literacy is not unlike Mishra and Koehler’s (2006) argument for TPACK in classroom teaching. A TPACK understanding of teacher knowledge must also be extended to educators’ digital literacy for professional learning.

In the specific case of #Edchat, these findings reinforce the conclusion of an earlier study (Staudt Willet, 2019): #Edchat may not be the most appropriate affinity space for preservice teachers, beginning teachers, or new Twitter users. #Edchat is a busy space with a large amount of self-promotion and little mutual engagement (Staudt Willet, 2019). In addition, this study’s results demonstrate that the boundaries of #Edchat are more complex than previously imagined. Expanding the conception of the #Edchat affinity space from the set of tweets containing the #Edchat keyword to also include the hashtag-thread mashup revealed a higher percentage of off-topic and didactic messages to sort through. This is more reflective of what an educator reading #Edchat tweets would actually
experience. In addition, beginning teachers hoping to ask questions or seek emotional support would likely be
frustrated by the volume of tweets—and comparative lack of social interaction—in #Edchat. If several super-users
were solely to blame for the tweet volume, the solution would be easier: advise new participants to block or mute the
#Edchat super-users. However, previous findings showed that a good portion of #Edchat’s tweet volume stemmed
from many one-time tweeters (Staudt Willet, 2019). It would not be feasible to mute or filter the tweets from all of
them. Rather than grow frustrated with #Edchat’s volume, beginning teachers could intentionally choose to participate
in a different hashtag with a narrower scope of conversation. For instance, they could consider some of the hashtags
that appear frequently alongside #Edchat tweets and give their attention to these more focused and less busy
considerations, such as those organized by subject area (e.g., #sschat) or grade level (e.g., #elemchat).

Educators may benefit from intentionally approaching Twitter as a collection of affinity spaces. This may
prompt reflection on what affinities they would like to follow or participate in, and this frame would also encourage
educators to access and interact with content in a manner that suits their own needs and context. Being an “active
participant could be as simple as reading #Edchat tweets, clicking on reply threads to see the more extensive
conversation in the hashtag-thread mashup, or telling offline colleagues about ideas and resources from Twitter. Each
of these actions indirectly adds value back to the affinity space. Indeed, these modes of participation in #Edchat could
qualify as forms of Lave and Wenger’s (1991) legitimate peripheral participation, a step in learning what it means to
be part of a community of practice. However, even when considering participation through the open and fluid affinity
space lens, participants should be mindful of a possible overload of messages being sent and received. Too many
messages being created too quickly creates a noisy affinity space, even if all content is relevant.

When participating in a Twitter hashtag affinity space, educators should remember to add the relevant hashtag
to every tweet— including replies—intended to contribute to the affinity space. A keyword search is limited by how
content has been tagged or indexed, and upstream replies without the hashtag make it harder for others interested in
relevant content to find these tweets. On the other hand, it is also helpful to keep in mind that affinity spaces can be
joined together and expanded by including multiple hashtags in a tweet or by adding a hashtag at the end of a reply
thread. Educators and other affinity space participants should take advantage of Twitter’s affordances for threading
replies, as affinity space may be much larger than first realized. Indeed, there may be different types of content present
outside the conventional boundaries of the space.

The results of this study also hold implications for educational research. Past approaches to Twitter research
may have omitted important content and interactions directly related to the phenomenon of interest—and likely present
in hashtag participants’ experiences. In the case of #Edchat, participants reply to each other and see a hashtag-thread
mashup that is larger than researchers would typically have considered (i.e., upstream replies in addition to the hashtag
replies containing the keyword text “#edchat”) as well as different in terms of numerous tweet attributes and content.

Researchers must become familiar with the affordances and constraints of Internet protocols and social media
features in order to understand what portals to an affinity space may exist and are in common use. This study’s results
demonstrate that the most straightforward way to define a space (e.g., by a keyword search for “#edchat”) can be
complicated and problematized by the mashup of technological features present in a social media platform—in the
case of Twitter, the threading of replies together combined with the presence or absence of a hashtag. These findings
should serve as a reminder to researchers, even when conducting quantitative research, to follow recommendations
from qualitative researchers (e.g., participatory action research) by seeking to immerse themselves in the research
context to better understand participants’ experiences. Additionally, triangulation techniques such as member checks
could also serve to highlight researchers’ blind spots. These traditionally qualitative techniques would add value to
quantitative researchers working with large amounts of data, as in the case of this current study.

A researcher’s choice of theoretical framework is also of utmost importance, as frameworks themselves
suggest how a study’s context is defined (Staudt Willet et al., 2017). A community of practice study may take into
account anyone who is developing a shared repertoire through mutual engagement (see Wenger, 1998). When the
phenomenon of interest is framed as an affinity space, researchers should try to understand all the ways participants
are interacting with shared content, seeking out as many of points of access (e.g., multiple hashtags) as possible (see
Gee, 2004). This is easier to do when studying a discussion forum (e.g., Reddit) whose content is relatively stable and
searchable at any point in time, but the tweet volume and unruly mass of Twitter content can create challenges. Twitter,
as a platform, has tried to solve this by adopting user-defined practices, such as making hashtags easily searchable and
threading replies together. Still, as discussed in the previous paragraphs, the mashup of these additional features may
complicate educators’ experiences as much as help.

Finally, this study has several important limitations. First, Glesne (2016) argued that to establish the
trustworthiness of qualitative research, a researcher must reflect on their positionality, answering, “Why do I notice
what I notice?” (p. 153). As the principal investigator in this study, I acknowledge that I am an educational researcher
who experienced adolescence at the same time the Internet went mainstream. I spent my teenage years in chatrooms

and have generally had positive online interactions throughout my life. As a white, straight, cisgender man, I can participate on social media with little risk of being the target of harassment. Still, I engage with social media as an observer first, preferring to read and retweet the words of others more than author my own. These various elements of my identity influence how I interpret the content of tweets in a hashtag-thread mashup. This is both the strength and the weakness of qualitative research. A second limitation is the relatively small sample size of tweets for content analysis. This resulted in overlapping error bars in the bar plots (Figures 2-3). Future research should take larger samples for content analysis to decrease those margins of error in hopes of better differentiating between various purposes and discourses. Third, this study has depended entirely upon digital trace data, inferring understanding of affinity spaces based on the tweets I was able to collect and observe. A future study should survey or interview educators to evaluate different understandings of Twitter hashtag affinity spaces, both in terms of how participants conceptualize the scope and bounds of a hashtag conversation as well as motivation for replying in different ways (e.g., including a hashtag in a reply or not).

Conclusion

It is likely that technology complicates the social dimension of learning, and findings from this study reinforce this assertion. Specifically, the purpose of this study was to explore what differences, if any, are evident in the nature of Twitter #Edchat conversations when taking into account Twitter’s various technological features. In affinity space terms, this study explored the differences evident between social interactions within the affinity space (i.e., hashtag-thread mashup) defined by the #Edchat generator, when taking into account two of the space’s portals: hashtag replies and upstream replies. I have argued that multiple types of conversations occur simultaneously within the #Edchat affinity space. The result is a space with a cohesive, shared affinity, but also containing a dual kludge of features and content that can be hard to navigate for educators and researchers alike. Particular importance rests on the various ways that an affinity space like Twitter #Edchat can be accessed. In addition, the inclusion of hashtags plays an essential indexing function. Including multiple hashtags in a tweet is a way to bring multiple spaces together, adding a hashtag at the end of a thread of replies is like building a bridge to a past conversation, and neglecting to include a hashtag in a thread of replies is like walking out of the room while a conversation is still ongoing.

References


TPACK’s Arc of Technology Transparency and Teachers’ Ethical Obligations: Understanding The Digital as the New Materia Medica of Pedagogy

Catherine Adams
Department of Secondary Education
University of Alberta, Canada
cathy.adams@ualberta.ca

Abstract: In his landmark essay on Pedagogical Content Knowledge (PCK), Shulman (1986) described technology as the “materia medica of pedagogy, the pharmacopeia from which a teacher draws” (p. 10). This crucial passage about curricular knowledge and instructional materials was overlooked by Mishra and Koehler (2006) in their popular formulation of Technological Pedagogical Content Knowledge (TPACK), yet it hints at important technoethical obligations for today’s teachers. For if technological solutions are indeed pharmacological in their pedagogical effects, then teachers must carefully weigh every new technology’s benefits against its possible risks and adverse effects on their students’ knowledge ecology and well-being, and by extension, the possible impacts on future cognitive, social, political and cultural environments. To remedy to this oversight, I examine TPACK’s arc of technology transparency as a critical site of ethical intervention. The arc of technology transparency, first identified by Cox (2008), marks the transition from T-PCK (when a technology is “present-at-hand” or conspicuously apparent) to PCK (when a technology has become “ready-to-hand” or transparently integrated into one’s teaching and learning practice). Standing at this border crossing—looking both forwards and back—teachers are best positioned to critically assess and ethically weigh the benefits and risks of adding a new digital technology to the already complex media ecologies of their students’ lives.

Technology is a branch of moral philosophy, not of science. (Goodman in Postman, 1992, p. ix)

Introduction

In his 1986 landmark essay on Pedagogical Content Knowledge (PCK), “Those Who Understand: Knowledge Growth in Teaching,” Lee Shulman described technology and the instructional materials used in classrooms as the “materia medica of pedagogy, the pharmacopeia from which a teacher draws” (p. 10).1 Evoking the ancient art and science of pharmacology, Shulman drew a parallel between a teacher’s knowledge of curriculum, of their students, and of instructional materials to a physician’s knowledge of disease, of their patients, and of medicinal solutions. A teacher’s professional practice was thus likened to a doctor carefully diagnosing a patient’s disorder then prescribing the most appropriate therapy from their kit of pharmacological treatments with due sensitivity to context, circumstance, “cost, interaction with other interventions, convenience, safety, or comfort” (p. 10). Twenty years later, Mishra and Koehler (2006) gave no mention of Shulman’s arcane metaphor of the pharmacopeia in their popular formulation of Technological Pedagogical Content Knowledge (TPACK). Indeed, Shulman’s suggestions that (1) technological knowledge is intimately linked to a teacher’s curricular knowledge and that (2) instructional materials including “texts, software, programs, visual materials,…films” (Shulman, 1986, p. 10)—i.e., Shulman’s materia medica of pedagogy—constitute the essential substrate of curricular knowledge, were both passed over in silence. This oversight was made despite Shulman’s (1986) explicit warning that while “we are regularly amiss in teaching pedagogical knowledge to our students, we are even more delinquent with respect to the third category of content knowledge, curricular knowledge” (p. 10).

What is curricular knowledge? According to Shulman, it is a teacher’s knowledge of “the full range of programs designed for the teaching of particular subjects and topics at a given level, the variety of instructional

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1 De Materia Medica—translated as “On Medical Material”—is a five-volume collection by 15th century Greek physician Dioscorides documenting the medicinal uses of hundreds of plants, minerals and other concoctions. Pharmacopoeia is from the Ancient Greek, φαρμακοποιία pharmakopoiia, which means the “making of (healing) medicine, drug-making” (OED); it is the root of our modern term, pharmacy.
materials available in relation to those programs, and the set of characteristics that serve as both the indications and contraindications for the use of particular curriculum or program materials in particular circumstances” (p. 10). Here, Shulman’s insight that technologies form the material ground and active pharmaceutical ingredients of teachers’ curricular knowledge portends crucial ethical obligations for educators in the 21st century. This is because, today, teachers are increasingly charged with selecting, prescribing and administering complex cocktails of new digital learning “solutions” for students, and as such, bear responsibility not only for their powerful effects (“indications”) but also for their side effects (“counterindications”). By not explicitly reckoning with technology as the “materia medica of pedagogy,” TPACK necessarily covers over a key ethical implication for teachers. Specifically, every technological intervention, every technology mobilizes both its “indications and contraindications” (Shulman, 1986, p. 10) in the context of students’ cognitive ecologies and knowledge ecosystems.

In this chapter, I suggest a minor modification to the TPACK model in an effort to reinstate Shulman’s insight regarding curricular knowledge and technology as pharmacological. This cosmetic change importantly inflects a key ethical-pedagogical understanding for teachers regarding technology use in schools. Specifically, the modification clarifies that once integrated into a knowledge practice, a technology tends to shift from being obvious and apparent to being “transparently” integrated (TPK —> PK), and its indications and contraindications thereby retreat from awareness and critical oversight. Further, it is only when TPK shifts to PK that the full range of a given technology’s effects and side effects are exercised, and thus become evident. A basic law of technology is discernible: while a given technology may powerfully extend some aspects of our students’ perceptual, actional and/or cognitive abilities, it simultaneously reforms their ways of thinking, being and doing in particular ways (Ihde, 1979; McLuhan, 1964). Some of these reforms may be intended (indications), some may not be (counterindications). A classic example here is a student’s use of an electronic calculator. One the one hand, the calculator can significantly extend a student’s higher order thinking (HOT) skills and number competence (two of the calculator’s indications); on the other hand, it can also result in a dramatic loss of previously won numeracy skills (one of the calculator’s contraindications). By understanding a technology’s contraindications, a teacher can adapt the student’s knowledge practices accordingly. For example, in the case of the calculator, the teacher may decide to develop students’ mental estimation skills to counter the probable loss of numeracy skills in the wake of regular calculator use (Duffin, 1999).

I begin by reviewing two otherwise unrelated empirical studies about TPACK. The first study reveals the lack of technoethical assessment in the TPACK framework (Yurdakul et al., 2012). The second study reexamined the meaning of TPACK once a technology has been transparently integrated into teachers’ practices (Cox, 2008; Cox & Graham, 2009; Phillips & Harris, 2018). I then turn briefly to the work of phenomenologist and early philosopher of technology, Martin Heidegger (1962) to help understand the meaning of “technology transparency,” and its epistemic and existential implications for teaching, learning and knowledge practices. From here, I propose formally designating the border between technological knowledge (TK) and all other forms of teacher knowledge as TPACK’s arc of transparency. The arc does not change the structure of TPACK, but instead clearly delineates the porous border territory where a technology-in-use moves from being “present-at-hand” (apparent, i.e., not yet integrated into practice) to “ready-to-hand” (transparent, i.e., seamlessly integrated and now underwriting the new cognitive or knowledge practice). This metabolic learning event—from technological appearance to transparency—occurs when “we seize hold of” a technology, learn to use it and ultimately absorb it as integral to our (new) knowledge practice (Heidegger, 1962, p. 98). Further, in the process of learning how to use a technology, its pharmacological implications—both its “indications and contraindications” (Shulman, 1986, p. 10)—are subsumed as part of our students’ taken-for-granted knowledge infrastructure and cognitive habits, and any collateral effects slip easily beyond the reach of teachers’ ethical oversight. The purpose of adding the arc of transparency borderline to TPACK’s Venn diagram is to formally mark the ground where teachers and educational technology researchers may most productively arrive at a more fulsome understanding of their core ethical obligations regarding technology selection and use.

TPACK, Ethics and Curriculum

In their review of PCK and TPACK at the 2018 SITE conference, Phillips and Harris (2018) pointed out that, “despite Shulman’s careful efforts to delineate the [complexity of a teacher’s professional] knowledge base,” of the seven knowledge categories he outlined, PCK has captured the lion’s share of attention among educational researchers (p. 2109). Mishra and Koehler’s TPACK is no exception. Of course, Mishra and Koehler made no claim to speak for Shulman’s other teacher knowledge categories. However, their emphasis on technological knowledge—while excluding curricular knowledge as technology’s larger knowledge category as per Shulman—has meant that the
TPACK framework simultaneously occluded pressing ethical responsibilities facing teachers regarding their choices and uses of digital technologies in schools today.

TPACK’s inability to adequately address ethical issues regarding technology choice has been previously noted. For example, Yurdakul, Odabasi, Kilicer, Coklar, Birinci and Kurt (2012) proposed “TPACK-Deep,” a model that gives TPACK a new set of wings, one each for Design, Exertion, Ethics, and Proficiency. The Ethics wing or “factor” in TPACK-Deep refers to “preservice teachers’ competencies in ethics regarding teaching profession but also to such technology-related ethical issues as privacy, accuracy, property and accessibilities” (p. 970). Here, ethics is described as a form of “awareness” and is framed as a competency involving “paying attention to” a variety of technology issues (e.g., copyright, student access, safety, privacy and technology access) with the following list of indicators:

- Behaving ethically regarding students’ access to technological sources (software, e-book, video, etc.) in the teaching-learning process
- Paying attention to copyright issues regarding digital sources used while designing instructional materials
- Guiding students toward reliable Internet sources in the teaching-learning process
- Obeying ethical norms in obtaining special information via technology while preparing a teaching activity
- Behaving ethically during the technology-based evaluation process for the evaluation of students’ achievement (p. 967)

Under their ethics rubric, Yurdakul et. al. make no mention of critically evaluating individual technologies, nor what ethical decision-making might look like with regards to individual technologies. Indeed, this formulation suggests an instrumental view of technology integration, well short of the ethical mark I am proposing here. Nonetheless, their “Design” wing or factor (or “designing instruction”) features several relevant teacher competencies including “determining of appropriate methods, techniques and technologies to be used in the teaching process” (p. 967). Here the Shulman’s (1986) delinquent “third category of content knowledge, curricular knowledge” (p. 10) and its relationship to technology begins to resurface. While Shulman did not employ the adjective “appropriate” to describe the teacher’s careful selection of the materia medica of curriculum, he did point out that curricular knowledge means that a teacher is able to adeptly choose “those tools of teaching that present or exemplify particular content and remediate or evaluate the adequacy of student accomplishments” (p. 10); like the mature physician prescribing medication, the experienced teacher selects technologies with due attention to multiple background factors and different contexts. This description fits with the Oxford English Dictionary’s definition of an “appropriate technology” which means “(a) technology considered suitable for a particular application; (b) technology in general, or a particular technology, that is designed to take account of the social, economic, and environmental circumstances in which it is employed.” Contextual knowledge of social, economic, and environmental circumstances is also the purview of Shulman’s curricular knowledge. Context consists of both the explicit (official) and the implicit (hidden) curricula; it includes knowledge of the complex infrastructure—including Programs of Study, School Acts, school buildings, lighting, rooms, desks, equipment, etc.—as well as the social practices, economic constraints, cultural norms, and political factors that inevitably shape local curricula, knowledge practices and learning activities.
In the TPACK model, the label “Contexts” signals the significance of such diverse contexts and shifting background factors. Further, the porous border that Koehler and Mishra added to their TPACK diagram in 2009 (Figure 1) helpfully suggests that every classroom situation is itself a soup of contexts that inevitably seep beyond and through the school walls, while simultaneously being informed and semi-permeated on all sides by the “outside world.” Here, Mishra and Koehler (2006) underscore the situatedness of all learning: “technology use in the classroom is context bound and is, or at least needs to be, dependent on subject matter, grade level, student background, and the kinds of computers and software programs available” (p. 1032). Indeed, their description of “Contexts” mirrors Shulman’s (1986) definition of curricular knowledge:

The curriculum is represented by the full range of programs designed for the teaching of particular subjects and topics at, a given level, the variety of instructional materials available in relation to those programs, and the set of characteristics that serve as both the indications and contraindications for the use of particular curriculum or program materials in particular circumstances. (p. 8)

And while Koehler & Mishra (2009) emphasize, “there is no ‘one best way’ to integrate technology into curriculum [but] rather, integration efforts should be creatively designed or structured for particular subject matter ideas in specific classroom contexts” (p. 62, bold emphasis in original), teacher’s curricular knowledge as such has been relegated to the nebulous “Contexts” territory outside of the TPACK model proper, without acknowledgement that this represents a specialized form of knowledge that had already been articulated by Shulman.

Yurdakul et. al. attempted to correct this by extending TPACK-Deep’s wings into TPACK’s surrounding “Contexts” area in an effort to account for “the complex web of relationships between content, pedagogy and technology and the contexts in which [these teacher knowledges] function” (p. 966). Yet TPACK-Deep also ends up losing touch with the meaning of its contextual ocean surround and of the porous shore touching the “outside world”. Once more, a teacher’s curricular knowledge—and its ethical implications—remains unspoken for. So while curriculum may be much discussed in TPACK circles, Shulman’s curricular knowledge—that is, an understanding of the medicinal and formative relationship of technology choice to learning—is absent from the TPACK model proper.²

TPACK’s Arc of Technology Transparency: Shifting from Apparency (TPCK) to Transparency (PCK)

² Recently, Mishra (2019) offered a key correction to the Context soup in which TPACK has been floating in since 2008. He renamed Contexts as “Contextual Knowledge” or XK and resituated it outside of the dotted circle. Contextual Knowledge is “everything from a teacher’s awareness of available technologies, to a teacher’s knowledge of the school, district, state, or national policies they operate within” (p. 76).
In their review of TPACK, Phillips and Harris’ (2018) also pointed to the importance of Susan Cox’s 2008 dissertation. Her research showed that when a new or emerging technology is integrated into a teacher’s practice, it eventually sinks into the taken-for-granted equipmental environment of the classroom: “TPACK becomes PCK as the technology becomes transparent” (2008, p. 99). Cox diagrammed this occurrence by pointing to the arc situated between TPACK and PCK; she labeled it “transparency of technology.” Cox drew a one-way arrow to mark the flow from TPACK to PCK. Based on other examples in her dissertation (for example, Dr. Rupper’s everyday use of PowerPoint where his TPK had clearly shifted to PK), I believe this arc of technology transparency should have been extended to the full circumference of TK. That is, whenever technological knowledge overlaps with other knowledges, the T will ultimately become transparent and thus slip from attention. This is also evident by her other two one-way flow markers from TPACK → PCK, TPK → PK, and TCK → CK (Cox, 2008; Cox & Graham, 2009).

Figure 2. TPACK with Cox’s (2008) showing her arc of technology transparency corrected to extend to PK and CK; and revised to reflect Mishra’s (2019) ConteXtual Knowledge (XK)

In light of this correction (Figure 2), it is tempting to retract TK entirely from TPACK, leaving only Shulman’s original PCK (Cox, 2008; Phillips & Harris, 2018). Indeed, Phillips and Harris (2018) propose that TPACK may represent “a special case of the PCK that sits within the considerably broader knowledge base for teaching …[and thus] teacher’s knowledge is arguably better represented in the way Shulman (1986) first defined PCK” (p. 2114, italics in original). Based on this, Phillips and Harris (2018) further suggest that when a new technology is introduced that,

a teacher needs to consider how asking her students to use this form of technology may influence her pedagogical approaches and assumptions….Over time, this teacher will become more familiar with the affordances and constraints of the technology (TK), the particular curriculum content learning that the technology can best facilitate (TCK), and the pedagogical methods and approaches that are effective when helping students to learn with this particular tool (TPK). (p. 2114).

Of course, the point of TPACK—beyond PCK—is that teachers are now inundated with an endless and evolving parade of new digital technologies which they are expected to “integrate” or “infuse” into the curriculum. Thus, new technology knowledge must be accounted for in some way, and TPACK provides such framework. Cox ultimately concludes along with Phillips and Harris that Mishra and Koehler’s “distinction between emerging and transparent technologies serves a valuable purpose” (Cox, 2008, p. 99). I agree.
As Cox (2008) discovered through her analysis of TPACK’s main knowledge constructs, the T in TPACK appears to be subsumed as part of a teacher’s Pedagogical Content Knowledge (PCK) once a technology has been fully, that is, “transparently” integrated into practice. Cox’s study leads me here to a discussion of early philosopher of technology Martin Heidegger’s (1962) insights regarding our everyday relationships to our world of equipment, and specifically, his distinction between two relational modes: “ready-to-hand” (when a technology is transparently integrated into one’s relational webs of practice) and “present-at-hand” (when a technology is not yet absorbed into practice, or when it is broken or is conspicuously absent, and thus is dislodged from its state of “handiness”).

To say a technology is transparently integrated into teaching, learning and knowledge practices means that we have developed an intimate or “primordial” relationship to it. It has become absorbed into our practice and in doing so, powerfully extends aspects of our perceptual, actional and/or intellectual selves. This fundamental or infrastructural absorption of the technology is crucial. As a child learns to read, for example, the technology of the alphabet must begin to fade into the background, in order to allow the words as spelled to increasingly leap or shine forth as meaningful. In his opus *Being and Time*, Heidegger (1962) uses the example of a hammer to show how we may experience any piece of equipment as either “present-at-hand” (*vorhanden*) or “ready-to-hand” (*zuhanden*). In its present-at-hand mode, a hammer appears to us as an object. That is, it stands as obstinate and conspicuous and other than us. In its ready-to-hand but more primal and usual “useful” mode, a hammer is absorbed “transparently” in the context of practice, of hammering.

In dealings such as this, where something is put to use, our concern subordinates itself to the “in-order-to” which is constitutive for the equipment we are employing at the time; the less we just stare at the hammer-Thing, and the more we seize hold of it and use it, the more primordial does our relationship to it become, and the more unveiledly is it encountered as that which it is—as equipment. The hammering itself uncovers the specific ‘manipulability’ [“Handlichkeit”] of the hammer. The kind of Being which equipment possesses—in which it manifests itself in its own right—we call “readiness-to-hand” [*Zuhandenheit*]. (Heidegger, 1962, p. 98).

As a technology quietly but handily (usefully) slips into our taken-for-granted background to support our knowledge practices, it also and necessarily falls from our critical attention. From this infrastructural vantage, a technology becomes part of the school’s “hidden curriculum” (Adams, 2015, 2017; Edwards, 2015). Understanding technology in its crucial infrastructural role in knowledge practices perhaps clarifies why Shulman characterized technology as the “material medica of pedagogy” and implicated it as an essential aspect of a teacher’s curriculum knowledge. For here, the medium—the “lived” or fully integrated technology—is the message. Or to use the Aristotelian language of change, technology takes up its role as the formal cause (eidos) of knowledge.

Formal causality kicks in whenever “coming events cast their shadow before them.” Formal cause is still, in our time, hugely mysterious: The literate mind finds it too paradoxical and irrational. It deals with environmental processes and works outside of time. (McLuhan, 2005, p. 182).

This is also why Neil Postman (1992) claimed that “technological change is neither additive nor subtractive, [but] ecological” (p. 18). Every time we invite a new technology into our lives, we are injecting a new way of knowing the world, and thereby altering our deeper knowledge structures. As Turkle (2004) put it, every (digital) technology is “a carrier of a way of knowing, a way of seeing the world” (p. B26). Software “affects our experience first and foremost through its infrastructural role, its import occurs prior to and independently of our production of representations’ (Hansen, 2000, p. 4).

Shulman’s suggestion that technology is the *material medica* of curricular knowledge similarly points to both its infrastructural role (i.e., as supporting scaffold), but also to its prescriptive nature (i.e., it is prescribed by the teacher to advance curricular interests), and which is subsequently absorbed in practice as a positive educational solution. Mishra and Koehler’s work has helpfully served to emphasize that technology is itself an important form of teacher knowledge with links and overlaps with other professional knowledge forms. However, technology is a special type of knowledge. This is because, once absorbed, technology sinks into the *formative undergirding of our knowledge structures*, with its pre-assumptions (pre-scripts) now inaccessible and thus closed to critical inquiry. There is no mystery here. In order for a technology to be useful, it needs to be absorbed transparently into our everyday lives, and thereby operate just below our actional and perceptual sensibilities. Yet in doing so, it disappears from the purview of our critical eye.
Re-opening the ethical border: studying breakdowns

Even though ready-to-hand artifacts recede from people’s attention, they… play a constitutive role in the human-world relations that arise around them. When a technological artifact is used, it facilitates people’s involvement with reality, and in doing so it coshapes how humans can be present in their world and their world for them. In this sense, things-in-use can be understood as mediators of human-world relationships. Technological artifacts are not neutral intermediaries but actively coshape people’s being in the world: their perceptions and actions, experience and existence. (Verbeek, 2011, p. 7-8)

It is notoriously difficult to predict the many possible effects and side effects of integrating a given technology into our cognitive ecosystem. This is in part because technology works its powerful “medicine” only when it is in use. Staring at a hammer reveals little of its true power until one grasps hold of it and begins to hammer (Heidegger, 1962). Consider a more contemporary example, the smartphone. It is well-nigh impossible to fully assess this technology’s manifold effects and side effects, without trying it out for oneself, discovering its possible uses, and ultimately integrating it seamlessly into one’s life. Yet even when one has thus domesticated a technology, it can still be difficult to account for the full range of changes it has wrought, though most will agree that they can no longer live without it! So how do we see the full picture?

A “breakdown” can provide a unique opportunity to “light up the relational web in which [a technology] is acting” (Olsen, 2010, p. 73) and thereby reveal to the attentive observer some of the key changes that have transpired via the technology-in-use including what has been gained, as well as what has been lost. In a moment of breakdown, a technology suddenly shifts from its taken-for-granted, “ready-to-hand” mode to “present-at-hand”. As Gunkel and Taylor (2014) note:

Heidegger’s distinction between present-at-hand and ready-to-hand contains a critical insight for those seeking to engage in critical media studies. Because we often consume media [and technology] as if they were transparent and invisible, the investigation of media [and technology] can only proceed by first making them conspicuous, obtrusive or obstinate. (p. 119).

In the context of a technology breakdown, “ready-to-hand” and “present-at-hand” modes collide but also oscillate: (1) the readiness-to-hand (transparent use) experienced just moments before still resides as shadow in one’s imagination, and (2) the presentness-at-hand of the technology’s broken state painfully reminds its user of what has been lost. In the moments following the breakdown and before the technology is once again restored to its functional, ready-to-hand state lies a key interval to observe and reflect on what is both lost and gained by having the technology seamlessly integrated into one’s life. Such breakdown moments can be artificially produced by deliberately removing a given technology from one’s life for a short period of time. In terms of TPACK, a breakdown event quickly transports a teacher (and/or student) to the unique border territory marked by the arc of technology transparency. By wakefully attending to the breakdown with a critical eye can develop a teacher’s technoethical insight.

As part of our Introduction to Educational Technology course in my Faculty of Education, we invite our preservice teachers to undergo a 24-hour fast from the 21st-century technologies in their lives. The exercise asks them to notice and document what changes they experience during the day. In this way, they have the opportunity to observe some of the existential implications and hermeneutic effects and side effects today’s technologies are enacting on their thinking, doing and being in the world. The experience is revelatory for some. We also study other borderland approaches—for example, the McLuhans’ (1988) four Laws of Media—to provide preservice teachers with multiple means to try to anticipate the manifold effects a given technology may have on their students’ developing knowledge ecologies, attentional well-being, etc. These nascent teachers are thereby encouraged to consider digital technologies as their pedagogical pharmaka—a set of potent cognitive, social and cultural medicinals at their disposal; they are simultaneously equipped with a set of heuristics to aid them in critically examining each technology as an algorithmed or designed “solution.” Taking up a pharmacological or materia medica view of technology—where technology is grappled with in its metabolic role in shaping our knowledge ecosystems—also reveals that teachers bear ethical responsibility for the technologies they prescribe for students. Knowing a given technology’s effects and side effects means teaching professionals can make more informed decisions regarding “appropriate” technology use in the context of today’s complex media environments, and with due regard for individual students needs and local contexts.
Conclusion

Examine each new technology before it is released, just as we study new drugs before we declare them safe for public use or consumption and refuse their release until they have been studied and found non-toxic, at least for our own culture. Are there antidotes? How can a culture or a user forestall or cure addiction? How can its disruptive effect on other media be minimized or prevented?

(McLuhan, 2019, p. 410)

It is patently absurd for us to engage in moral and ethical evaluation without first having some understanding of the very phenomenon we are evaluating. And while [Marshall] McLuhan was no scientist, he understood the value of holding judgment, of dispassionate assessment, of objectivity as an ideal that we can never quite obtain but we can still aspire to and approach. We begin by observation, by paying attention to our surroundings, by making the invisible environment visible. But what happens after we assess what is gained and what is lost, the functions and dysfunctions, the positive and negative effects, the costs and benefits?

(Strate, 2020, p. 7)

In this chapter, I tried to show that in the process of being integrated into practice, (1) technologies typically move from a present-at-hand (apparent) to a ready-to-hand (transparent) relational position in order to be useful; (2) TPACK’s arc of technology transparency points to technology’s powerful infrastructural role in scaffolding our students’ cognitive habits and knowledge ecosystems, i.e., technology as “hidden curriculum”; and (3) by consciously stepping back across the arc (e.g., via a breakdown or by employing other heuristics), teachers can identify key technoethical issues that may otherwise go unnoticed or be ignored. Teachers prescribe and facilitate the development of powerful, ready-to-hand, human-technology knowledge relations for students; such a role requires professional and ethical oversight.

Reckoning with digital technologies as materia medica or pharmacological solutions—a theory supported by contemporary philosophers of technology and media scholars (Stiegler, 2011; Hansen, 2016), as well as curriculum scholars and educational philosophers (Lewin, 2016)—recuperates Shulman’s original understanding of technologies in relation to curricular knowledge. Several actions follow from such a view:

(1) Educational technology researchers and educators should be methodically curating a pharmacopoeia of educational technologies. That is, for each digital technology-in-use and for-use in schools, scholars and teachers should be striving to reveal and catalogue its:
   a. benefits (its cognitive, pedagogical, relational, cultural, etc., effects);
   b. risks (its cognitive, pedagogical, relational, cultural, etc., side-effects and possible adverse effects);
   c. possible “interactions with other interventions” (i.e., how it combines, interoperates and/or reacts with other technologies or techniques that are already part of a student’s media and knowledge ecology).

Attending to and generating new insights along TPACK’s arc of technology transparency is one way for educators to begin to navigate and map this otherwise hidden curricular territory.

(2) Teachers must take up their technoethical responsibility to carefully weigh each new technology’s benefits, i.e., its likelihood to produce an intended result (e.g., efficacy, effectiveness, engagement, etc.) against its possible risks and adverse effects to their students’ well-being, attentional health, ecology of knowledge forms, etc., and by extension, consider the implications of using these technologies in future social, political and cultural contexts.

(3) Teacher education programs should be integrating curricular knowledge (Shulman, 1986), which includes facilitating preservice teachers in developing their own critical pedagogy of technology, where all technologies, but especially today’s educational software, are understood as part of the indelible substrate of our evolving epistemological and existential infrastructure. Technologies “are not only carriers of symbolic freight but also crafters of existence” (Peters, 2015, p. 15), and thereby warrant special ethical and pedagogical attention as a “hidden curriculum” (Adams, 2017; Edwards, 2015; Jackson, 1968).

A tall order. Yet in light of growing concerns regarding some of the adverse effects of digital media technologies on the lives of our children and youth, it is simply no longer tenable for teachers to maintain an ethically neutral stance towards the unprecedented range of new technologies they are inviting into their classrooms. Technologies—whether books and blackboards, or Google and ClassDojo—are “not pedagogically innocent” (Segall, 2004, p. 498). Rather, they must each be handled with due care and ethical responsibility, through developing a more robust and critically attentive grasp of their unique mediating influences in the lives of children and youth. Including the arc of technology
transparency in TPACK is one more step towards reminding us of teachers’ important professional role in making wise technology choices for their students.

References


Digital Storytelling through Authoring Simulations with Teacher Moments

Garron Hillaire
Laura Larke
Justin Reich
Massachusetts Institute of Technology, United States
garron@mit.edu
larke@mit.edu

Abstract: In this paper we explore how to support teacher educators to author their own digital clinical simulations to prepare K-12 pre-service computer science teachers. Teacher educators have the potential to create simulations about relevant content for their teacher preparation programs and contextualize those simulations for their students. To benefit from this unique perspective, we support teacher educators in authoring simulations. We consider the relationship between authoring simulations and digital storytelling to inform our authoring tools and supports. In this study, we report results on what kinds of supports are needed for authoring simulations based on a co-design workshop with 12 teacher educators from nine U.S. states across all regions of the country. We examine how these authors set context, select content, and engage in the simulation authoring process to gain insight into supporting teacher educators as digital storytellers.

Introduction

In this study, we describe digital clinical simulation (DCS) as a scripted simulation where the participant in the simulation interacts with scripted conversational prompts that are approximations of interactions a teacher might have. When it comes to authoring DCSs, teacher educators have the potential for curricular expertise which is defined as the ability to select and convey content appropriate to the learner within a particular context (Ennis, 1994).

We describe a digital platform called Teacher Moments that uses authoring tools to facilitate digital storytelling. We examine how the platform can support teacher educators in building simulations for training pre-service teachers. Teacher Moments is a mobile app that immerses novice teachers in multimedia vignettes of challenging classroom decisions. Participants provide improvisational audio responses to scenarios involving students, parents or other school personnel (Thompson et al., 2019). Responses are recorded for reflection, discussion, and expert feedback, and data can be analyzed by researchers for program evaluation purposes.

While teacher educators may be well prepared to author DCSs based on their ability to contextualize learning material, we hypothesized that they would require support to author simulations in a digital platform. The need for support is apparent when we recognize that authoring simulations for training is a form of digital storytelling (Dörner, Grimm, & Abawi, 2002). Creating tools to author digital stories requires design expertise about how to author a digital story (Dörner et al., 2002). While teacher educators are thought to have curricular expertise, they may not have expertise in authoring digital stories.

Digital storytelling is comprised of multiple components, such as purpose, story, plot, and narrative (Sharda, 2007; Smeda, Dakich, & Sharda, 2010). In this study, we focus on supporting teacher educators in setting the purpose of their digital stories. Purpose is defined as the “goals, aim and objective of the story” (Smeda et al., 2010). We support teacher educators in selecting the purpose by identifying a problem of practice—defined as a challenging interaction a pre-service teacher will encounter when they become a K-12 classroom teacher. To illustrate the strategy for teacher educators to author simulations for teacher education, we first define the gap that Teacher Moments fills in the use of simulations for teacher education and illustrate why the platform is a good candidate for authoring tools. Second, we illustrate a typical simulation in Teacher Moments and draw an explicit connection between the simulation and components of digital storytelling. We then outline the development of authoring tools and prototypes of supports for teacher educators to author simulations. The aim of this work is to empower teacher educators as digital storytellers to generate simulations that are relevant to pre-service teachers along dimensions of problems of practice (or purpose) and context. This work raises the following three research questions:
RQ1. What kinds of contexts do teacher educators describe when authoring digital clinical simulations?
RQ2. What problems of practice do teacher educators consider when authoring digital clinical simulations?
RQ3. How do teacher educators describe the experience of authoring digital clinical simulations?

From Analog Simulations to Digital Clinical Simulations

There is a long tradition of using simulations in teacher education. We start by considering analog simulations where the simulation occurs in face-to-face settings. For example, role-playing is considered an effective practice in teacher education (Kilgour, Reynaud, Northcote, & Shields, 2015). While this approach provides opportunities for practicing conversations, there are a few limitations. One of the limitations is that reflection on the content of the conversation is considered both critical and difficult to achieve due to the logistics of recording such conversations (Richards, 1985). Another limitation in the literature on role-play is that depending on the partner you are assigned, the quality of the activity may be variable (Nestel & Tierney, 2007).

One strategy to address the variable quality of the teacher-teacher interaction is to set up role-play where one person is a student and the second is a paid actor. This approach is frequently used with medical students to practice patient interactions (Dotger, 2013). In medical education, this approach is referred to as clinical simulations, which have been used when training the actor is considered critical to delivering authentic interactions (Dotger, 2013). While many medical simulations have medical students interact with actors, some medical simulations are set where students interact with mannequins. The use of actors verses mannequins raises questions of authenticity (i.e. how close is the simulated experience is to real world experiences) and fidelity (e.g. to what extent am I interacting with a lifelike partner in the simulation) (Hamstra, Brydges, Hatala, Zendejas, & Cook, 2014). The use of actors represents a focus on the fidelity of the simulated experience (Hamstra et al., 2014). However, when using mannequins for the simulation, and the simulation is about an authentic problem, students have a capacity for willful suspension of disbelief which can bring realism even when fidelity is low (Hamstra et al., 2014). While clinical simulations address the variable quality of role-play, students must be physically co-located within simulation rooms and have access to the resources necessary to either train actors or purchase simulation equipment, which can be prohibitive.

Mursion, a virtual reality career training platform controlled by live actors, addresses the barrier of access to a physical simulation room by having paid actors interact with teachers in a virtual space (Hudson, Voytecki, & Zhang, 2018; Peterson-Ahmad, Pemberton, & Hovey, 2018). In Mursion, a paid actor manipulates avatars in the simulation as a controller (Hudson et al., 2018) while users have opportunities to practice interactions through a virtual environment. Mursion occurs in a virtual space (Hudson et al., 2018; Peterson-Ahmad et al., 2018) and uses controllers prepared to manipulate the actions of the students (Hudson et al., 2018), so we classify this as a virtual clinical simulation. While virtual clinical simulations – simulations between students and actors facilitated in virtual space – have a clear strategy to address the barrier of physical access, the remaining key challenge is creating virtual environments and preparing controllers to address a wide range of challenges that teachers face in a variety of different contexts. This approach towards contextualization may be cost prohibitive to many communities.

Teacher Moments addresses the barrier of access to a physical simulation room by having students interact with computer-generated dialog. Rather than interacting with an actor, the student interacts with unintelligent agents that script what students, parents or other school personnel might say during the simulation. The agents are considered unintelligent as they do not dynamically respond to what the student-user says. The Teacher Moments simulations may be less authentic than interacting with an actor, but early evidence suggests it is authentic enough for students to find it useful for learning (Thompson et al., 2019). When simulations are authentic to the student, then they will be more likely to bring realism to the experience (Hamstra et al., 2014). We illustrate the spectrum of analog to digital simulations in Figure 1, proposing the gap of DCS we aim to fill with Teacher Moments.
When considering Teacher Moments as a digital clinical simulation we have illustrated how authoring supports the generation of simulations in the Teacher Moments platform. The other side of the experience is using the simulations. Once a simulation has been authored the user experience is going through the simulation. As we indicated above the simulations follow a simple linear path meaning that participants experience the simulation in a uniform and consistent manner. That user experience of the simulation is comprised of interacting with prompts and providing responses. The prompts are comprised of text, video embeddings, and images. Responses can take the form of text or audio recorded response. To illustrate how authors are supported to create simulations with a common structure we next examine a digital storytelling perspective on Teacher Moments to highlight how the building blocks of prompts and responses are used to author digital clinical simulations.

A Digital Storytelling Perspective on Teacher Moments Simulations

When connecting a Teacher Moments simulation to digital storytelling we consider that digital stories are comprised of events, story, plot, and narrative which are related but unique (Sharda, 2007; Smeda et al., 2010). An event is an incident that takes place in the story while a story is a sequence of events. The plot is the way in which events are linked to create emotional engagement, and the narrative is the actual order of events (Sharda, 2007; Smeda et al., 2010).

In a Teacher Moments simulation, the user goes through a sequence of slides that are organized by four categories: context, anticipate, enact, reflect. We consider context and enact to be the critical digital storytelling elements. Context sets the stage for the story; the sequence of enact slides constitute the plot of the digital story. The anticipate and reflect phases are learning supports that allow user of Teacher Moments to record responses prior to the story in anticipate and consider their interactions in the story with reflect.

Context slides typically provide text to describe the context for the simulation such as the school background (e.g., you teach at a high school). Context slides may make the purpose of the simulation explicit (e.g., you are managing a conflict between students during a group work assignment). After reading the context slides, participants interact with anticipate slides that ask the participant questions that prime them to think about what might happen during the simulation (e.g., what do you think a teacher’s role is in a student’s academic success?). After setting context and asking anticipatory questions the participant enters the enact slides. The enact slides are usually a series of conversational turns where the participant is provided with dialog and asked to respond (e.g., “StudentA: I hate group work, can I just do this by myself?”). The sequence of enact slides can represent either conversational turns with one digital conversation partner (e.g., a student) or can be authored as a series of vignettes where the participant interacts with a variety of conversation partners (e.g., talking to multiple students working on a group project). After going through the enact phase, participants interact with reflect slides where they are asked to reflect on their experience in the simulation. At times, reflect slides retrieve and display responses the participant provided during the simulation and are used to ask questions about their behavior. For the purposes of this study, we mainly focus on participants’ use of authoring tools for the context slides.

As Teacher Moments simulations follow a simple linear format, this is described in terms of digital storytelling as a very low level of complexity for the narrative (Smeda et al., 2010). While the simulations in Teacher Moments are very simple in terms of narrative, we anticipate that the straightforward nature of these simulations predispose them to distributed authorship by teacher educators. We rely on the perspective that with simulations, the relevance of the content of the simulation produces engaged students who make the simulation closer to a real
experience (Hamstra et al., 2014). To achieve simulations that are relevant to students, in this study we rely on teacher educators to author contextualized scenarios about relevant problems for pre-service teachers.

Creating Authoring Tools and Supports for Teacher Educators

A framework for creating authoring tools for digital storytelling (Dörner et al., 2002) suggests that three groups must work together to create a digital storytelling authoring system: (1) the technology group who understands how technology can support authoring digital stories, (2) the design group who are experts in authoring digital stories, and (3) the application authors, defined as the users of the authoring system. In this study, we considered staff and researchers at our lab to be the design group as they were the most familiar with authoring simulations using the Teacher Moments system. The application authors in this study are the 12 teacher educators recruited to author digital stories (see Participants), and the technology group in this study is a group of developers with expertise in multimedia web application development. The design group provided functional requirements to the technology group and the design group created low fidelity prototypes of supports for the application authors (see Materials). With added features and functions to create a simulation in Teacher Moments.

In the editor (see Figure 2), the simulation is authored through a series of slides. First, the author adds slides to the simulation. Second, the author adds slide content. We use the title of the slide to distinguish the phases of context, anticipate, enact, and reflect. The author can edit a slide by adding components, with each component falling into one of three categories: content, prompts, and embed previous response. The content component is a “Rich Text” editor that supports images, video, and text. Prompts are intended to allow the author to elicit a response from the user. Teacher Moments supports “Text Input Prompt”, “Audio Response Prompt”, and “Multiple Button Prompt” (with single select functionality). The “Embed Previous Response” component displays a previous response from the simulation (i.e., text, audio, or multiple button responses) designed to support users reflecting on how they previously responded. Once a simulate is authored, Teacher Moments provides authors with functionality to preview the simulation and publish the simulation, making it available for others to use.

![Figure 2. Authoring tools for teacher moments.](image)

The first point we focus on in supports is the purpose for authoring the story, one of the components of digital storytelling (Smeda et al., 2010). We frame the purpose for teacher educators by asking them to identify a problem of practice. We define the problem of practice as a challenging interaction a pre-service teacher will encounter when they...
become a classroom teacher. After selecting a purpose for authoring a simulation the next step is to provide supports for authoring.

To support authoring in a simulation, we provide four potential approaches to setting simulation context. The template supported setting the context by providing examples of 1) school background, 2) providing the time/day/location, 3) using scripted dialogue, and 4) using teacher observations about the school. In Table 1, we provide examples of each of the four context support types. Our expectation was that teacher educators would use these supports to describe contexts relevant to the K-12 schools where their pre-service teachers will be placed.

<table>
<thead>
<tr>
<th>Support</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 School Background</td>
<td>You teach CS in a community college. Your student body is comprised of mostly Latino/Hispanic students.</td>
</tr>
<tr>
<td>1.2 Time, Day, Location</td>
<td>Your weekly schedule is 7:00 a.m. - 3:00 p.m. In your course at 8:00 am, you will teach computer science to high school students in the 9th grade</td>
</tr>
<tr>
<td>1.3 Dialogue</td>
<td>William: Do you mind if I work by myself? Maybe Carol and Maria can work together? You: William, you have been working for years in industry, we want to learn from you! Please share some of your wisdom. Also, Maria and Carol have great ideas to share too!</td>
</tr>
<tr>
<td>1.4 Observation</td>
<td>You recently taught recursion in class. Students are confused about how recursion works and they don’t know how to program, and it is now time to program in teams to share knowledge.</td>
</tr>
</tbody>
</table>

Table 1. Support for Context Slides

In addition to authoring support for establishing a problem of practice, we provided support across authoring the three phases of anticipate, enact, and reflect so that authors could expand the problem they select into a DCS. We suggested anticipating: 1) their role as a teacher, 2) the needs of the student, 3) how to achieve their goals, and 4) what might generally happen. We suggested enacting: 1) response to dialogue and 2) response to student work. To support anticipate authoring we provided examples of questions authors might anticipate in these four categories (see Table 2)

<table>
<thead>
<tr>
<th>Support</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 your role as a teacher</td>
<td>What do you think a teacher's role is in helping students to be successful in school?</td>
</tr>
<tr>
<td>2.2 the needs of the student</td>
<td>What's are some best case and worst case scenarios for the student? What would success for the student look like here? From your perspective, what does it mean for a student to be successful in school?</td>
</tr>
</tbody>
</table>
2.3 how to achieve your goals
Before you begin, what are your thoughts on Ms. Bobson’s interactions with Greyson? What do you hope to get out of the conversation?

What would you like to prepare before going into your meeting with Ms. Bobson? What artifacts would you like to bring or look at?

2.4 generally what might happen
After skimming the scenario, what do you anticipate might happen?

<table>
<thead>
<tr>
<th>Support</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 an equity dimension</td>
<td>It's common opinion that &quot;effort and sacrifice guarantees students will have opportunities to succeed. &quot; What is your opinion on this statement?</td>
</tr>
<tr>
<td>2.2 whole or part of the conversation</td>
<td>Review the entire conversation, did you... Review your response, did you..</td>
</tr>
<tr>
<td>2.3 bringing something from the individual experience to a group conversation</td>
<td>Finally, pick one moment to talk about during the group discussion. In the group, you'll be asked to describe what you noticed, any assumptions you made, and how that shaped your interactions with the student.</td>
</tr>
<tr>
<td>2.4 the role of the teacher</td>
<td>During the simulation, how did you think about your role as a teacher?</td>
</tr>
<tr>
<td>2.5 the experience of the student</td>
<td>How did Darius experience the situation?</td>
</tr>
</tbody>
</table>

Table 2. Support for Anticipate Slides

We also suggested reflecting on: 1) an equity dimension, 2) whole or part of the conversation, 3) bringing something from the individual experience to a group conversation, 4) the role of the teacher, and/or 5) the experience of the student. For each of the five reflection supports we provided examples that could help authors create reflections within their own simulations.

Table 3. Support for Reflect Slides

Participants

We recruited fellows to participate in this study by publicly advertising a fellowship to teacher educators who prepare pre-service K-12 computer science teachers. There were 151 applicants for the fellowship, of which 15 were selected for phone screens and 12 were awarded the fellowship. Selection was based on geographic diversity, previous experience with issues of equity, educational technology, and artificial intelligence in the classroom. Experience with equity work was important as we sought fellows to author equity focused simulations. Experience with educational technology was important because the fellowship required implementing innovative technology in the classroom and related experience would demonstrate fellows were familiar with challenges associated with technology adoption. Finally, we examined experience with Artificial Intelligence (AI) as one of the longer-term aims of the project is to integrate AI into Teacher Moments and we wanted Fellows as thought partners around what AI might improve Teacher Moments. The fellows indicated that they would work with, on average, 20 pre-service teachers each over the course
of the study. The selected fellows represent geographic diversity as they are from nine different U.S. states across all regions of the U.S. (two from the Northeast, five from the Southeast, two from the Midwest, one from the Southwest and one from the West Coast).

**Procedure**

We conducted a two-day, in-person workshop with the 12 fellows. On the first day we had the fellows use existing simulations, provided them with details about designs for simulations, and presented three case studies of how Teacher Moments simulations had been implemented previously in teacher education contexts. We outlined how dimensions of equity relate to simulation design. In research on digital clinical simulations we focus on generating low stakes environments to practice high stakes interactions. In the case of this project we achieve the high stakes interaction by orienting around issues of equity. After discussing issues of equity, we had fellows co-construct problems of practice that K-12 computer science teachers would face when entering the classroom. Fellows each selected a problem of practice to author a DCS on, using supports provided in a low-fidelity prototype, which was a google slides template that looked like the Teacher Moments platform. The reason we used a low-fidelity prototypes was to test authoring supports (outlined previously in Tables 1 through Table 3). Finally, the fellows answered four questions as exit tickets about their experience on the first day of the workshop. On the second day of the workshop, the fellows tested a simulation created by a peer and provided feedback before exploring potential future directions for the Teacher Moments system. Finally, the fellows self-reported where they were on a learning curve by placing writing their name on a whiteboard within the Cartesian space generated by two dimensions. The X-Axis was labeled on the bottom with the word Unaware and the label on the top was Aware representing a continuous dimension of awareness. The Y-Axis was labeled on the left with incompetent and the label on the right was competent creating a continuous dimension of competence. We then ran a focus group discussion describing the four quadrants of this learning curve (unaware-incompetent; aware-incompetent; competent-aware; competent-unaware). We had fellows reflect on their own learning at the end of the procedure as a self-report measure to help us understand how competent and aware they were in using tools we introduced to them in the workshop as well as provide insights into how we might continue to support them over the coming year.

**Co-Constructed Problems of Practice List**

We asked teacher educators to co-construct a list of problems of practice on a shared document to help inform their and the other fellows’ storytelling.

**Low Fidelity Prototypes of Supports**

To support authoring DCSs for teacher education, we created a low fidelity prototype of authoring supports around four phases of the simulation: context, anticipate, enact, and reflect. We suggested they create 2-3 context slides, 2-3 anticipate slides, 8-12 enact slides, and 4-6 reflect slides. Each of the slide types had their own template with instructions to add text on the left using supports on the right (see Figure 3).
Co-design Workshop Exit Survey Questions

The first day of the co-design workshop focused on authoring DCSs. We administered the following four questions at the end of the day to collect data about the experience teacher educators had while authoring simulations.

1. I used to think _____ now I think _____?
2. What worked well?
3. What was most helpful?
4. What changes would you recommend for future workshops?

Learning Curve Activity

At the end of the second day of the co-design workshop, we asked fellows to reflect on any activity from the workshop and self-identify how they felt during the activity in terms of the learning curve by showing them the cartesian space comprised of the continuous dimension from unaware to aware and the continuous dimension from incompetent to competent. After writing their name on the quadrant (unaware-incompetent; aware-incompetent; competent-aware; competent-unaware) that described their experience, we ran a focus group discussion describing the experience for each quadrant.

Analysis

To answer RQ1, we conducted thematic analysis on the context slides authored by fellows to describe dimensions used to set the context of simulations. We then mapped the context themes to the supports. To answer RQ2, we conducted thematic analysis on the co-constructed list of problems of practices. To answer RQ3, we
conducted thematic analysis on the exit survey questions and reported the number of fellows in each of the four quadrants of the learning curve activity.

**RQ1. What kinds of contexts do teacher educators describe when authoring digital clinical simulations?**

We conducted a thematic analysis on the context slides and four themes emerged (see Table 4): institutional setting (10 of 12 fellows); engagement (8 of 12 fellows); demographics (6 of 12 fellows); and background knowledge (5 of 12 fellows). As both institutional setting and demographics were suggestions provided by the supports this indicated many authors used the supports for context. In addition, the authors commonly focused on engagement and background knowledge indicating a potential need for authoring supports for those two themes.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional setting</td>
<td>Institution type in an urban/rural setting</td>
<td>“A total of 13 students studying computer science fundamentals in CS at a Community College”; “You are a teacher of CS for high school seniors”;</td>
</tr>
<tr>
<td>Engagement</td>
<td>Students/teacher engagement</td>
<td>“The students have been attentive so far, and many seem even very excited …”; “Veteran Teacher 1: Good luck. We hope you stay, but don’t blame you if you leave for a better school.”;</td>
</tr>
<tr>
<td>Demographics</td>
<td>Race, SES, IEP, ELL</td>
<td>“Your students are 70% white, 20% black, and 10% Hispanic.”; “94% African American, 5.5% Latinx and 0.5% Multi-Racial.”</td>
</tr>
<tr>
<td>Background Knowledge</td>
<td>Presence/Absence of skills for Students/Teacher</td>
<td>“However, many of your students have no experience with computer science.”; “students know more than the teacher …”</td>
</tr>
</tbody>
</table>

**Table 4. Context Slides Theme Descriptions**

When mapping the themes from the context slides to the supports, Table 5 illustrates evidence of a high level of support utilization. The institutional setting theme was set in context slides using approaches described in the Time, Day, Location support. The demographics theme was set in context slides using approaches described in the school background support. The background knowledge and engagement themes were set in context slides using approaches described in the dialogue or observation supports. Overall, there was evidence of support utilization as indicated by Table 3. The thematic analysis on the context slides surfaced that this engagement was set using the dialog and observation supports. The remaining context themes had a one-to-one mapping onto the supports provided. These results indicate that teacher educators using the provided supports generated very specific contexts for DCSs.

<table>
<thead>
<tr>
<th>Theme</th>
<th>1.1 School Background</th>
<th>1.2 Time, Day, Location</th>
<th>1.3 Dialogue</th>
<th>1.4 Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional setting</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Demographics</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Background Knowledge</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Engagement</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

**Table 5. Context slides theme descriptions**

**RQ2. What problems of practice do teacher educators consider when authoring digital clinical simulations?**

The 12 fellows created a list of 61 problems of practice during a 30-minute exercise (see Table 6). We identified six themes in the list of problems of practice co-constructed by the fellows: Student engagement (11 of 61); group work (11 of 61); appropriate challenge (9 of 61); accessibility (7 of 61); emotion regulation (5 of 61); and conceptual understanding (5 of 61). While these problems appear to be common problems in classroom settings, the novelty in this study is authoring simulations that allow one to practice interactions around these common problems. See Table 4 for descriptions and examples of each theme. In addition to the six themes, there were a series of problems
of practice that were mentioned by three or fewer fellows in the list, including: technical resources, ethical issues, assessment, cheating, workforce readiness, and class discussions. Overall, the teacher educators were able to quickly identify many problems of practice, demonstrating their familiarity with the problems of practice confronting K-12 computer science teachers. After generating the list, we asked teacher educators to pick one problem of practice as the purpose of the simulation they would author.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student engagement</td>
<td>Students doing minimal to no work on assignments</td>
<td>1. Student have gone off task doing other activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Students doing just the very basic assignment</td>
</tr>
<tr>
<td>Group work</td>
<td>Preference to work alone or preference for different task types</td>
<td>1. Students are pair programming and one student in the pair says they work better independently</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. When you have assigned a group project and a student is adamant about working alone</td>
</tr>
<tr>
<td>Appropriate challenge</td>
<td>Assignment is to easy or to hard</td>
<td>1. Students seem to be lost after instruction is provided</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Student completes the assignment quickly before others</td>
</tr>
<tr>
<td>Access</td>
<td>Pulling students out of computer science class due to IEP or ELL status</td>
<td>1. Pulling out students with IEPs for specialist time from CS classes when the school has a CSforAll vision</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Conversation with principal about ELL or IEP students being scheduled to be pulled out during CS class</td>
</tr>
<tr>
<td>Emotion regulation</td>
<td>Frustration, Sadness, melting down</td>
<td>1. Getting stuck and melting down</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Student is crying at her desk</td>
</tr>
<tr>
<td>Conceptual understanding</td>
<td>Connecting concepts/applications with computer science</td>
<td>1. Elementary students don't see the relationship between unplugged CS activities and computer science</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Students fail to see the purpose of the content, not grasping the applicability of CS and/or programming</td>
</tr>
</tbody>
</table>

Table 6. Problems of Practice Themes Generated During Fellow Workshop

RQ3. How do teacher educators describe the experience of authoring digital clinical simulations?

We first conducted thematic analysis on exit survey items administered at the end of the workshop’s first day, during which fellows had begun authoring DGSs. The twelve responses to each of the four questions generated one data set of 48 responses which resulted in four themes: peer feedback (11 of 48 responses), authoring (11 of 48 responses), activity variation (8 of 48 responses), and supports (8 of 48 responses). See Table 7 for descriptions and examples of each theme. As the focus of this study was on supporting teacher educators to author simulations, we were interested in whether exit ticket responses commented on the usefulness of the supports that we provided. When looking at the comments which highlighted authoring supports, they indicated that they were well supported in their learning of how to author DGSs. The main criticism about supports was a need for more support authoring the scenario.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer Feedback</td>
<td>“Discussion with other participants”; “Hearing questions people had on other scenarios was really interesting. It made me realize how unique the different perspectives were and how we all brought our own passions (and pain-points) to the activity.”;</td>
</tr>
<tr>
<td>Authoring</td>
<td>“I used to think that creating a practice space would be more complicated, now I realize they can be generated in shorter periods of time and refined over time.”; “I also appreciate that it is largely generative/hands-on, not simply listening.”</td>
</tr>
<tr>
<td>Activity Variation</td>
<td>“Having people write case studies and then present them to others is a really nice design”; “Writing a case and getting feedback on it.”; “Working the thinking by ourselves and then Group discussions then sharing out worked very well.”</td>
</tr>
<tr>
<td>Supports</td>
<td>“I learned a lot today, specially how to contextualize scenarios to different backgrounds. I just needed more guidance on how to create the scenario part.”; “The scaffolded slides for creating the practice space were super helpful!”;</td>
</tr>
</tbody>
</table>

Table 7. Exit Survey Themes
We next considered how teacher educators classified their learning experiences from the learning curve activity (see Table 8). 8 out of 12 fellows self-identified as aware-incompetent, 3 out of 12 fellows self-identified as aware-competent, and 1 out of 12 fellows self-identified as unaware-competent. We then conducted a focus group discussion to describe those experiences. The majority of fellows (8 out of 12) described aware-incompetent experiences when they reflected on the workshop.

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unaware-Incompetent</td>
<td>[N/A]</td>
</tr>
<tr>
<td>Aware-Incompetent</td>
<td>1. Not having experience about particular situations and at times overthinking what to do.</td>
</tr>
<tr>
<td></td>
<td>2. They had experience with a lot of contexts, but a lack of experience with different possible actions</td>
</tr>
<tr>
<td></td>
<td>and potential responses within those contexts.</td>
</tr>
<tr>
<td></td>
<td>4. Looking up best practices to formulate questions about what to do.</td>
</tr>
<tr>
<td></td>
<td>5. When action was taken there was a degree of uncertainty about those actions.</td>
</tr>
<tr>
<td></td>
<td>6. It will take time to unpack their learning and peer feedback may be a part of that process.</td>
</tr>
<tr>
<td>Aware-Competent</td>
<td>1. Confident with what they know but also drawn towards staying with what they know.</td>
</tr>
<tr>
<td></td>
<td>2. Aware of future goals, but not yet an expert on how to achieve those goals.</td>
</tr>
<tr>
<td></td>
<td>3. An ever-growing awareness of what they don’t know which provided clarity for the task at hand as</td>
</tr>
<tr>
<td></td>
<td>well as an appreciation for the complexity of the work</td>
</tr>
<tr>
<td>Unaware-Competent</td>
<td>1. Connecting the current efforts to prior similar experiences which felt familiar making assumptions</td>
</tr>
<tr>
<td></td>
<td>and automated behavior possible</td>
</tr>
</tbody>
</table>

Table 8. Learning Curve Themes

By considering the descriptions they provided of those experiences, it paints a picture that the fellows have context knowledge but lack familiarity with specifics about what happens within those contexts. Specifically, they mention not knowing what kinds of conversational responses from students or colleagues might occur within the context. This lack of familiarity appears to cause confusion and struggle as they formulate their DGS’ story. When seeking support, they consider best practices and peer feedback. During the focus group discussion, they specifically mentioned a lack of experience with different possible actions and responses which would only occur when authoring the enact phase. Taking these two points together provides evidence that teacher educators may need more support when authoring the enact phase of their scenarios.

Discussion and Future Work

The reactions from the workshop indicated that Teacher Educators sought support outside of the tool through avenues such as peer-feedback. This highlights the need to consider aspects outside of the technology when exploring how Teacher Educators adopt novel technologies. Future work should consider how to support the social aspects of technology adoption for platforms that support authoring simulations.

We confirmed our expectation that teacher educators have a unique perspective on context and problems of practice when authoring DCSs. We see some commonalities between themes from context and themes from problems of practice (e.g., engagement is represented in both context and problems of practice; the problem of practice about appropriate challenge has a relationship with the context theme of background knowledge; the context theme of demographics has a relationship with the problems of practice theme of access). As three of the four context themes have potential relationships with problems of practice theme, future work should more closely examine the potentially contextual nature for problems of practice. While we found evidence that teacher educators are comfortable setting context and selecting problems of practice for simulations, future work should also examine the extent to which the pre-service teachers they serve perceive these simulations as relevant to their learning. The supports prototyped in this study appeared to be useful, but it was indicated in the exit survey and focus group comments that they fell short in terms of modeling the conversations in the simulation during the enact phase. Teacher educators self-described as not prepared to predict what will happen in the contexts. As this study supported digital storytelling through supports for purpose, the challenge that teacher educators experienced in authoring the enact phase suggests further supports should be developed for additional digital storytelling aspects such as plot, narrative, story characters, and dramatic questions.
Beyond improving supports there is a pressing need to evaluate how in-/pre-service teachers learn from using simulations authored by Teacher Educators. Future work should examine transfer of learning between simulations and transfer of learning from simulations to actual classroom practice.

References


Acknowledgements

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Humanizing Digital Mentorship: Using Video-based Remote Supervision for Student Teachers Abroad

Jennifer Rider
Di Ryter
Fort Lewis College, United States
jrider@fortlewis.edu
daryter@fortlewis.edu

Abstract: This case study inquired into the use of video-based remote supervision of three student teachers conducting their 15-week internship in an American accredited Pre-K to 12 school in Costa Rica. A common challenge of student teaching abroad is the lack of physical connection and communication between student teachers and college faculty. Using video-based remote supervision through Iris Connect technology allowed for student teachers to be supervised by a faculty member from their teacher education program. As a result of this case study, there were three main findings. The video-enhanced observation technology and software platform allowed for self-reflection by the student teachers; the technology helped student teachers feel more comfortable receiving and reflecting on constructive criticism from teacher education program faculty members (college supervisors); and the video technology provided an opportunity for collaborative reflection on the teaching practice.

Introduction and Context

Innovative technologies have transformed the way we connect and communicate across broader spaces and contexts (Zawacki-Richter & Naidu, 2016). Even in traditional face-to-face models, teachers are using technology for a variety of purposes beyond the delivery of information (Anderson, 2008; Jones, 2002). How faculty integrate technology into the learning and communicative processes are an essential component of teaching in higher education. Jones (2002) claims that most of today’s college students do not even know of a world before the internet, and that they rely on it for social and academic purposes. He argues that the internet is central to their communication, and they can be considered pioneers of new technology trends. Undoubtedly, technology is an essential part of the professional, academic and social lives of students and faculty in higher education institutions and can be a primary factor in the pedagogical design of education.

Just as technology plays a prominent role in the interactions of college students, a large part of the college experience is learning to develop and maintain personal and professional relationships. College students are expected to interact with professors and fellow students on a different level from what they had previously experienced. A significant body of research exists that demonstrates how positive interpersonal relationships between faculty and students impact student motivation, academic achievement, and affect toward their college experience (Komarraju, Musulkin, & Bhattacharya, 2010; Pascarella, 1980; Umbach & Wawrzynski, 2005). Building relationships with students plays a crucial role in their academic success (Chen, 2000; Komarraju et al., 2010; Nieto, 2008; Pascarella, 1980; Rolón-Dow, 2005).

Positive relationships between faculty and students can help foster a stronger reflective process of learning and growth. Establishing trust and collaboration in the student teaching supervision allows the student teacher and faculty member to mutually identify goals, procedures and outcomes relevant to a successful student teaching experience (Liu, Miller, Dickman & Monday, 2018). Additionally, the use of video-enhanced observations also creates an opportunity for deeper self-reflection by student teachers, allowing for observation of microteaching within authentic classroom contexts. It allows for deeper critical reflection and analysis than live observation due to the ability to replay clips (Santagata, Zannoni & Stigler, 2007).

The purpose of this case study is to investigate the design of a newly-implemented student teaching abroad program and the technology platforms and tools that could be used to humanize online interactions and enhance the mentorship of student teachers abroad by Teacher Education faculty members. This study inquired into the effectiveness of video-based observation and digital platforms to conduct classroom observations of student teachers while they completed their 15-week internship abroad. The use of technology can enhance and even transform faculty's
ability to support students in multiple environments and contexts, including overseas. The objectives of this study were:

● To utilize and evaluate the effectiveness of a VEO technology platform for lesson observation and debriefing with student teachers abroad
● To explore how student teachers use technology to reflect more deeply on their pedagogical practice of teaching and learning.
● To understand student teachers’ perspective on maintaining a mentoring relationship with faculty at their home institution.

This study informs the professional growth of preservice teachers in the Teacher Education Department, providing important information on how to optimize the program for the most effective international experience to preservice teachers as they move into the K-12 classroom.

**Literature Review**

**Mentorship through Student-Teaching Supervision**

Building relationships, trust, and respect with students is crucial to their academic success (Chen, 2000; Komarraju et al., 2010; Nieto, 2008; Pascarella, 1980; Rolón-Dow, 2005). Umbach and Wawrzynski (2005) conducted empirical research about faculty behaviors and interactions with students in the undergraduate classroom to evaluate the role that faculty play in student learning. The authors studied the relationship between the context faculty created and student engagement, student perceptions of environment, and student self-reported gains. They found that one of the primary indicators of quality undergraduate education is interactions with faculty and peers, which adds value to student learning (Umbach & Wawrzynski, 2005).

Student teaching observations is one of the few opportunities where student teachers receive individualized instruction and interaction, and mentorship becomes a critical element to support student teachers’ professional development during their internship (Allen, Wood, Sponberg & Arnold, 2019). Traditional supervision for out-of-area student teachers typically means finding a college supervisor (CS) within the internship setting or sending a CS from the home institution. These options create challenges. The first option does not allow the students to remain connected with their college faculty (Hager, Baird and Spriggs, 2012). Their CS may be someone they do not know and do not have a relationship with. This lack of relationship can affect students’ motivation and achievement (Komarraju et al., 2010; Pascarella, 1980; Umbach & Wawrzynski, 2005). The second option for supervision by a teacher education faculty member takes more time and money to support an out-of-area student teacher (Van Boxtel, 2017; Hager et al., 2012; Liu, Miller, Dickmann and Monday, 2018; Schmidt, Gage, Gage and McLeskey, 2015).

For example, Kansas State University (KSU) had a traditional student-teaching supervision model of hiring part-time supervisors that often come from a pool of retired educators. Because of the value of instructor quality in education, and due to declining local resources and the increasing demand for teachers in high need areas, KSU embedded digitally mediated supervision with video-based feedback systems into their Masters of Arts in Teaching program (Allen et al., 2019). The use of remote video-based technology allows for faculty members in Teacher Education programs to maintain a professional relationship with student teachers who are completing their internship out-of-area. This technology also allows faculty from the home institution the opportunity to serve as student teachers’ CSs and allows the CSs to have more time to spend mentoring, observing lessons and supporting student teachers because they spend less time traveling to out-of-area sites (Van Boxtel, 2017). While the majority of studies on remote, video-based supervision describe the use for student teachers in rural and out-of-area schools (Allen et al., 2019; Hager et al., 2012; Liu et al., 2018; Schmidt, Gage, Gage and McLeskey, 2015; Van Boxtel, 2017), there is little to no research around using video-enhanced observation (VEO) with student teachers abroad.

**Video-Enhanced Observation for Critical Reflection on Teaching**

The use of VEO has been a common practice with a substantial body of research. Gaudin & Chalies (2015) reviewed the research literature from the past 10 years with a focus on video observation of preservice teachers, and through their analysis of over two-hundred and fifty-five articles they found that VEO has been a significant part of teacher preparation programs on almost every continent. VEO provides advantages such as greater access to a variety of classroom events, facilitation of video viewing for professional analysis, and contributing to institutional reforms.
Most importantly, the researchers found that the use of video along with substantive analysis of teaching provides opportunity to improve the quality of instruction and to modernize education (Gaudin & Chalies, 2015).

Analysis is essential to using VEO for professional growth. Santagata et al. (2007) investigated preservice teachers analyzing videos of others teaching as classroom practice prior to being placed in the field.

...preservice teachers were required to see beyond superficial features and to analyze teaching in more elaborated ways. These included analyses of the content presented in lessons; of cause-effect relationships between teacher actions and student learning; and of students’ thinking and understanding of specific concepts and ideas (p. 125). Santagata et al. (2007) presents two assumptions that many preservice teacher preparation programs are based on: “1) exposure to examples of teaching creates learning opportunities for prospective teachers; and 2) through field experience, preservice teachers meld theory into practice” (p. 124). However, the authors argue that these assumptions are not always true due to a wide programmatic focus, abstract terms and concepts presented in teacher preparation courses, and an expansive array of teaching styles and practices in the field. However, Santagata et al. do not believe that field experience should be removed from programs. They argue that “teaching is a cultural activity, and cultural routines are more easily unveiled when the teaching process is slowed down and critically analyzed” (p. 125). The use of video in teacher preparation allows for observation of microteaching within authentic classroom contexts and for a deeper reflection and analysis than live observation due to the ability to replay clips.

Christ, Arya and Chiu (2017) argue that different types of video use can trigger different outcomes; for example, reflecting on video with peers might help preservice teachers find solutions to issues in the classroom. The authors highlight that although there are many studies that prove the benefits of video use in improving teacher education outcomes, there is not enough research regarding the extent that video is used in preservice teacher training (e.g. structure, frequency, purpose). Based on their research findings from 208 teacher educators across the country, the authors make four recommendations for teacher educators: 1) using video more frequently throughout a course; 2) using more varied forms of video observation and evaluation; 3) provide effective supports such as graduate assistants; and 4) lighten course loads so that instructors have more time to implement technology in their teaching practice (Christ et al., 2017).

Aside from providing opportunities for analysis and reflection, Sherin (2000) highlights the use of teacher video recording as a way for teachers to regain motivation and excitement for teaching in the midst of their careers. The use of video clubs gives interested teachers the opportunity to view recordings of their lessons, reflect on what occurred during a lesson and discuss potential new instructional strategies based on their observations. Sherin argues that reflection through video allows teachers to take a narrower focus on specific events in the lesson without having to multitask all of the happenings of a classroom during a live lesson. Video clubs also allow teachers an opportunity to come together with colleagues to explore teaching practices. “To develop a video club that encourages reflection, focus, and community, club members must investigate, not evaluate, teaching” (Sherin, 2000, p. 37). This investigation not only focuses on teacher moves but more so on student learning and thinking processes, which ultimately prepares teachers to make in-class pedagogical decisions based on students’ thinking, questions and actions in the classroom.

The benefits of VEO range from deeper critical reflection of teaching, to greater access to observation of preservice teachers, to increasing motivation for teaching. VEO allows the observer, often faculty or CS, to provide more support for the preservice teacher because of reduced travel time and more investment in mentoring and feedback (Van Boxtel, 2017). Candidates in Van Boxtel’s (2017) research preferred video observations to traditional, face-to-face observations because they valued the opportunity to view themselves teaching while viewing the detailed, guided feedback from their supervisor on ways to improve their instruction. The VEO process offers an opportunity for student teachers to reflect more critically on their practice compared to traditional observation formats. In traditional observation formats, a CS observes the student teacher deliver a lesson and often provides written feedback on an observation form. The student teacher and the CS then discuss the observations. This approach to supervision can be a one-sided discussion in that the supervisor is telling the student teacher what went well and what they could change in the next lesson. This approach can limit the student teacher’s opportunity to critically reflect on their own practice.

Liu (2015) argues that critical reflection is a framework for transformative learning in teacher education. Other studies use VEO to provide student teachers opportunities to reflect on their teaching practices (Crow, 2013; Kleinkecht and Groschner, 2016; Naidoo and Kirch, 2016; Santagata et al., 2007; Sherin, 2000). Self-reflection can be a major contributor to the growth of a preservice teacher. Allen et al. (2019) argue that deep reflection includes observing the lesson and responding to the observed lesson, justifying the reasoning for why the lesson was successful or unsuccessful, and making connections to future lessons. Liu (2017) states:

I consider the task of inculcating critical reflection in prospective teachers as an act of intertextual analysis, understanding the classroom, the individual and triad meetings, and the ePortfolio as dialogic texts. The
supervisor’s role is to assist the prospective teacher in creating a coherent narrative that supports their transformative learning (p. 3). The goal of self-reflection is to grow as a teacher and implement change with the purpose of enhancing student learning (Lui, 2015). Using a VEO platform that allows for both CS and student teachers to comment and make critical reflections on student teachers’ practices synchronously or asynchronously provides a dialogical space for student teachers’ critical reflection and potential for transformative learning (Liu, 2017).

Conceptual Framework

The researchers used Ruben Puentedura’s SAMR (Substitution, Augmentation, Modification, and Redefinition) model as a conceptual lens to investigate how video-enhanced observation can transform the student teaching experience. The SAMR model encourages technology use to go beyond enhancement and into transformation (Puentedura, 2014). As substitution, technology is used as a direct tool substitute, such as observing a video-recorded lesson. With augmentation, the technology allows for functional improvement, such as video observation with time-stamped feedback comments. In modification, the technology allows for significant task redesign, such as video observation with collaborative, real-time feedback within the video. Redefinition of the task is creating a process that was previously inconceivable, such as reflective self-evaluation within the lesson video and mentor-student teacher debriefing via video-conferencing technology.

Methodology

This qualitative case study included three student teachers from a teacher education program in a small liberal arts college. The study inquired into the effectiveness of student teachers and college supervisors (CS) using video technology to observe and debrief with student teachers, how faculty can maintain mentoring relationships while student teachers are abroad, and the potential for student teachers to reflect on their practice.

The goal of using video-enhanced observation was to be able to observe student teachers’ classrooms remotely and to maintain a professional relationship with student teachers abroad. The significance of this goal was to maintain a professional mentoring relationship with our student teachers abroad to help motivate them and complete their internship successfully. Two research questions guided this study:

- How do remote, video-enhanced observations help faculty maintain mentoring relationships with student teachers abroad?
- How do video-enhanced observations support student teachers’ reflective practices?

Research setting, participants and technology

This research took place in three settings. It began and concluded at a small liberal arts college in the western part of the United States. The college’s Teacher Education program is small and students often have two or three classes with the same instructors—who also serve as their CSs—which creates strong student-faculty relationships. Traditionally, when student teachers do their 15-week internship out-of-area, the college hires out-of-area CSs that the student teacher may not know. The second setting of this study was situated in an American-accredited school in Costa Rica, where three student teachers were placed for their 15-week student teaching internship. Through the use of video-enhanced observation technology, two faculty members of the Teacher Education Department were able to serve as CSs to the three student teachers. The video-enhanced observation technology used in this study was Iris Connect, creating the third setting for this study. Lessons were recorded and uploaded to students’ Iris Connect accounts. The lessons were then shared with their CS. They were able to view the recording of their own lesson and reflect on their practice using time-synced comments throughout the video recording. Iris Connect was used in conjunction with online video conferencing to discuss observed lessons with student teachers, as well as to have three-way discussions among student teachers, cooperating teachers, and the CS, mirroring a traditional student teaching evaluation process.

Iris Connect hardware includes two iPads to record video of the class from two angles, covering virtually the whole classroom. It also includes two iPods to audio record the student teacher and the class. One iPod is worn by the student teacher with a lanyard around the neck or clipped on a pocket. The other iPod can be positioned anywhere in the classroom so that student conversations can be recorded. Once the video and audio devices start recording, the
iPad screens go black so that students are not distracted by the recording. When the lesson and recording ends, student teachers upload the recording to their individual account and the Iris Connect software syncs the two videos and audio recordings into one recording. Students can then share the recording of the lesson with their CS at their home institution. Additionally, once the videos are uploaded to an individual account, the videos are automatically erased from the iPads, which provides security of privacy.

**Data Sources and Analysis**

There were three forms of data collected in this study. The researchers, serving as CSs, conducted three video-enhanced observations of lessons taught by each of the three student teachers in their field placement, which included reflective comments by both the student teacher and the CS. Secondly, at the end of the semester students completed a questionnaire comparing their experience with having a faculty member from their home institution as a CS versus an on-site supervisor. The student teachers worked with both types of supervisors during their student teaching internship in Costa Rica, which allowed them to compare the mentorship process between an on-site supervisor and a supervisor from their home institution. Lastly, an in-person focus group interview was conducted at the home institution at the end of the semester with the three student teachers. The purpose of the interview was to learn about the student teachers’ perspectives using video-enhanced observation technology and the extent that it helped support them during their 15-week student teaching internship abroad.

There are different kinds of triangulation that can help the critical review of data. Denzin (1989) suggests that triangulation can be implemented by the use of multiple perspectives, the use of multiple data sources, or the use of multiple observers. In this study, triangulation of data sources was used, as well as having two observers/analysts. Data triangulation helps to strengthen the construct validity of this case study (Yin, 2018). Following Creswell and Creswell’s (2018) process for analyzing qualitative data, the researchers organized the questionnaire data to get a sense of student teachers’ responses. The questionnaire and focus group interview data were then hand-coded to identify descriptors. The descriptor codes were organized into broader themes (Creswell and Creswell, 2018). To ensure qualitative validity and reliability, the researchers independently coded the data and used the same analytic process. This allowed the researchers to “cross-check” the codes for 100% intercoder agreement, as used by Creswell and Creswell (2018). A second round of coding of the two sets of coded data was conducted and larger themes were established. Though case studies are not often generalizable (Stake, 2000), this study offers insights on factors contributing to student teachers’ reflective practices and faculty maintaining mentoring relationships with students who are student teaching abroad.

**Findings**

There were three main findings from this study, which were supported by the literature and aligned with the goals of the study. In investigating how video-enhanced observation supports student teachers’ reflective practices, we found that the digital technology allowed for greater self-reflection than traditional methods of observation. In seeking to understand how VEO helps faculty maintain mentoring relationships with STs abroad, the researchers found that the technology helped student teachers feel more comfortable receiving and reflecting on constructive criticism from faculty members/CSs from their teacher education program; and Iris Connect made the remote observations feasible.

The first main finding from the study was that the video-based remote observation process helped student teachers reflect more deeply on their practice. Two of the students said they felt uncomfortable watching themselves, but thought that recording, observing and reflecting on their lessons was a valuable practice. Kristin said, “You don’t know how you teach until you see yourself teach.” Allyson commented, “Looking and commenting on the lesson was very helpful.” She also commented on how she appreciated the opportunity to see “what students see.” Sally said she valued the opportunity to reflect on her teaching practices through the videos and observe how students responded to the lesson. The first round of observations conducted by the researchers, also serving as the CSs, took a fairly traditional approach. The first lesson was observed and comments were made throughout. Students then responded to the CS’s comments, followed by a video conference meeting with the student teacher to discuss observations and provide more detailed and dialogic feedback. This digital version simulated how an observation may take place in a face-to-face setting where the CS observes a lesson and then provides the student teacher feedback after the lesson is taught.
In the second round of observations, Allyson took the initiative to reflect and comment on her lesson prior to the CS viewing the lesson or providing feedback. She had transformed the process of reflecting on student teachers’ practices. Because of the extent to which Allyson reflected on her lesson and identified what went well in the lesson and areas needing change, the CSs asked Sally and Kristen to do the same with their lesson observations. This practice was found to be much more useful to student teachers because they were critiquing and reflecting on their own practices before the CS observed the lesson and added further comments and feedback. An outcome of this study was that the student teachers often observed and commented on the same pedagogical practices that the CSs would have brought to the discussion as strengths or room for growth. This exemplified the pedagogical alignment between the student teacher and the home institution. There were times that student teachers missed an opportunity to reflect on a particular practice, which left room for deeper feedback from the CS about opportunities for growth.

The second finding that emerged from this study was that students valued having a CS that was a faculty member from their teacher education program. Students felt more comfortable receiving constructive criticism because they had a previous relationship with the CS. Allyson said that because she knew her CS from having her as an instructor in the teacher education program, it gave her more confidence and made her more comfortable. Sally said, “You know us better than our [on site] supervisor… Debriefing with someone I knew was nice.” Kristin said she knew what was expected of her because her CS came from the program in which she was taught.

Even though all three student teachers felt supported and preferred being observed by their home program’s CS, they had mixed feelings about being observed by their on-site CS from the host school. One technique the on-site CS used was unannounced drop-in observations. Initially, the drop-in observations made all three student teachers uneasy and anxious. The student teachers felt that the drop-ins interrupted their class because they lost concentration on their lesson and were focused on being observed. Eventually two of the student teachers became comfortable with the drop-in observations and said that it helped establish their teacher identity because the drop-ins helped them prepare for all lessons as best as they could. Also, they were no longer distracted when the host school’s CS entered their class. However, the drop-in observations made one student teacher uneasy and uncomfortable throughout the internship. This student felt uncomfortable communicating with someone new, as the on-site CS did not know her and she did not know the CS.

Lastly, Iris Connect, the remote observation platform, provided the necessary elements to make remote observations successful. The software and hardware were both user friendly, which allowed students to independently set up the hardware in their classroom abroad. This alleviated students’ concern about technological problems with the devices. Once students had experience setting up the equipment, they could do it in about a minute. Initially, there were minor recording errors with video and audio recording not working, but these errors were ironed out with more practice with the devices. Ultimately, providing students with more practice prior to going abroad will help students feel more comfortable using the technology.

Discussion

The findings indicate that through video enhanced observations (VEO) student teachers were able to reflect on their own teaching practices and student learning. Self-observation allowed for critical reflection that led to teachers making micro-adjustments in their teaching (Liu, 2015). This practice of observation and reflection using asynchronous video observations is supported by Gaudin and Chalies’s (2015) review of literature related to the use of VEO for in-service and pre-service teachers, and builds off of Liu’s (2017) framework of reflection and transformative learning. Student teachers’ self-reflection of their lessons, pedagogy, and student learning helped them to make changes to their practice and grow as teachers. Using technology for redefinition of the student-teaching observation process also provided more opportunity for self-reflection, transforming the student-teaching growth process (Puente, 2014). Given the video-enhanced observation technology capabilities, students abroad are able to focus on their micro-moves within teaching as well as analyze their pedagogical decisions based on students’ actions in the classroom (Sherin, 2000). Beyond the pedagogical response, the technology also creates a structure for student teachers to capture their thinking processes as they self-evaluate their teaching, ultimately helping them to create a process for growth beyond the student teaching experience. A consideration for further implementation of VEO with student teachers abroad is to utilize Schwille’s (2008) framework for video-based supervision, providing a more explicit structure for feedback and evaluation from both the student teacher as well as the college supervisor.

The mentoring framework developed from Schwille’s (2008) research team reflects a professional skill set necessary for effective digital-mediated supervision. These include: a) a deep understanding of the learner; b) an accurate, individualized, and continual professional assessment of mentee performance, and; c) attend to immediate development with long term goals in mind, or *bifocal vision* (Allen et al., 2019, p. 548). This depth of reflective
practice can only be achievable with significant structure, appropriate technology, and with the support of a mentor or supervisor who can provide the individualized feedback that Allen et al. (2019) recommend.

The extent to which faculty have a professional relationship with students can have a significant impact on students’ learning, growth, and motivation (Chen, 2000; Komarraju et al., 2010; Nieto, 2008; Pascarella, 1980; Rolón-Dow, 2005; Umbach & Wawrzynski, 2005). Through the use of Iris Connect, faculty from the participants’ Teacher Education program were able to serve as college supervisors while they completed their 15-week internship in Costa Rica. The findings illustrate their preference to reflect and receive critical and constructive feedback from a faculty member that they know because they have a relationship with them and know what is expected of them based on pedagogical content received throughout their training. Because of this study and the initial use of Iris Connect to maintain relations with student teachers abroad, faculty in the Teacher Education Department at this Liberal Arts college have been able to supervise student teachers abroad in subsequent semesters, providing a solid method for continuing the mentorship throughout the entirety of their pre-service teaching career.

This study confirmed the primary themes that the body of VEO literature encompasses: 1) video-based remote supervision (Van Boxtel, 2017) allows college faculty to maintain professional relationships with out-of-area student teachers (Allen et al., 2019); 2) it allows student teachers to continue to work with faculty they know while out-of-area; and 3) it provides an opportunity to be efficient by not having to travel to out-of-area locations. More importantly and deeply rooted to individual and professional growth, the use of video-based observations provides student teachers opportunities to reflect on their teaching practices (Crow, 2013; Kleinknecht and Groschner, 2016; Naidoo and Kirch, 2016; Santagata et al., 2007; Sherin, 2000). This opportunity for critical reflection supports the claim that VEO could be used in any context and at any point throughout the preservice teaching program.

Conclusion

While this study builds on the research that exists around VEO for remote student teachers, it also provides contextual ways in which faculty and program coordinators can use these tools in their own fields, disciplines, or programs. Remote supervision can be used to alleviate the challenges associated with rural student teaching placements, as well as to maintain connections between a home institution and student teachers abroad. Although this is a new context for analyzing the use of video observation, the process remains parallel to other contexts. Based on this initial use of VEO with student teachers abroad, the researchers would recommend providing more structure to the observation process that could be transferable to any remote observation for teachers. This structure could be mirrored after the study conducted by Santagata et al. (2007) in which students were asked to watch the lesson recording three times and to focus on a different aspect each time they watched it:

1. Parts of the lessons and learning goals;
2. Students’ thinking and learning;
3. Alternative teaching strategies.

Focusing on these three areas provided students with the opportunity to dive more deeply into the analysis of the lesson (Santagata et al., 2007), and could be used to support the reflective process for teacher interns in any environment.

This study informs the professional growth of preservice teachers in a teacher education program, and also provides important information on how to optimize faculty support and maintain a mentoring relationship with student teachers abroad through the use of video-based remote supervision. This technology has been primarily used to support preservice teachers in rural regions in the United States. However, this study illustrated the unique aspect of using video-based remote supervision with student teachers in a more global context. Furthermore, the potential for self-reflection can be used by all preservice teachers in various stages of their program, not solely for student teachers. This reflective practice can lead to a transformative learning experience.

References


Abstract: With shortages in the STEM workforce, it is important to foster children’s interest in STEM subjects at early ages. New teachers must be prepared to engage learners in STEM experiences upon their entry into the profession. This study investigated the impact of a STEM professional development school (PDS) on teacher candidate (candidate) self-efficacy. Embedded within an introductory educational technology course, the PDS engages candidates in planning, teaching, and evaluating integrated STEM lessons to elementary students throughout the semester. Data were collected from PDS and non-PDS candidates enrolled in different sections of the same course. A teaching self-efficacy survey was used to measure candidate self-efficacy at the beginning and end of the semester. Data were analyzed using descriptive and inferential statistics. Findings indicated statistically significant increases over time with medium effect sizes for both PDS and non-PDS candidates, however, only PDS candidates experienced a calibration of their beliefs.

Introduction

Currently there are not enough STEM workers to fill STEM jobs in the U.S. (Fayer, Lacey, & Watson, 2017; Xeu & Larson, 2015). By 2026, 3.5 million computing-related jobs will be available, but most will go unfilled as there will only be enough US graduates to fill approximately 17 percent of them (National Center for Women and Information Technology, 2018). Schools have attempted to better prepare K12 students and increase their interest in STEM disciplines primarily in secondary school settings, which likely is too late to adequately interest learners in STEM (Gibson, 2012). Additionally, many teachers lack the knowledge, skills, self-efficacy, and beliefs needed to effectively implement quality STEM learning experiences for their students (Barr & Stephenson, 2011). As teacher education programs have worked to better prepare teacher candidates (candidates) for teaching integrated STEM lessons, most effort has been on the integration of science and mathematics, with technology and computational thinking often overlooked (Herschbach, 2011; Rinke, Gladstone-Brown, Kinlaw, & Cappiello, 2016). Therefore, a critical issue facing teacher education is how to prepare candidates to effectively teach integrated STEM lessons in which educational technology and computational thinking have a central role. The purpose of this study was to expand the literature by investigating the influence of a STEM professional development school (PDS) program on the beliefs that candidates maintain about their ability to develop and teach integrated STEM lessons (i.e., self-efficacy).

Integrated STEM

There is no agreed upon definition of integrated STEM Education in the literature, although it has been defined as the combination of two or more STEM disciplines within a single learning experience (Asghar, Ellington, Rice, Johnson, & Prime, 2012; Honey, Pearson, & Schweingruber, 2014). These experiences tend to be mostly design-based where engineering-oriented activities become the catalyst for problem-solving as part of an authentic issue or context (Honey et al., 2014; Kelley & Knowles, 2016). The integration of STEM subject areas has also been found in both the Common Core State Standards for Mathematics (http://www.corestandards.org/Math/) and the Next Generation Science Standards (https://www.nextgenscience.org), which recommend learners engage in asking
questions, modeling, planning and carrying out investigations, analyzing and interpreting data, computational thinking, developing innovative solutions, and communicating results (Honey et al., 2014). There are several benefits of integrated approaches to teaching STEM, such as increased content relevancy and learner engagement as concepts are connected across disciplines (Frykholm & Glasson, 2005; Koirala & Bowman, 2003). Researchers have also found that in integrated STEM experiences, learners engage more in critical thinking, problem-solving, creativity, and are more successful at retaining what they have learned while also becoming more self-reliant and technology literate (Ellis & Fouts, 2001; Ge, Ifenthaler, & Spector, 2015; King & Wiseman, 2001; Morrison, 2006; Smith & Karr-Kidwell, 2000). In addition, Guthrie, Wigfield, and VonSecker (2000) found students were more motivated to engage in learning when integrated STEM experiences were available.

Although there are several benefits to teaching integrated STEM lessons, teachers often lack knowledge, skills, and self-efficacy about teaching STEM disciplines. Multiple researchers have argued this is due to the limited exposure to STEM during initial teacher preparation (e.g. Corcoran, 2009; Eilks & Markic, 2011; Weiss, Banilower, McMahon, & Smith, 2001). Therefore, it should come as no surprise that teachers have lower confidence and negative beliefs about STEM subjects (Appleton, 2003; Dembo & Gibson, 1985; Epstein & Miller, 2011; Sterling, 2006; Weiss et al., 2001), especially when integrated technology and computational thinking are emphasized, as those areas have rarely been the focus of integrated STEM efforts (Herschbach, 2011; Rinke, Gladstone-Brown, Kinlaw, & Cappiello, 2016). Therefore, teacher education programs may better prepare candidates by exposing them to integrated STEM learning experiences in which technologies and computational thinking have a central role.

Candidates’ Self-Efficacy & Teaching with Technologies

Teachers’ lack of confidence and subsequent resistance to integrated STEM with a technology and computational thinking focus should also be expected given the lack of emphasis on STEM instructional practices when their belief systems were developed (Blackwell, Lauricella, Wartella, Robb, & Schomburg, 2013; Collins & Halverson, 2009; Parette, Quesenberry, & Blum, 2010). Confidence, or self-efficacy, is a fluid belief that changes as a result of everyday experiences (Bandura, 1977, 1986, 1997). As individuals experience successes and failures while completing a task, they gain knowledge that allows them to better judge how well they can complete a specific task (Bandura, 1997; Brown & Lent, 2006; Lent, Brown, & Hackett, 1994; Usher & Pajares, 2008). Self-efficacy is most strongly influenced by personal experiences where mastery in a task can be achieved, but can also be influenced by other experiences, such as (a) vicarious experiences, where others’ successes or failures are observed, (b) persuasion, where feedback can support and convince individuals they are capable of completing a task, and (c) emotional reactions, where arousal can drive individuals’ beliefs about needing to be successful (Bandura, 1977, 1986, 1997). Typically, when individuals have higher self-efficacy beliefs, they are more motivated to engage in novel experiences, even if they prove to be complex and difficult (Bandura, 1997; Gonida & Leondari, 2011; Klassen, 2006; Schunk & Pajares, 2009). However, the process of calibration, by which individuals iteratively align their perceived abilities to better reflect their actual abilities (Bandura, 1986, 1997), can prove to be beneficial in promoting conceptual change (e.g., “I’m not really as good as I thought I was; I need to learn more”; Siwatu & Chesnut, 2014) and establishing initial beliefs about ability (e.g., “this isn’t that hard; I can do this with a little more work”, Wheatley, 2002).

A teacher’s self-efficacy can be described as the beliefs that a teacher maintains about his or her ability to plan and teach a lesson to meet specific learning targets (Gavora, 2010). Teacher self-efficacy has been consistently found to promote teacher longevity and commitment to the profession, culturally responsive practices, and accommodations for special needs students (Chesnut, 2017; Chesnut & Burley, 2015; Chesnut & Cullen, 2014; Lam, 2015; Siwatu, Chesnut, Alejandro, & Young, 2016; Siwatu, Putnam, Starker, & Lewis, 2015). Research on teachers’ integrated STEM self-efficacy is quite sparse. In one of the few studies available, a professional development institute that culminated in the implementation of integrated STEM lessons by practicing teachers found teachers’ self-efficacy had increased at statistically significant levels (Knowles, 2017). In this quasi-experimental study, science and technology teachers’ self-efficacy developed following differing trajectories. Science teachers experienced significant growth initially (p-value = 0.001, Cliff’s Delta = 0.5), whereas technology teachers experienced significant growth in their self-efficacy after implementing an integrated STEM lesson (p-value = 0.001, Cliff’s Delta = 0.4). Given the overall lack of studies detailing approaches to teacher integrated STEM self-efficacy development, including the impact of those approaches, it is logical to examine how self-efficacy develops in contexts other than STEM. One area of specific interest is candidate self-efficacy development in PDS programs.
Professional Development Schools

Emerging from situated learning experiences (Lave & Wenger, 1991) where candidates learn through embedded field- or place-based experiences, PDS programs are formed as part of university and school partnerships where both institutions agree to work together in the preparation of new and current teachers (Castle, Fox & Fuhrman, 2009; Castle, Fox, & O’Hanlan Souder, 2006; Long & Morrow, 1995; Mourlam & Montgomery, 2015; Tusin, 1992). There are several design elements that characterize PDS programs, but according to Goodlad (1993) perhaps most important is having a shared vision and clear communication among stakeholders so that trust among partners can be developed. In addition, other design elements, such as professional learning opportunities for all partners, and a commitment to innovation and reflection have also been identified as important for successful partnerships (Heil, 1986; Killion, 2011; National Association for Professional Development Schools, 2008; Nelson, 1986; Williams, 1986). When successful PDS partnerships exist, candidates are positively impacted in multiple areas, such as licensure exam pass rates, self-efficacy, teacher professionalism, and pedagogical knowledge (Castle et al., 2009; Castle et al., 2006; Houston, Hollis, Clay, Ligons, & Roff, 1999; Levin & Rock, 2003; McDermott, Gormley, Rothenberg, & Hammer, 1995; Reinhardt & Stetson, 1999). In a mixed method comparative study examining three PDS replication studies, candidates in PDS partnerships appeared to take more ownership of their learning through their use of more personal possessive adjectives: “almost as if the non-PDS teacher candidates were practicing for the real thing while the PDS teacher candidates were doing the real thing” (Castle et al., 2009, p. 66). Given the success of PDS programs in contexts other than STEM education, and that to the best of the authors’ knowledge no STEM PDS currently exists in the extant literature, the following research questions guided this study: (a) to what extent do candidate self-efficacy beliefs change during the course of a semester for those enrolled in the PDS program and those not enrolled in the PDS program? and (b) to what extent does participation in the PDS program influence candidate self-efficacy beliefs at the end of the semester, controlling for prior self-efficacy beliefs?

Methods

This study took place at University of South Dakota, a medium-sized research university in the midwestern region of the US where each of the authors are faculty in the School of Education. The undergraduate teacher education program has an approximate annual enrollment of 450 students. The university is in a community of approximately 10,000 people with an annual K12 enrollment of approximately 1,300 students in the public-school system. While most children in the community are White (76%), there is a relatively high number of Native American students (10%), as well as students from economically disadvantaged families (30%).

The STEM PDS Program

The STEM PDS program was implemented in an introductory educational technology course typically taken by freshman and sophomore level candidates seeking initial teacher certification in elementary education. The second author, the instructor of record for the course, was the only author that interacted or participated in the STEM PDS program. Candidates enrolled in the course are typically also concurrently enrolled in separate field experience and foundations of American education courses. In this course, candidates learn about a variety of educational technologies (i.e. iPads, interactive whiteboards, Google Drive, etc.) and how they can be used during instruction to support student learning. This course has a specific focus on the integration of educational technologies through graphical-based coding with the other STEM subjects, in addition to other topics such as digital citizenship and media literacy. Built upon design-based learning experiences, the PDS program has also been designed to support candidate engagement in mastery and vicarious experiences, and persuasive feedback from peers and their professor as they learn about integrated STEM teaching approaches that they then implement as they plan, teach, and evaluate integrated STEM lessons to elementary school students throughout 12-weeks of the semester.

Candidates engage in a variety of activities, within the PDS program designed to impact their self-efficacy, in addition to their knowledge and beliefs about integrated STEM, such as instructor modelling of STEM lessons, opportunities to teach STEM lessons, and peer feedback (see Figure 1.). Typically, candidates plan and teach four integrated STEM lessons that they will teach throughout the semester. Candidate lessons are designed to be collaborative, problem- and design-based experiences for elementary learners. Each lesson includes content from at least two of the STEM subject areas, and is aligned with state content standards and ISTE Standards for Students
In the sections that follow, the process through which candidates progress as they engage in lesson planning, implementation, and evaluation is described.

**Figure 1.** STEM PDS elements.

*Lesson Modeling & Practice*

Candidates first engage in the STEM PDS through lesson modeling and practice as part of problem-based learning experiences related to the STEM lessons they will teach to elementary students. This occurs intensively in the first four weeks of the course, then periodically throughout the remainder of the semester. As part of lesson modeling, candidates take on the role of elementary student and vicariously learn about an integrated STEM instructional practice by watching their professor model all aspects of the lesson. As part of this experience, there are opportunities for candidates to develop mastery of the targeted elementary content standards, the modeled teaching strategies, and the technology tools used in the lesson. Mastery experiences exist in the form of practicing each component of the STEM lesson through a problem-based learning instructional approach. For example, in a STEM lesson where candidates teach third graders to create interactive posters similar to a museum exhibit on world climates, the professor first introduces and explains each part of the lesson before candidates complete the lesson as though they were the elementary student. In this lesson, candidates, and eventually third graders, are asked to: (a) research world climates using reliable online resources, (b) compile and present key information about two world climates on a poster, (c) create original artwork of plants and animals located in the climate, as well as graphs comparing weather data from each climate, (d) code a computer animation to share information about their climate using the online coding application Scratch, (e) use an inexpensive technology called Makey Makey that creates an interactive connection between the poster and the Scratch animation using with areas on the poster that conduct electricity (e.g. aluminum foil “buttons”), and (e) present their final products and what they learned to peers. The professor walks candidates through each part of the lesson by showing examples, demonstrating technology, and facilitating small and large group discussions. As candidates complete the STEM lesson, they apply prior knowledge from earlier course units. In the example lesson on world climates, this would include content knowledge about media literacy and computational thinking topics candidates learned in prior units, such as identifying trustworthy sources, citing sources, and debugging a computer program. This results in multiple pathways for learning to achieve the same learning objective and ultimately forms the foundation for candidate lesson plans. It is through this problem-solving that candidates’ knowledge of course themes are reinforced.

*Lesson Planning*

At the beginning of the semester, candidates are introduced to lesson planning through multiple in-class activities. This begins with a lecture and discussion reviewing course readings from *Invent to Learn* (Libow Martinez & Stager, 2013) on constructivist and constructionist learning theories that provide the theoretical foundation for
STEM lessons taught in the PDS, the components of a lesson plan and their function, and an opportunity to review and deconstruct exemplar lesson plans. Then, in teaching teams of two, after lesson modeling has concluded, candidates create their own lesson plan to be used when they teach elementary students. Candidate lessons are required to use the Think, Make, Improve engineering design process (Libow Martinez & Stager, 2013) to structure the learning and problem-solving process where elementary learners are presented with a problem to consider solutions and constraints (Think), create and test solutions (Make), and enhance their final solution (Improve). A lesson plan template is provided to support candidates due to their lack of experience creating lesson plans. The following information is provided: (a) targeted South Dakota content standards, (b) learning objectives, (c) suggested materials and equipment, and (d) broadly stated recommended activities, such as a lesson opener or a key activity like researching world climates. Candidates then design the instructional sequence by selecting and organizing activities that align and fit with lesson content topics and technologies. It is through this lesson design process that candidates engage in mastery experiences where their knowledge, self-efficacy, and beliefs are developed.

Professor Feedback

Lesson plans are reviewed by the candidates’ professor before candidates teach. Substantial feedback is given to each candidate regarding lesson design to: (a) identify any gaps within the instructional sequence, (b) ensure content topics are adequately addressed, (c) determine the suitability of questioning and formative assessment strategies, and (d) to evaluate lesson technology integration. In doing so, the attempts to motivate candidates by confirming successful practices demonstrated in lesson plans and persuade candidates to change specific areas of their lesson planning by addressing any misconceptions they may have that would ultimately lead to an unsuccessful lesson. Candidates then make lesson revisions and resubmit their lessons for additional feedback. This feedback-revision process continues until the professor believes candidates are prepared as evidenced through well designed lesson plan, with most students completing one to two rounds of revisions.

Lesson Implementation

Candidates, in teaching teams, teach their one-hour lessons to small groups of elementary learners following a co-teaching framework (Cook & Friend, 1995) where one candidate leads instruction and the other observes. Elementary student groups typically range in size from 3-5 students depending on total grade level enrollment. During lesson implementation, candidates serve as lead teachers for elementary students while in-service teachers are available to support both candidates and elementary students. This often occurs with special elementary student learning needs or classroom management related issues. During lesson implementation, the professor observes candidates teaching their lessons, providing support as needed. Each lesson is taught twice to different groups of elementary learners where candidates alternate between lead teacher and peer observer weekly.

Peer Observation

During lesson implementation, in teaching teams one candidate observes for lesson strengths and weaknesses, learner engagement and understandings of the content, as well as any aha moments for future lesson use. Observing candidates also assist in the lesson as needed. Often this includes answering elementary student questions, retrieving any additional materials and equipment needed to complete the lesson, and troubleshooting any technology issues that occur.

Reflective Dialogue with Peers & Professor

Each week after the one-hour lessons conclude, candidates engage in reflection and dialogue about their performance beginning with a reflective journal entry. Candidates’ journaling encompasses lesson successes, concerns, and questions. Teaching teams then discuss the peer observer’s notes to reflect on the overall success of the lesson, including any necessary lesson revisions. Finally, as a class, the professor poses multiple discussion prompts for candidates to openly reflect on, such as lesson success, classroom and behavior management, and lesson difficulties. Discussion concludes with the professor providing feedback from observations, noting individual
candidate successes and areas for growth shared by all candidates. Reflective dialogue sessions with candidates provides the opportunity to both motivate them by reaffirming their interactions with elementary students, while also assisting with the development of their knowledge and beliefs as they are encouraged to try new strategies to better meet the needs of the learners and lesson objectives.

**Data Collection & Analysis**

Institutional Review Board (IRB) approval was obtained to access existing self-efficacy data that were collected as part of a program evaluation survey used by the School of Education for accreditation and program renewal. The survey, which was completed at the beginning and end of the semester for all candidates, includes items from a teacher self-efficacy survey instrument (Skaalvik & Skaalvik, 2010). The teacher self-efficacy survey consisted of six dimensions, including (a) instruction, (b) adapting education to individual students’ needs, (c) motivating students, (d) keeping discipline, (e) cooperating with colleagues, and (f) coping with changes and challenges. Each dimension included four items for a total of 24-items where candidates responded using a 7-point scale ranging from “Not certain at all” (1) to “Absolutely certain” (7). The survey was not modified from the original, which underwent construct validity testing through confirmatory factor analysis and structural equation modelling. Reliability testing in the original instrument resulted in alphas ranging from .81 to .90 for each dimension (Skaalvik & Skaalvik, 2010). Cronbach’s α was used to confirm reliability, resulting in an alpha of .97 for both the pre- and post-survey.

All analyses, completed by the first author, were conducted in R (R Core Team, 2019; v. 3.6.1) using a variety of base and add-on libraries available through the Comprehensive R Archive Network (Hornik, 2012). Paired-samples t-tests were calculated to answer the first RQ concerning the growth of candidate self-efficacy during the semester for those enrolled in and not enrolled in the PDS program. Cohen’s d effect sizes were calculated using the `psych` package (Revelle, 2018; v. 1.8.12) in R. To answer the second RQ, concerning the influence of the PDS program on candidate self-efficacy beliefs, a hierarchical regression was conducted predicting post-semester self-efficacy beliefs starting with prior self-efficacy beliefs, then adding the PDS program binary indicator (i.e., 0 = Non-PDS, 1 = PDS), and then allowing these predictors to interact, as would be introduced in a moderation analysis.

**Participants**

Participants (N = 71) were students in three sections of an introductory educational technology course taught in the School of Education at the University of South Dakota. Candidates in one section of the course (N = 24) participated in the PDS program embedded at a local elementary school, while candidates in the other two sections (N = 47) participated in just the lecture and lab-based learning experiences in their sections of the course taught on the campus of University of South Dakota (henceforth referred to as non-PDS). Candidates enrolled in the PDS were primarily female (18) and were sophomores (15), juniors (7), or seniors (2), and identified as White (21), Hispanic (1), Hispanic and White (1), or Black and White (1). All candidates in the PDS were between the ages of 18 and 22. PDS candidates were primarily elementary education majors (21), nine of whom were also double majoring in special education. There was also one secondary education major, one physical education major, and one student that did not identify a major. Half of PDS candidates were also enrolled in a separate field experience course.

There were freshman (3), sophomore (40), junior (3) and senior (1) level candidates enrolled in the non-PDS sections of the course. Non-PDS candidates were primarily White (44) with one candidate identifying as both Black and White, one candidate identifying as Asian, and one candidate identifying Native American and White. Non-PDS candidates were mostly female (34) and between the ages of 18 and 22 except for two candidates (one 26 years-old, one 29 years-old). Non-PDS candidates were elementary education majors (26), five of whom were also double majoring in special education, secondary education (16), and physical education (3). There was also one nursing major. Of the 47 non-PDS candidates, 32 were enrolled in a separate field experience course.

**Results**

Analysis of candidate responses on the teaching self-efficacy survey indicated that candidates in both the PDS and non-PDS sections had a moderate sense of self-efficacy at the beginning of the course (see Table 1). Those
in the PDS were slightly higher (mean = 5.45) than their peers not enrolled in the program (mean = 5.27), but not significantly different ($t_{69} = 0.86$, $p(>|t|) = 0.390$).

| Group   | Pre- $M$ (SD) | Post- $M$ (SD) | Mean Diff | $df$ | $t$   | $p(>|t|)$ | $d$  |
|---------|---------------|----------------|-----------|------|-------|----------|------|
| PDS     | 5.45 (0.78)   | 5.96 (0.67)    | 0.51      | 23   | 2.15  | 0.042    | 0.70 |
| Non-PDS | 5.27 (0.88)   | 5.79 (0.70)    | 0.53      | 46   | 4.21  | 0.001    | 0.66 |

Table 1. Self-efficacy Beliefs Before and After Coursework

As Figure 1A illustrates, corroborated by the results of a pair-samples t-test, candidates experienced parallel increases in their self-efficacy in both groups from the beginning of the semester to the end. To understand individual trend differences, a hierarchical regression was used. Table 2 summarizes the results. The first model was developed to predict candidate self-efficacy beliefs after coursework using responses collected prior to coursework. This model was not statistically significant, and only accounted for 5% of the variance in self-efficacy beliefs after coursework. In the second model, the binary PDS variable was added as a predictor of self-efficacy beliefs after coursework. This model was not statistically significant, only accounting for 6% of the variance in self-efficacy beliefs after coursework. The addition of PDS as a predictor only slightly improved model fit with the data ($\Delta SS = 0.27$), but was not statistically significant. While one would typically stop the hierarchical regression when model additions fail to improve fit, the results from the prior analysis (i.e., significant gains in self-efficacy beliefs for both groups) made us question if the PDS was influencing the trajectory of the relationship between self-efficacy beliefs before and after coursework. In the third model, the interaction between the binary PDS and self-efficacy beliefs prior to coursework was added as a predictor of self-efficacy beliefs after coursework, to determine if being involved in the PDS moderated the gains in candidates’ self-efficacy beliefs. This model was statistically significant ($F_{(3, 67)} = 4.239$, $p(>F) = 0.008$), accounting for 16% of the variance in self-efficacy beliefs after coursework. The addition of the interaction significantly improved model fit ($\Delta SS = 3.27$, $F_{\Delta SS} = 7.74$, $p(>F) = 0.007$).

<table>
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<th>Model Description</th>
<th>Residual SS</th>
<th>$\Delta SS$</th>
<th>$F$-value</th>
<th>$p(&gt;F)$</th>
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<td>Pre Self-Efficacy + PDS</td>
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<td>Pre Self-Efficacy + PDS + (PDS*Pre Self-Efficacy)</td>
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<td>3.27</td>
<td>7.74</td>
<td>0.007</td>
<td>.16</td>
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</table>

Table 2. Hierarchical Regression with Model Fit Statistics

Results from the final model suggest that the relation between self-efficacy beliefs before coursework and self-efficacy beliefs after coursework is moderated by participation in the PDS. These findings are summarized in Table 3 and illustrated in Figure 1B. For Non-PDS students, self-efficacy beliefs prior to coursework were significantly and positively associated with self-efficacy beliefs after coursework ($b = 0.342$, $SE = 0.108$, $\beta = 0.420$, $p(>|t|) = 0.002$). Conversely, self-efficacy beliefs prior to coursework were significantly and negatively associated with self-efficacy beliefs after coursework for the PDS students, with an unstandardized shift in the slope of $b = -0.568$ ($SE = 0.204$) and a standardized shift in the slope of $\beta = -0.696$ ($p(>|t|) = 0.007$). While results from the first RQ demonstrate that both PDS and Non-PDS make overall gains in self-efficacy beliefs, the overall trajectory is moderated by involvement in the PDS. More specifically, a candidate who had lower self-efficacy beliefs at the beginning of the semester continued to have a relatively low self-efficacy beliefs at the end of the semester. Even though there may have been statistically significant gains for non-PDS candidates, candidates retained the same relative positions in their distributions, pre- and post-coursework. Conversely, candidates with a relatively low appraisal of their self-efficacy beliefs initially ended the course with relatively high levels of self-efficacy, while those candidates starting high ended relatively lower in their respective distribution of scores.

| Predictor                  | $b$ (SE)    | 95% CI              | $\beta$ | $t$   | $p(>|t|)$ |
|----------------------------|-------------|---------------------|---------|-------|----------|
| Intercept                  | 3.989 (0.578) | [2.835; 5.144]     |         | 6.899 | <.001    |
| Pre Self-Efficacy          | 0.343 (0.108) | [0.126; 0.559]     | 0.420   | 3.163 | 0.002    |
| PDS (binary)               | 3.195 (1.113) | [0.972; 5.417]     | 2.194   | 2.869 | 0.006    |
| PDS by Pre Self-Efficacy   | – 0.568 (0.204) | [– 0.975; – 0.160] | – 0.696 | – 2.782 | 0.007   |

Table 3. Results from Final Model Predicting Self-efficacy Beliefs after Coursework
Figure 1. Figure 1A illustrates parallel growth in self-efficacy beliefs from pre- to post-coursework. Figure 1B illustrates the moderated relationship between pre- and post-coursework self-efficacy beliefs due to PDS.

**Discussion**

The first research question addressed whether there were any statistically significant differences in the growth of candidates’ self-efficacy beliefs for those enrolled and not enrolled in the PDS program. As the results indicated, both PDS and non-PDS candidates experienced statistically significant increases in their self-efficacy from the beginning of the semester to the end. This shows that both participation in a STEM PDS with an emphasis on educational technology and participation in a traditional university classroom experience in educational technology are associated with increases in self-efficacy. The results are similar to those from other studies where candidates have reported increases in their self-efficacy beliefs as a result of their participation in a PDS program (Levin & Rock, 2003; Reinhartz & Stetson, 1999). Given the lack of studies on PDS programs focused specifically on integrated STEM and educational technologies, additional research needs to be conducted within these contexts to fully understand changes in candidate self-efficacy beliefs, and the practices through which beliefs are developed across different contexts and settings.

The second research question addressed whether there were any statistically significant differences in candidates’ trajectories of change for those starting with different levels of self-efficacy based on their enrollment in the PDS program. A hierarchical regression showed differences between the two groups when pre-coursework self-efficacy beliefs, the binary PDS variable (i.e., 0 = Non-PDS, 1 = PDS), and their interaction were used to predict post-coursework self-efficacy beliefs. While non-PDS candidates remained consistent in their trajectory (candidates who initially indicated low self-efficacy increased at a statistically significant level but remained generally low in their self-efficacy compared to their peers in the Non-PDS), PDS candidates appeared to undergo calibration in their beliefs (see also, Bandura, 1986, 1997). That is, as candidates participated in the PDS, they were better able to understand their abilities for teaching integrated STEM lessons in an authentic context and adjusted their self-efficacy appraisals accordingly (some candidates adjusted down while others adjusted up, but overall for PDS candidates their self-efficacy remained relatively high). Therefore, at the end of the semester, having planned, taught, and evaluated their own integrated STEM lessons with a strong educational technology focus, PDS candidates had more realistic appraisals of their self-efficacy beliefs, with some becoming more confident and others becoming less confident. This demonstrates that participating in a STEM PDS program may help candidates more accurately understand their beliefs regarding their ability to teach. When considered alongside the results of Knowles’ (2017) study, in which it was only after technology teachers had implemented integrated STEM lessons that their self-efficacy changed, the current results may indicate that STEM lesson implementation is an important factor influencing candidates’ self-efficacy for lessons involving integrated technology. This begs the question, how does experiencing this calibration early in a candidate’s program of study impact their self-efficacy, as well as their knowledge and dispositions, as they progress through their degree program, in particular through their methods coursework and clinical experiences? Researchers should explore this question in future research using a longitudinal design so that a more complete understanding of candidates’ participation in a STEM PDS program can be understood. Doing so would likely prove valuable for
programs seeking to implement PDS programs in STEM or educational technology, in addition to propelling the field forward in this area. In addition, as teacher educators explore STEM-based PDS programs, they should consider the multiple ways through which candidates can engage and participate in the PDS program. At the University of South Dakota, as a result of new temporary policies due to the COVID-19 pandemic, the STEM PDS program has now transitioned to a distance education format where candidates will engage in many of the same experiences, such as professor modelling, lesson planning, and feedback, but will do so from the university classroom and implement their lessons online. While we plan to investigate this unique approach in the coming months, we encourage others to examine the underlying structures and assumptions of PDS programs and their implementation in an effort to make PDS programs more sustainable as our world continues to change in unexpected ways.

Limitations

A limitation of this study is the candidates’ self-selection into the PDS program. Candidates could sign up for any section of the course, although elementary education majors were encouraged to enroll in the PDS given the grade level that candidates in this section would be teaching. However, due to candidate self-selection that resulted in non-equivalent groups, it is difficult to draw conclusions regarding the differences between PDS and non-PDS candidates. Researchers should attempt to better control for this in future research. Another limitation of this study was the use of a generic teaching self-efficacy survey to measure candidate confidence in integrated STEM education. Additionally, this instrument was initially developed for Norwegian teachers and may not be suitable for use with U.S. educators. Due to the lack of available integrated STEM self-efficacy survey instruments, researchers should address this limitation by developing instruments that assess candidates’ beliefs related to the integration of STEM disciplines, rather than using generic teaching focused or disciplinary STEM focused instruments. Finally, this study occurred in the Midwestern region of the U.S. and the sample consisted of primarily female, Caucasian, 18 to 22-year-old students. The results may not be similar to those in other contexts and regions of the world. Candidates from other demographic groups may experience the PDS program differently and subsequently report different levels of self-efficacy.

References


Williams, D. (1986). Introduction to the research question: Can a comprehensive public school-university partnership meaningfully contribute to the solution of educational problems?

Developing Pre-service Elementary Teacher’s Computational Thinking Knowledge Through Coding and Mathematics Pedagogy

Cory Cleasman  
Tennessee Tech University, United States  
cgleasman@tntech.edu

ChanMin Kim  
Pennsylvania State University, United States  
chanmin@psu.edu

Abstract: As computer science education standards are disseminated to K-12 school districts nationally, teacher education programs are left with the challenge of ensuring pre-service teachers are prepared to enter their first classroom with the skills and knowledge necessary to align instruction with the new standards. This paper examines the use of a learning intervention called “Block-Based Coding and Computational Thinking for Conceptual Mathematics” (B2C3Math) that aimed to help pre-service teachers majoring in early childhood and elementary education learn and apply computational thinking concepts to their elementary mathematics teaching. Ten pre-service teachers all at the same stage in their teacher preparation program participated in this convergent mixed-methods study. A focus of the research was placed on how participant’s computational thinking knowledge changed following the implementation of B2C3Math. Findings suggest that there were changes in the participants’ views of computational thinking application to elementary mathematics teaching following the implementation of B2C3Math. Implications for research and instructional practices using B2C3Math for teacher education are discussed.

Introduction

It is recommended state education systems across the United States develop computer science teaching pathways for elementary teachers (Code.org, 2017). Computer science and computer coding are frequently misclassified as the same entity. The study of computer science is much broader and encapsulates theory and concepts around computing. Computer coding can be considered a skill, however, learning any skillful act is reliant upon concepts and knowledge bases to fuel deep learning. Although distinctive terms, educational reform has relied on the use of computer coding as an approach to introduce computer science content to K-12 students (K12 Computer Science Framework Steering Committee, 2016). Coding presented at the K-12 level prepares students for careers requiring even the most basic computer science knowledge due to students being required to understand basic principles such as abstraction, efficiency, and sequencing while learning to code (Barr, & Stephenson, 2011; National Science and Technology Council, 2016). A large portion of various new K-8 computer science standards focus on coding. As educational standards and reform initiatives call for the introduction of computer science through coding, teachers need to be trained to keep up with these demands.

Literature Review

To adequately prepare teachers for 21st-century technological teaching, coding needs to integrate into professional development and more importantly, teacher preparation. Currently, thirty-three states in the U.S. have computer science certifications for high school and middle school teachers (Computer Science Teachers Association, 2018). It is now recommended that elementary teachers rely on professional development to ensure the integration of computer science into curricula (Code.org, 2017). Dismissing the importance of coding at the elementary teacher preparation level is not sensible as coding is a vital 21st-century skill regardless of students’ career path choices (Goode, Flapan, & Margolis, 2018; K12 Computer Science Framework Steering Committee, 2016). Pre-service
teachers need training to conceptually integrate computer science instruction through coding, providing them with foundational knowledge and skills making future professional development even more valuable.

Countries and private entities have developed content-specific coding courses and curriculums concentrated on the integration of coding into K-8 education (Falloon, 2016; Moreno-León, Robles, & Román-González, 2016). These types of curriculums, although useful, serve as a drag-and-drop curriculum; frequently leaving elementary teachers without the understanding of how computer science instruction can be incorporated into their already loaded instructional schedule. Practically, integrating coding into disciplines currently being taught allows teachers to more efficiently cover all mandatory content and standards. Coding has been paired with a multitude of elementary disciplines to enhance learning. Historically, dating back to 1980, Seymour Papert’s work with LOGO programming was tied to mathematics learning using constructionism learning theory (Papert, 1980). Due to the usability and feasibility of block-based coding for K-12 education, continuing to identify ways in which coding concepts can be crosscut and made more interdisciplinary is vital to its integration into teaching and learning.

**Conceptual Framework: Computational Thinking, Coding, and Mathematics**

To further emphasize computing concepts, computational thinking has been used as a viable avenue to introduce coding fundamentals and vice versa (Brennan, & Resnick, 2012). For teachers to find computational thinking useful, it needs to be defined and integrated within a specific context and classroom practicality needs to be shown (Barr, & Stephenson, 2011). Within Scratch, programming blocks are color-coded and categorized by specific computational thinking concepts. Brennan and Resnick’s (2012) framework advances the Böhm-Jacopini Theorem and identifies seven computational thinking concepts present in coding: “sequences, loops, parallelism, events, conditionals, operators, and data” (p. 3). Coding and computational thinking are concretely interwoven using Brennan and Resnick’s (2012) framework.

Computational thinking is required when coding and block-based coding has proven to enhance mathematics teaching and learning (K12 Computer Science Framework Steering Committee, 2016; Lye & Koh, 2014). Furthermore, computational thinking has been identified as a way to connect coding with elementary mathematics for teaching (Gleasman & Kim, 2020). Recently, research has focused on how learners connect computational thinking to mathematics and then how those connections can enhance mathematics education. Middle school students have been shown to struggle with the concept of looping as it relates to mathematics (Grover & Basu, 2017), while Bakos and Thibault (2018) noticed elementary students struggle relating algorithm patterns with number repetition. Benton, Hoyles, & Kalas (2017) further recognized the concept of algorithms as difficult for both students and teachers alike to grasp when connecting mathematics and computational thinking. Pre-service teachers have identified specific computational thinking concepts, such as events and loops, as having more direct connections to elementary mathematics concepts (Gleasman & Kim, 2020). Computational thinking exists outside of both programming and elementary mathematics, however, Brennan and Resnick’s (2012) specific computational thinking framework can help bridge the two fields (see Figure 1).
Figure 1. The intersection of elementary mathematics and block-based coding.

Taking into account the relevancy of mathematics and computational thinking connections and the importance of integrating coding into elementary teacher preparation programs, Block-Based Coding and Computational Thinking for Conceptual Mathematics (B2C3Math), was developed to assist pre-service teachers in learning to integrate coding into their K-5 mathematics instruction giving them skills and pedagogical knowledge to adhere to computer science initiatives. K-5 Common Core Mathematics Standards served as the intervention’s mathematical content constructs. B2C3Math provides evidence of helping pre-service teachers understand their teaching practice and how computational thinking concepts can be integrated. B2C3Math also provides teacher educators responsible for developing teacher education curriculum with a set of design guidelines to integrate into their teacher preparation instruction (Gleasman & Kim, 2020). Table 1 outlines B2C3Math instruction.

<table>
<thead>
<tr>
<th>Instructional Weeks</th>
<th>Learning Objective(s)</th>
<th>Instructional Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-service teachers will be able to understand computational thinking and its application to both mathematics and block-based coding separately. Students will continue to learn the block-based coding language.</td>
<td>-Computational thinking concepts lecture and formative activity. -Block-based coding/computational thinking exploration activity #1</td>
</tr>
<tr>
<td>2</td>
<td>Pre-service teachers will investigate elementary mathematics learning opportunities and be able to recognize different instructional methods. Students will continue to learn the block-based coding language.</td>
<td>-Think, pair, share mathematics teaching activity -Block-based coding/computational thinking exploration activity #2</td>
</tr>
<tr>
<td>3</td>
<td>Students will be able to proficiently code using the specified block-based programming platform and will be able to identify and extract computational thinking concepts being utilized during coding processes for learning purposes.</td>
<td>-Modeled integrated elementary mathematics and block-based coding lesson -Block-based coding/computational thinking exploration activity #3</td>
</tr>
<tr>
<td>4</td>
<td>Pre-service teachers will be able to create an integrated elementary mathematics and coding lesson where learning is transferred through one’s understanding of computational thinking.</td>
<td>-Lesson design</td>
</tr>
<tr>
<td>5</td>
<td>Pre-service teachers will micro-teach their lesson and receive feedback from peers and instructor.</td>
<td>-Micro-teaching opportunity -Reflective practitioner activity</td>
</tr>
</tbody>
</table>

Table 1. B2C3Math Instructional Outline
Methods

In this section, we describe in detail the process followed for conducting a convergent mixed-methods study. For the purpose of triangulation, both qualitative and quantitative data were gathered and merged, following data collection (Creswell, 2015). Quantitative descriptive statistics were merged with qualitative open-ended survey questions to gain a deeper understanding of the posed research question. Datasets remained separate until analysis, ensuring qualitative and quantitative data did not inform the implementation of the intervention.

Research Question

The purpose of this study was to engage elementary pre-service teachers in B2C3Math and examine how their computational thinking knowledge was altered. The following research question guided the study:

- How did B2C3Math affect elementary pre-service teachers’ knowledge and perception of computational thinking?

Participants and Research Context

Ten early childhood and elementary education pre-service teachers attending a large public Southeastern University opted to participate in the Institutional Review Board-approved study. Participants enrolled in a 5-week elective course. The course curriculum consisted of the 5-week intervention module, B2C3Math (see Table 1), which introduced computational thinking as a way to connect elementary mathematics with coding. Each participant was at the same point in their academic coursework and was recruited from a cohort pursuing elementary education bachelor’s degrees. Participants had prior experience with block-based coding and robotics through their participation in a National Science Foundation funded project (No. 1712286) and had been enrolled in a mathematics teaching methods course prior to the study. Participants had no formal introduction to computational thinking or how to crosscut coding and mathematics for teaching purposes during their teacher education before this study.

Data Sources

Two data sources were used during this study. The Transformative Robotics Experience for Elementary Students (TREES) assessment (Chen et al., 2017) was used to access participants’ understanding of computational thinking, programming structures, and perceptions of programming to teach mathematics. The instrument measures challenges and growth associated with the learning of computational thinking (Chen et al., 2017). Originally intended for the examination of computational thinking learning growth in elementary-aged students, during this study it was used to examine pre-service teachers’ learning associated with computational thinking. This instrument was chosen because other computational thinking instruments evaluate computational thinking growth within specific contexts (i.e., Scratch, Alice, etc.) by analyzing products created in these contexts. The TREES assessment stresses the transfer of computational thinking to various contexts without relying on context-specific product analysis. The TREES assessment was used to examine participants’ knowledge before and after engaging in B2C3Math.

Yadav et al. (2011) open-ended questions were used to collect qualitative data regarding participants’ operational definition of and thoughts about computational thinking and coding within the context of elementary mathematics education. Open-ended survey questions were developed and validated by Yadav et al. (2011).

Data Analysis Methods

Quantitative and qualitative analyses were used to overcome any weaknesses linked to either method (Creswell et al., 2003). Triangulation was implemented to combine the multiple data sources in an effort to increase the validity of results (Greene, 2007). Quantitative findings were enriched and advanced using participants’ descriptions and thoughts about computational thinking and coding for the purpose of elementary mathematics.
education. Sanitation of data ensured participants’ sensitive information was masked from all data sets before analysis.

Descriptive analysis was applied to multiple-choice questions on the TREES instrument datasets investigating percent and mean. A dichotomous scoring scale: 0 for incorrect and 1 for correct, was used to score TREES questions. In order to apply the TREES instrument to the computational thinking concepts used within B2C3Math, each item set was analyzed using Brennan and Resnick’s (2012) computational thinking framework. Table 2 lists how Brennan and Resnick’s (2012) computational thinking framework concepts relate to specific TREES item sets.

The original TREES instrument consisted of the six sets of assessment items. Due to time constraints, item set 3 on the original instrument was eliminated and the rest of the item sets were renumbered. Item sets 1-2 were themed around everyday scenarios. Item sets 3-5 were focused on robotics activity. An extra code was added to item set 5 directions to provide an additional avenue for participants to use conditionals, a computational thinking concept. The code was “-> if touching [] then []” tells the robot being coded to perform a selection control structure. Please note that the entire instrument is not included. The use of the instrument in this research was granted by Dr. Guanhua Chen.

<table>
<thead>
<tr>
<th>Item set</th>
<th>Computational Thinking Concept and Programming Structure Utilization (specific item set number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>computational thinking: Data (1.1,1.2,1.3, 1.4), Operators (1.1, 1.2, 1.3, 1.4), Parallelism (1.2), Conditionals (1.3, 1.4)</td>
</tr>
<tr>
<td>2</td>
<td>computational thinking: Sequence (2.1, 2.2, 2.3), Conditionals (2.2), Data (2.1, 2.2, 2.3), Operators (2.3)</td>
</tr>
<tr>
<td>3</td>
<td>computational thinking: Sequence (3.3), Operators (3.1, 3.2, 3.3), Data (3.1, 3.2, 3.3), Parallelism (3.2, 3.3)</td>
</tr>
<tr>
<td>4</td>
<td>computational thinking: Sequence (4.1, 4.2, 4.3, 4.4, 4.5), Loops (4.4, 4.5)</td>
</tr>
<tr>
<td>5</td>
<td>computational thinking: Sequence (5.1, 5.2, 5.3, 5.4, 5.5) Event (5.2, 5.3, 5.4, 5.5), Parallelism (5.3, 5.4), Conditional (5.5)</td>
</tr>
</tbody>
</table>

**Table 2.** TREES Item Sets Associated with Computational Thinking and Programming

Theme identification was used when qualitatively coding open-ended survey responses. Coding nodes within NVivo were developed using relevant research related to computational thinking, mathematics education, and block-based coding. Once one research coded two data sets, a second researcher reviewed the coding to ensure agreement, then the initial researcher coded the rest of the data. Qualitative data were triangulated with the statistical analyses of TREES assessment results.

**Findings**

We first present findings about changes in overall computational thinking knowledge scores and then place a focus on specific concepts.

**Overall Computational Thinking Knowledge Scores**

When examining the overall pre- (72%) and post- (76%) percentage score averages of the TREES assessment, it was found that pre-service teacher’s computational thinking knowledge increased minimally following B2C3Math implementation. Upon examining percentages on an individual participant basis, the results showed that only two participants scored lower on the post-assessment in contrast to the pre-assessment. However,
when comparing pre- and post-open-ended responses, multiple participants articulate a more comprehensive understanding of what computational thinking is within the B2C3Math context. For example, one student stated on pre-survey, “Computational thinking is placing commands in a specific way into a computer device, so they are understood”. In comparison, the same participant stated on their post-survey: “Computational thinking is to code using specific ideas that apply to a curriculum”. Another participant stated on their post-survey, “Computational thinking is the skills and strategies used in problem solving”. It appears participants may be thinking about computational thinking through a teaching and learning lens compared to her original application of computational thinking to computer devices. A participant sharing a similar sentiment stated “computational thinking is using computer skills” on her pre-survey, while on her post-survey she stated, “Computational thinking is using problem-solving methods that a computer can execute. It is also a way to express problems and find solutions.” Regardless of the TREES assessment score, it seems B2C3Math may have facilitated pre-service teachers to view computational thinking through a lens geared towards teaching and critical thinking, an original goal of the intervention.

The TREES scores of three participants, did not change, while the scores of five participants increased. A 20% overall increase was the largest differential between pre and post TREES scores. Each participant regardless of their computational thinking knowledge growth responded in short form that computational thinking and block-based coding applied to elementary education. However, certain participant responses highlight their perception that the use of computational thinking to teach elementary mathematics with coding may elicit either conceptual or procedural learning. One participant who increased their computational thinking content knowledge following B2C3Math stated, “Students can use computational thinking and coding to show multiplication, division, coordinates, and many more math concepts using procedural knowledge.”. Another participant who had a TREES score which went unchanged stated, “Computational thinking is doing something according to a set of procedures.” A participant who scored lower on the TREES post-assessment stated, “Computational thinking and coding can be used to help students have a deeper understanding of mathematics concepts. They can learn about why an equation works the way it does.” Another participant stated, “Computational thinking is having the ability to think through a concept using the context of coding or mathematical reasoning.” Participants with varying computational thinking knowledge scores seem to have varying views of the instructional methods of coding and computer science integration for mathematics teaching. It is apparent computational thinking knowledge does not affect how teachers view computational thinking as an avenue to facilitate conceptual or procedural mathematics learning, but this difference in viewpoints is apparent. Overall, TREES percentage scores between pre/post assessments changed only slightly, a deeper analysis of valid percentages for specific questions was required.

<table>
<thead>
<tr>
<th>Question #</th>
<th>Pre- % Correct</th>
<th>Post- % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1.1</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Q1.2</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Q1.3</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Q1.4</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Q2.1</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Q2.2</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Q2.3</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Q3.1</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Q3.2: “If we can build all three parts simultaneously, what is the total time needed to build and assemble one machine?” (Shen, 2017, p. 5)</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Q3.3</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Q4.1</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Q4.2</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Q4.3: “Which of the following sequence of these commands, if run by the robotic arm, will produce a rectangle shape on the paper?” (Shen, 2017, p. 6)</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>Q4.4: “Now you have a new command “-&gt;REPEAT x.” The variable x represents the number of times the previous command will be repeated. What would be the result of running the following code?” (Shen, 2017, p. 7)</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Q4.5</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Q5.1</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Q5.2</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>
Q5.4: “A team member wants the robot to move 5 steps to the left, and writes the following code.
The code didn’t work as expected. Explain why it did not work.” (Shen, 2017, p. 9)

| Q5.5 | 70 | 70 |

### Table 3. TREES Pre/Post Assessment Scores by Question #

Comparing pre/post valid percentages for most questions indicates no more than a 20% change (see table 3). In general, this change was positive. Questions 3.2, 4.4, and 5.4 had greater than a 20% increased change. Question 4.3 was the only question resulting in greater than a 20% decrease change between pre- (80%) and post- (40%) scores (see table 3). When investigating changes based on framework-specific computational thinking concepts, a deeper analysis emerged aligned with participant’s understanding of specific computational thinking concepts.

### Understanding of Specific Computational Thinking Concepts

Pre-service teachers’ understanding of events, loops, and parallelism improved substantially. Valid percentages associated with the general computational thinking knowledge scores were useful; however, within the context of B2C3Math, computational thinking was examined through a particular framework (Brennan & Resnick, 2012). To elaborate on how the knowledge of framework-specific computational thinking concepts changed, each TREES assessment question was correlated to the framework (see Table 2). Valid percentages of correct framework-specific computational thinking concepts assessed within pre/post answers for TREES items are noted in Table 4.

<table>
<thead>
<tr>
<th>Computational Thinking Concepts Assessed</th>
<th>Pre-Score Average</th>
<th>Post-Score Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence</td>
<td>70.7</td>
<td>78.5</td>
</tr>
<tr>
<td>Event</td>
<td>67.5</td>
<td>85</td>
</tr>
<tr>
<td>Loops</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>Conditionals</td>
<td>67.5</td>
<td>67.5</td>
</tr>
<tr>
<td>Parallelism</td>
<td>66</td>
<td>84</td>
</tr>
<tr>
<td>Data</td>
<td>74</td>
<td>76</td>
</tr>
<tr>
<td>Operators</td>
<td>67.5</td>
<td>71.25</td>
</tr>
</tbody>
</table>

### Table 4. Valid Percentages of Computational Thinking Concepts Assessed Correlated to Specific TREES Items

Three participants operationally defined computational thinking listing multiple and/or all computational thinking concepts within their open-ended response. Valid pre/post score averages increased for all but one of the computational thinking concepts, conditionals, which remained the same. The largest positive changes (>17 %) occurred between pre/post scores for the computational thinking concepts events, loops, and parallelism. Valid percentages indicate knowledge of loops and parallelism changed similarly between the administered pre/post TREES assessments. Events resulted in the highest valid percentage post score (85%) of any computational thinking concept assessed. However, loops had the lowest valid percentage post score (55%), but the greatest positive difference between post- and pre-score averages (20%). Participants’ knowledge of conditionals went unchanged overall. Following B2C3Math, Participants scored a valid percentage post score of > 70% on questions associated with all computational thinking concepts; except conditionals and loops.

### Discussion

Understanding the participants’ knowledge of computational thinking can allow for a deep examination of the learning process behind the integration of B2C3Math. It can be acknowledged that B2C3Math had no
statistically significant impact on changing participant computational thinking knowledge, however, participants grasped the knowledge of specific computational thinking concepts more effectively than others after engaging with B2C3Math. Following a deeper investigation into specific questions on the TREES assessment, it was found that pre-service teachers’ understanding of events, loops, and parallelism improved. Furthermore, it seems B2C3Math prompted pre-service teachers to start viewing computational thinking as an elementary mathematics teaching and learning tool. This is valuable as effective computer programming teacher education is among the most important factors for ensuring the development of future teacher’s positive attitudes towards information and communication technologies (Yildirim, 2000). Their perception of computational thinking was less procedural and more conceptually holistic as a result of B2C3Math instruction. Although not significant, pre-service teachers had a better understanding of all seven computational thinking concepts, except for the conditionals after engaging with B2C3Math. Percentage scores showed pre-service teachers overall had a greater than 70% understanding of all seven computational thinking concepts identified within the TREES assessment, after participating in B2C3Math, except for loops and conditionals. It should be noted that these findings are only based on descriptive analysis and are not statistically significant.

Findings suggest regardless of a positive or negative change in computational thinking knowledge scores, these pre-service teachers viewed computational thinking as an instructional way to connect mathematics and coding for instructional purposes. Furthermore, computational thinking scores do not solely indicate pre-service teachers’ perception of computational thinking. However, based on open-ended responses it is apparent there is a differentiation in procedural vs. conceptual teaching methods when it comes to integrating computational thinking, and further research is required.

Implications and Conclusions

There is much work to be done to understand the best avenue of reform for elementary teacher education to keep up with computer science initiatives. As computational thinking has surfaced as a way to understand large computing principles, it is important to relay this educational opportunity to developing teachers. B2C3Math is not an answer, but a step in the right direction. As with any instructional material, iterative revision needs to be made following teacher reflection. Enhancing teachers’ computational thinking knowledge and facilitating an investigation of a teaching strategy that does not place more stress on a loaded curriculum but makes teaching interdisciplinary is beneficial for both teacher preparation programs and pre-service teachers. More research is needed to understand how B2C3Math and its corresponding guidelines can be revised to better serve pre-service teachers, as well as, how the learning of computational thinking explicitly relates to mathematical teaching attitudes.

References


Acknowledgements

This research is partially supported by grant 1712286 from the National Science Foundation (USA) to PI ChanMin Kim. Any opinions, findings, or conclusions are those of the authors and do not necessarily represent official positions of NSF.
Abstract: This ongoing study focused on implementing coding and robotics in an integrated STEM semester with 20 pre-service teachers (PST) in an undergraduate elementary certification program. Constructionist theory framed the integrated STEM semester approach as well as the study which addressed the specific research question: *How do pre-service teachers describe their perceptions of coding and robotics for STEM throughout their experiences in an integrated STEM semester?* Qualitative analysis of PSTs’ written reflections, combined with participant-researcher observations and artifacts of PST classwork, indicated positive perceptions of coding and robotics and productive dispositions toward exploration and collaboration over the course of the semester-long integrated STEM experience. Findings suggest that the two-pronged approach of integrating coursework and infusing coding and robotics within elementary PSTs’ teacher preparation can lead to positive outcomes.

Introduction

In order for teachers to promote and enact the kinds of innovative science, technology, engineering, and mathematics (STEM) learning experiences needed to develop students’ 21st century skills, they must have opportunities to engage in innovative STEM learning experiences themselves. One elementary teacher certification program is attempting to provide those experiences for undergraduate pre-service teachers (PSTs) during an integrated STEM semester. During this STEM semester, cohorts of PSTs enroll in coordinated content, methods, and practicum courses, and course instructors collaborate to infuse coding and robotics as a cross-cutting STEM theme. The focus of this paper is to describe PSTs’ perceptions of coding and robotics for STEM learning during this semester-long integrated experience.

The elementary teacher preparation program in this study has traditionally emphasized constructivist (Piaget, 1964) approaches to teaching and learning in math and science methods courses. Ackermann (2009) summarized three implications of constructivism: “1) teaching is always indirect, 2) the transmission model, or conduit metaphor, of human communication won’t do, and 3) a theory of learning that ignores resistances to learning misses the point (p.3),” which can support how teachers are prepared to support student learning. Integrating STEM coursework with a coding and robotics theme introduces new opportunities to engage PSTs in building knowledge through collaboration and play involving new tools, an approach that is characteristic of constructionist theory (Harel & Papert, 1991; Papert, 1980). Viewed through the lens of constructionism, effective learning results not from more or better ways of instruction, but from *less teaching* in order to make room for *more child-driven exploration* (Eguchi, 2010). Modeling opportunities for PSTs to play, explore, and experience constructionist approaches within teacher education introduces a minimalist approach might be otherwise unfamiliar to them. Constructionist theory frames with the STEM semester approach and the research in this paper.

Background

Traditionally, elementary teacher preparation programs have structured content methods courses as separate, discipline-specific learning experiences. In contrast, an integrated STEM approach to teacher preparation typically includes blended assignments and relates content-specific learning to accompanying methods courses (Adams, Miller, Saul, & Pegg, 2014). For instance, students might develop a unit plan in a math methods course but could also integrate science and technology into that unit. Regardless of whether siloed or integrated STEM approaches are incorporated in teacher preparation programs, most U.S. elementary school teachers are trained as generalists rather content specialists (Adams et al., 2014; Li, 2008; Schwartz & Gess-Newsome, 2008). Elementary teachers’ generalist
backgrounds and elementary classroom structures may create more favorable conditions for teaching integrated STEM, as compared to secondary math and science teachers who perceived communication, scheduling, and course-specific barriers to cross-curricular STEM integration (Al Salami et al., 2017; Herro & Quigley, 2017; El-Deghaidy et al., 2017).

While elementary teachers’ backgrounds and classroom structures may offer opportunities to implement integrated STEM, they may still feel underprepared to teach STEM content. In a recent national survey of U.S. elementary teachers, 77% felt very well prepared to teach reading/language arts, 73% felt very well prepared to teach mathematics, but only 31% felt very well prepared to teach science and fewer yet (6%) felt very well prepared to teach computer science/programming (Banilower et al., 2018). Feeling underprepared to teach STEM content can impact teachers’ perceptions of its usefulness, as well as how they implement STEM into their classrooms (Adams, et al., 2014). Indeed, a literature review of teachers’ perceptions of STEM integration indicated that teachers’ self-efficacy and beliefs about the value of STEM impacted their willingness to implement integrated STEM curriculum (Margot & Kettler, 2019). It is crucial that elementary teacher education programs support PSTs’ development of content knowledge, pedagogical practices, self-efficacy, and dispositions they will need in order to embrace opportunities for teaching integrated STEM to children.

In addition to developing competence and confidence with STEM content, teaching integrated STEM encourages teachers to embrace multiple approaches to problem solving. The umbrella term of problem solving includes complex issue decomposition, developing unique solutions for problems, and innovation, which is imperative to drive future generations (Yadav, Gretter, Good, & McLean, 2017). Exposing students to open-ended, integrated approaches develops creativity and allows them to make connections between multiple content areas within the school culture (Siew, Amir, & Chong, 2015). When students use critical thinking and problem-solving skills within STEM learning experiences, this can mirror the kinds of real-world, ill-structured situations scientists and problem-solvers often encounter (Siew, et al. 2015). Expanding knowledge of content and problem-solving gives PSTs the ability to make connections to their future curriculum.

Preparing elementary PSTs to teach integrated STEM with deep problem solving opportunities can include many tools and approaches. In particular, coding and robotics can be incorporated in STEM curriculum to connect across STEM disciplines and engage in problem solving. As Alimisis and Kynigos wrote, “Robotics as a learning tool is usually seen as interdisciplinary, project-based learning activity drawing mostly on Science, Maths, Informatics and Technology and offering major new benefits to education in general at all levels” (2009, p. 17). Coding and robotics benefit students by providing instant feedback on their computational thinking and problem solving, allowing them to adjust in real-time (Ortiz, Bos, & Smith, 2015). Atmatzidou and Demetriadiis (2016) found that robotics can increase critical thinking and promote higher-order thinking skills. According to Jaipal-Jamani and Angeli (2017), exposing elementary students to robotics provided opportunities for students to learn STEM concepts earlier than expected and positively impacted students’ self-efficacy for pursuing STEM subjects in the future. In order to realize the opportunities coding and robotics offer for student learning, PSTs must be well-prepared and confident enough to implement robotics to support their classroom teaching. Despite research suggesting that elementary students benefit from integrated STEM approaches, coding, and robotics, few studies have examined programmatic attempts at STEM integration within elementary teacher preparation, particularly with a focus on coding and robotics as tools for integrated STEM teaching and learning.

Context of the Study

This ongoing study takes place within the undergraduate elementary education certification program at a large, Midwestern university. Building upon successful prior collaborations between mathematics and teacher education faculty (Heaton & Lewis, 2011) and between instructional technology and math education instructors (Thomas, Peterson, & Abebe, 2019), this program altered its coursework sequence to include mathematics content, mathematics methods, science methods, instructional technology, and practicum coursework during the same cohorted semester. Beginning in Fall 2019, all elementary education majors must enroll in this STEM semester after admission to the professional phase of the program, which is typically the fourth or fifth semester of a 4-year program.

Instructors from each of the STEM semester courses collaborated to identify redundancies and commonalities among courses and to plan for assignments that span across multiple courses. To further model an integrated approach, STEM semester instructors selected coding and robotics as a theme to embed across multiple classes. Each section combined resources such as micro:bit, Scratch, Spheros, and Edison and embedded them within the curriculum to allow students to see connections of coding within and across courses. For their practicum class, PSTs worked in pairs within an elementary classroom two full days each week, so PSTs could implement math and science lessons with
children. Implementation of integrated STEM activities in elementary classrooms proved challenging because, although computer science was a priority in the partnering school district, coding and robotics were rarely incorporated in content-based lessons. Other content that was integrated across STEM semester courses included engineering habits of mind, engineering design process, and unpacking students’ identities as STEM learners and teachers.

The coding and robotics theme was launched with a block-coding workshop during the first two weeks of the semester. The workshop, held during the math methods course, introduced PSTs to Scratch block coding using online tutorials at scratch.mit.edu, and challenged students to create block codes that would draw specific geometric shapes. A few weeks later, in the science methods course, PSTs applied block-coding to program micro:bits for collecting soil moisture and temperature data, as shown in Figure 1. During that same week, PSTs were introduced to Bee Bots (see Figure 2) in an activity focused on using and connecting mathematical representations. Later, PSTs spent an entire 75-minute class period exploring and playing with three new types of robotics: Edison bots, Ozobots, and Cubelets, then discussing and reflecting upon the STEM connections and teaching opportunities they noticed. A separate class period was dedicated to engaging PSTs in a more content-focused learning experience that infused coding and robotics. In that class, PSTs were challenged to design a Fraction Street (Goo, 2019) to creatively represent fractions on a number line, and to program a Dash robot to function as a tour guide of Fraction Street (see Figure 3).

![Figure 1. Micro:bit.](image1)
![Figure 2. Bee-bot.](image2)
![Figure 3. Fraction Street with Dash.](image3)

After these opportunities to explore and learn with a variety of robotics, PSTs worked in teams to design an integrated STEM learning experience for elementary students. The assignment emphasized creativity, collaboration, and innovation that transcended the constraints they perceived in traditional practicum settings. Subsequent coding and robotics learning opportunities included a perimeter and area math lesson using Sphero robots and a mathematics content course assignment that required block coding to explore and solve a challenging mathematical problem. In this proposal, we report on the coding and robotics experiences leading up to the integrated STEM project.

**Methods**

This study employed a descriptive case study design (Yin, 2003) involving one cohort of STEM semester students to investigate the research question: How do pre-service teachers describe their perceptions of coding and robotics for STEM throughout their experiences in an integrated STEM semester? Participants in this study include one of the three STEM semester cohorts enrolled in the first implementation of STEM semester during Fall 2019. This cohort was comprised of 20 PSTs (19 female, 1 male) with no PSTs of color (this is consistent with the state, where 95% of teachers statewide are white). At the time of this study, the cohort of participants were enrolled in the same sections of math content, math methods, science methods, instructional technology, and practicum coursework. In this paper, we report on data collected during the first ten weeks of the 16-week semester. The researchers were participant–researchers, due to teaching and co-teaching sections of one STEM semester course in which the participating cohort was enrolled. Data were collected through a variety of sources to ensure reliability and transferability. Data sources in this study include artifacts of PST work (written assignments, products created during
classwork, and videos/images of PSTs’ work with coding and robotics), written reflections from PSTs at three different points in the program, and participant-researcher observations of PSTs’ class work. For this study, written reflections were aggregated by reflection prompt for PST anonymity. Table 1 identifies the prompts and when they were administered within a 16-week semester.

<table>
<thead>
<tr>
<th>Written Reflection Prompt</th>
<th>Timing of Prompt</th>
<th>Timing of Prompt</th>
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<tbody>
<tr>
<td>#1 How was your experience with the micro:bit training? What did you like? What would you change? Questions you still have? How has your experience with coding in your courses changed your view on your ability as an educator to use technology in your future classroom?</td>
<td>Week 5: Immediately following micro:bits introduction and training.</td>
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<tr>
<td>#2 What connections are you noticing across STEM semester courses so far?</td>
<td>Week 5: During the week that micro:bits were introduced and after experiencing the coding workshop (Week 1) and BeeBots (Week 4).</td>
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<tr>
<td>#3 What do you see as the strengths and challenges of using the [Edison bots, Ozobots, Cubelets]? What STEM connections do you see? What was your general impression of the robotics you explored today?</td>
<td>Week 8: Immediately after a 75-minute open exploration with multiple robotics (Edison, Ozobots, and Cubelets).</td>
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<tr>
<td>#4 What were your takeaways from the Fraction Street activity? Given the opportunity, would you use this activity with students? Why or Why not? What adaptations would you make?</td>
<td>Week 10: Immediately after a 75-minute content-focused STEM activity (Fraction Street).</td>
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Table 1. Written Reflection Prompts

This study is still in progress and will include additional iterations in future semesters, thus data analysis is ongoing. To generate findings for this paper, the researchers began by openly coding PSTs’ reflections from the prompts listed in Table 1. Open codes were collapsed into axial codes, which were used in the next phase of analysis to generate themes related to each of the three prompts. Because the prompts were aligned with specific coding and robotics experiences in STEM semester coursework, artifacts of student work and participant-researcher observations relating to those learning experiences were used to supplement the themes for each prompt.

Preliminary Findings

Preliminary findings indicate positive PST perceptions of coding and robotics, as well as embracing exploration and collaboration as important aspects of STEM learning.

Positive perceptions. For the most part, PSTs communicated positive perceptions of the robotics and coding activities to which they were introduced. Words such as fun, love, and enjoy were frequently used in written reflections to describe PSTs’ experiences and perceptions, and visually evident in images such as Figures 4 and 5. Examples of student reflection excerpts to support this conclusion include:

- I am absolutely in love and NEED one [micro:bit]! The ease of coding and all the different possibilities to use them in lessons. (Written reflection #1, micro:bits)
- I had so much fun. Even though I am 20 years old, I was very invested and had a great time. I loved exploring and trying to figure them out. Some were more challenging to figure than others but overall it was fun and I want them all in my future classroom!! (Written reflection #3, Cubelets, Edison, and Ozobot exploration)
Loved this activity! It was engaging and explorative and I wanted to continue to do more and more with this technology. It was super easy and I know my second graders would love this! (Written reflection #4, Fraction Street with Dash).

However, not all students embraced coding and robotics immediately. Observations during the initial coding workshop noted more negative perceptions such as, “This is too hard,” and, “I don’t see the point of elementary teachers having to learn this.” By the robotics explorations in Week 8 of the semester, observations did not indicate negative sentiments, but one student still noted in her written reflection, “Not sure how it’s related to teaching elementary students.” And while anonymously aggregated data in this study did not allow for tracking individual changes over time, some students noted their own growth. For instance, one student wrote of the Dash Fraction Street activity, “This is the first activity I have really enjoyed and felt could be super engaging and exciting for students. Not that the other bot activities haven’t been great, I just had the best experience with this activity.” By Week 10, observed reluctance and skepticism of coding and robotics for elementary STEM was no longer observable or evident in written reflections. Instead, comments such as, “I really liked how learning to code can be fun and interesting, (Written reflection #4, Fraction Street with Dash)” became commonplace.

Embracing exploration and collaboration

Throughout the first ten weeks of the integrated STEM semester, PSTs also indicated their willingness to embrace collaboration and open-ended exploration with coding and robotics in the context of STEM learning. Early in the semester, the participant-researchers observed frequent reluctance to engage in challenging tasks or ill-defined problem solving experiences. This was observed in the form of seeking immediate instructor support at the first sign of struggle and verbal comments about wanting to be “shown how” before engaging in a challenging problem. During coding and robotics lessons, PSTs had many opportunities for open exploration as a way to learn how to use new tools. Open-endedness that was observed to be frustrating for PSTs during the Week 1 coding workshop began to be embraced by students in later coding and robotics learning experiences:

- I really like how we were given the opportunity to have control of our learning. It has given me a new perspective on teaching. (Written reflection #1, micro:bits)
- I am learning that it is important to let your students discover things on their own because it engages them in the learning. (Written reflection #2, STEM connections)
- I really enjoyed being free to create or try new things. Normally this is not my personality as I enjoy having clear instructions, however I think I needed this today. Before class, I felt that I would really love the Ozobot and I was really looking forward to using the app that I had downloaded but when we were turned loose to explore I found that I enjoyed the cubelets the most. I am still really curious as to what more can be done with the Edison bots, but I feel that would need a full class period to accomplish anything. (Written reflection #3, Cubelets, Edison, and Ozobot exploration)
Loved this activity! It was engaging and explorative and I wanted to continue to do more and more with this technology. It was super easy and I know my second graders would love this!...It was a creative, engaging way to explore coding and technology to discuss a not so fun math topic. (Reflection #4, Fraction Street with Dash)

PSTs’ written reflections also indicated that they embraced collaboration as an important component for exploring and learning STEM with robotics and coding. Participant-researchers observed productive collaborations among PST groups as they figured out how to use Edison bots (Figure 6) and noted the extent to which all PSTs substantively contributed to group Fraction Street with little instructor direction (see Figure 7). At the end of week 10, self-selected groups of PSTs met to design integrated STEM learning experiences for elementary-aged students and leveraged collaborations to create innovative projects that extended well beyond in-class learning experiences, as shown in Figure 8. Written reflections included:

SO FUN. It was fun to explore and think about how we could use these in the classroom and try to answer questions with each other. (Written reflection #3, Cubelets, Edison, and Ozobot exploration)

This activity was really fun. It allowed us to collaborate with each other. I would use this within a classroom because students could get a better understanding of their subject and collaborate with other students. (Written reflection #4, Fraction Street with Dash)

Discussion

Positive perceptions of robotics and coding for STEM and embracing exploration and collaboration are desirable outcomes for the first iteration of the elementary education program’s integrated STEM semester. The initial skepticism observed during the coding workshop is not surprising based on relationships between teachers’ STEM self-efficacy and perceptions of usefulness (Adams et al., 2014; Margot & Kettler, 2019). While the data is insufficient to claim causation, repeatedly and purposefully infusing coding and robotics activities across STEM semester coursework did coincide with PSTs’ positive perceptions of STEM, robotics, and coding.

It is also notable that PSTs embraced more exploratory problem solving and collaboration in only ten weeks. A teacher-led, procedure-focused orientation toward learning is not uncommon in the participant-researchers’ experiences, and the math methods course specifically addresses supporting productive struggle (NCTM, 2014) to
emphasize that grappling with challenging problems is important for learning. Coding and robotics experiences required PSTs to engage in productive struggle, themselves, and learn through play, exploration, and collaboration with peers, consistent with constructionist theory (Harel & Papert, 1991; Papert, 1980). Reluctance to embrace and engage in constructionist learning experiences shifted throughout the semester, providing PSTs an opportunity to feel the value of a minimalist approach that values exploration and collaboration over well-defined structure and individual work (Eguchi, 2010). By experiencing open-ended integrated approaches involving coding and robotics, PSTs were able to make connections among STEM content areas and develop more productive dispositions for supporting their future students’ problem solving and deep learning (Alimisis & Kynigos, 2009; Atmatzidou & Demetriadis, 2016; Siew et al., 2015).

This study involved a two-pronged approach to supporting elementary PSTs’ preparation for teaching STEM: purposeful integration across STEM content and methods courses for elementary PSTs and infusing coding and robotics as a cross-cutting theme within those courses. The preliminary results presented here suggest that this is a promising approach for teacher education programs who share the goal of preparing teachers who feel very well prepared to teach mathematics, science, and computer science/programming (Banilower et al., 2018). This ongoing study intends to address limitations by including additional data sources (e.g., focus group interviews, samples of student work, instructor journals) and additional class sections to increase the sample size. Because this study took place during the first iteration of the STEM semester integrated approach, future research will also yield insight about the longevity and reliability of these initial findings.

References


Game Design Features for Facilitating Identity Exploration: 
An Exploration of Minecraft EE Chemistry Lab

Mark Petrovich Jr.
Chris Fornaro
Amanda Barany
Aroutis Foster
Drexel University, United States
mep64@drexel.edu
cff688@drexel.edu
amb595@drexel.edu
anl37@drexel.edu

Abstract: As video games and similar digital experiences become more ingrained in everyday society, researchers have sought to utilize these environments for educational outcomes. Game environments have been celebrated for their capacity to emphasize players’ exploration of possible selves through the use of virtual apprenticeships. However, there is a lack of research which highlights the specific game design mechanics that enable change in a player’s identity. This preliminary study presents a qualitative deductive approach utilizing the Playing Research Method to analyze a player-researcher’s experience in Minecraft Educational Edition: Chemistry Lab. Results indicate a number of game mechanics which indicate the potential for change across players’ knowledge, interests and valuing, regulated actions, and self-perceptions and self-definitions. Implications and directions for future studies are discussed.

Introduction

The prevalence of video games in contemporary media has contributed to a steady increase in the amount of time K-12 students dedicate to exploring digital experiences. A cumulative 72% of teens aged 13 to 17 in the United States play games across a variety of digital devices, with that number increasing to 84% of boys in an identical age range (Pew Research Center, 2015). On average, United States youth ages 8 to 18 spend over 440 hours playing games throughout the year, or around 73 minutes per day (Rideout, Foehr, & Roberts, 2010). As a result, researchers have sought to harness game-based learning opportunities for a variety of educational outcomes. Specifically, game-based environments have been lauded for their potential to support learning as an active and self-directed process of cognitive and affective self-transformation, or identity exploration (Plass, Homer, & Kinzer, 2015; Shaffer, Squire, Halverson, & Gee, 2005). Games provide opportunities to explore virtual worlds and virtual apprenticeships which manifest in the experimentation of possible selves (Khan, 2012; Squire & Jan, 2007). Despite these claims, research on facilitating identity exploration within game-based learning environments is nascent (Foster & Shah, 2016). For example, few studies have explored which specific game design features have the potential to support identity exploration processes (Bharathi, Singh, Tucker, & Nemkhard, 2016). Identification of these game features has the potential to aid educators and researchers in choosing and designing experiences which can enable identity exploration. In order to address this gap, this research study sought to address the following research question: How can game mechanics in the chemistry lab of Minecraft Education Edition support constructs of identity exploration toward science careers?

This study aims to highlight preliminary findings concerning the game design features in a specific game-based learning environment, Minecraft Education Edition (EE): Chemistry Lab, which can facilitate the process of learning as identity exploration. The subsequent sections elaborate on the theories that formed the basis of the theoretical framework; provide a review of the literature concerning game-based learning and identity exploration; highlight the methodological approach; and present the study’s findings.
Theoretical Framework

Projective Reflection

Projective Reflection (PR) conceptualizes learning as a process of identity exploration measured repeatedly over time (Foster, 2014). From this perspective, a learner is measured throughout an experience to identify an initial current self, exploring possible selves, and a desired new self at a specific endpoint. This process of identity exploration is measured as change across four key constructs: knowledge, interest and valuing, self-organization and self-control, and self-perceptions and self-definitions. In addition, learners are prompted by a series of six questions which are mapped to the aforementioned constructs: 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 game-based 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 self-identifies (self-perceptions and self-definitions). These questions, measured in tandem with the key constructs, aid in identifying a learner’s starting self, explored possible selves, and a new desired self. The changes across these constructs over time, which manifest as the differences between a learner’s starting self and new desired self at a specific endpoint within a game-based experience, is the process of identity change as defined by Projective Reflection (Shah, Foster, & Barany, 2017).

Learning Mechanics - Game Mechanics

Though the pedagogical approaches utilized for learning and the game design features built into commercial game-based experiences have been viewed as being at odds, Gee (2003) surmised that the game-mechanics inherent in well-designed games are synonymous with fundamentally sound learning principles and pedagogy. In an effort to make this connection explicit, Arnab and colleagues (2015) defined a set of serious game mechanics (SGMs) as the “design decision that concretely realises the transition of a learning practice/goal into a mechanical element of gameplay for the sole purpose of play and fun” (p. 393). This set of SGMs, the Learning Mechanics-Game Mechanics (LM-GM) framework, makes meaningful connections between high-level pedagogical approaches and low-level gameplay mechanics. The framework can be utilized to aid in the design of game-based learning experiences by identifying desired learning outcomes and facilitating their occurrence through the selection of matching game mechanics. Additionally, the LM-GM framework can be utilized to analyze and dissect existing experiences for specific learning outcomes as enabled by game mechanics. From the perspective of this study, LM-GM was utilized in the deductive coding process to translate observed player behaviors in a game-based experience to actionable game mechanics.

Literature Review

A situative perspective on learning and identity (Oyserman, 2015) explains how digital games and virtual worlds support transformation of game-players’ knowledge and self through participation in a gaming activity that involves the whole person in a continuously changing individual-environment interaction. Scholars in the field have pointed to games and virtual learning environments as contexts with potential to promote “situated understandings, effective social practices, powerful identities, shared values, and ways of thinking of important communities of practice” (Shaffer, Squire, Halverson, & Gee, 2005, p.7). Research suggests that games are indeed conducive for identity change (Foster, 2008; Khan, 2012) and, in turn, that identity change contributes to academic learning, motivation, and interest (Cadely, Pittman, Kerpelman, & Adler-Baeder, 2011; Flum & Kaplan, 2012). Over the past decade, games have been highlighted for their designed affordances that can support learners’ personal identity and goals towards engagement in academic domains and professional careers (Foster, 2008; Shaffer, 2006; Squire, DeVane, & Durga, 2008). However, this domain is still in its infancy and requires research to develop theories of change mechanisms, evidence-based measurement, and design principles for virtual learning (games, virtual realities, simulations) experiences that affect learners’ knowledge, identity processes, and career paths. While research into design features have been successful in linking game mechanics to specific learning outcomes, there is a distinct lack of focus in the realm of these identity processes.
The integration of game mechanics and learning mechanics provides game designers and educators the opportunity to utilize targeted pedagogical processes to enhance specific learning outcomes within game-based experiences. Game mechanics are understood as the various actions, interactions, roles, relationships, and mechanisms that are enacted by players of a game (Hunicke, Leblanc, & Zubek, 2004). As a result, the balancing of game mechanics is necessary not only for narrative-driven games for entertainment, but also for those games which seek to enhance and facilitate various learning outcomes. Researchers have developed a number of frameworks to guide the integration of game and learning mechanics including the Learning Mechanics-Game Mechanics (LM-GM) Framework and the Games, Motivation and Learning framework (Garris, Ahlers, & Driskell, 2002; Lim et al., 2015). Through the implementation of careful design considerations, research has demonstrated simple, intermediate, and complex learning outcomes as well as the capability of individual mechanics to elicit multiple learning outcomes (Ampatzidou & Gugerell, 2019). Additional investigation has highlighted targeted game design as a method of preventing or limiting the development of undesirable outcomes or behavior (Grey, Grey, Gordon, & Purdy, 2017). Though a number of connections between game design features and learning outcomes have been identified, there continues to be a lack of research into how design features enhance learning as a process of identity exploration. This study seeks to present a targeted approach for linking game design features with processes related to identity exploration.

Methodology

To address the research question, this project used a qualitative deductive coding approach to identify video game design features with potential for supporting learning as identity exploration. The Chemistry Lab library for Minecraft EE was selected as the unit of analysis. Data collection involved the recording of 30 minutes of uninterrupted play conducted by a player-researcher, as supported the Playing Research Method (PRM) (Aarseth, 2003; Foster, 2012). Video data was then deductively coded using the LM-GM framework to identify design features experienced by the player. Finally, design features were deductively coded (Mayring, 2000) based on their designed capacity for supporting learning as identity exploration as informed by the PR theoretical framework (Shah, Foster, & Barany, 2017; Foster, 2014). The following sections introduce the game setting, data collection, and data analysis in greater detail.

Setting

The Chemistry Lab library for Minecraft EE was created by the makers of Minecraft EE to give an interactive world where chemistry experiments could be conducted. For example, specific element blocks were created that could be combined to make molecules and compounds on a digital lab bench. This library was chosen due to having a set of structure while keeping the open world aspect of Minecraft. There are non-playable characters (NPCs) that scaffold what is possible in the game and provide mini lessons. Additionally, there is a prebuilt laboratory with unlimited resources so the player can begin tinkering without the need to worry about resource management or the typical crafting sequence. The crafting sequence of Minecraft has the player collect resources (e.g. stone, iron, gold, etc.) to create new crafting environments (e.g. crafting table, smelter, furnace, etc.). This path is not an issue with Chemistry Lab as it takes on a creative mode to provide unlimited resources to the player. Lastly, Chemistry Lab was chosen as it puts the player in the direct role of a lab bench chemist and identity exploration as a scientist would be attainable.

Data Sources, Collection, and Analysis

The Playing Research Method suggests that game research can be approached in three ways: 1) observing gameplay to understand how players interact, 2) playing the game directly to explore game design and rules, and 3) examining game ecosystems (aesthetics, history, gameplay and game rules) through a combination of observation and play. Data may be collected from secondary sources (i.e. research, player data), but optimally occurs from direct play (Aarseth, 2003). As such, three graduate researchers analyzed their own observations and direct play. Data collection was completed by recording 30 minutes of video and audio of a single player’s gameplay experience in Minecraft EE’s: Chemistry Lab. The player used screen and audio recording software so gameplay and audio was available to be analyzed. The player did this in isolation of the research team to ensure no outside perspectives were
given on gameplay. During analysis, the research team did not consider the player’s dialogue unless it provided clarification on a game mechanic.

Two researchers observed the gameplay data separately and recorded any potential game mechanics that were present during the thirty-minute play session. After these observations were recorded, the two lists were condensed into one list of game mechanic observations with redundant observations not being removed. By not removing redundant codes, it provided an opportunity for consistent coding across similar mechanics to be determined within the list. Gameplay observations were coded according to the 38 game mechanics described within the LM-GM framework (Arnab et al., 2015). During our game mechanic coding process, observations were coded by researchers independently and then each code assigned was discussed amongst the two researchers until consensus was reached. For the game mechanic coding process, the player was not involved in the coding process in an attempt to remove bias in observing their own gameplay.

After reaching consensus on game mechanics for our observational data, a frequency list of game mechanics was created. The researchers took the list of eighteen identified game mechanics and coded them according to the four constructs of identity exploration in PR (Shah, Foster, & Barany, 2017; Foster, 2014). Once consensus was reached amongst all three researchers, a review of the data was conducted to look for emerging themes and connections.

Findings

Our initial observations of gameplay yielded 102 codes between two doctoral researchers. After individually coding these observations for the use of explicit game mechanics (as guided by Arnab et al., 2015), 75 of the 102 observations were deemed to include at least one explicit game mechanic. The other 27 observations did not fit into the game mechanics model as they were auditory notes by the player, pertained to observations external to the game environment, or other similar reasons. The 75 mechanic-containing codes were then compiled into a frequency chart and coded based on their designed affordances for supporting one or more of the four Projective Reflection constructs. Broadly, Tutorial (n=31), Feedback (n=17), and Movement (n=11) mechanics were identified most frequently within the play session. Conversely, Ownership (n=2), Goods/Info (n=2), Roleplay (n=1), and Design/Editing (n=1) were among the least observed mechanics within the environment.

While certain game mechanics appeared more frequently in the dataset than others, mechanics that appeared more often did not necessarily support a higher number identity exploration (PR) constructs in players. For example, the Tutorial mechanic was identified as having appeared across 31 instances throughout gameplay while the Roleplay mechanic was identified as occurring just once throughout the play session. Despite this imbalance, Tutorial was deemed to generally support constructs for knowledge and interests and valuing while Roleplay demonstrated support for interests and valuing, regulated actions, and self-perceptions and self-definitions. Overall, knowledge constructs (n=98) were most often supported through game mechanics, followed by interest/valuing (n=89) constructs, self-organization/self-control (n=85), and with self-perception/self-definition (n=17) being supported the least by game mechanics within this game session.

Mechanics that Support Knowledge

The game mechanics within Minecraft EE: Chemistry Lab were analyzed for the extent to which they support a player’s construction of knowledge as it relates to foundational knowledge (i.e. content knowledge and game/technical literacy), meta knowledge (e.g. problem solving, critical thinking, communication), and humanistic knowledge (i.e. life skills, ethical awareness, emotional awareness). A majority of the mechanics identified as supporting knowledge constructs focused on foundational knowledge outcomes. Specifically, Tutorials presented information to the player about how they can interact with the game environment (game/technical literacy) through specific actions. Alternatively, Tutorials were also utilized to present content knowledge to players surrounding the topic of chemistry and the interactions between elements that lead to complex chemical compounds.

Questions/Answers was another mechanic which supported players in interacting with non-player characters (NPCs) through dialogue which prompt players for responses in relation to content knowledge in the domain of chemistry. From the perspective of Rewards/Penalties and Metagame mechanics, players are supported in the development of meta knowledge. The considerations of Rewards/Penalties prompt players to think critically about strategies to accomplish tasks while avoiding setbacks. The Metagame mechanic highlights players interactions which transcends the space of the game itself. Minecraft EE: Chemistry Lab provides players with
forum and wiki resources which facilitate communication and problem solving through strategization. None of the mechanics identified were aligned with humanistic knowledge outcomes.

**Mechanics that Support Interest/Valuing**

Though a relatively fewer number of mechanics were identified as supporting a player’s interest and valuing, there existed multiple opportunities for players to take agency and explore personally relevant materials which can be viewed as meaningful for their use in real-world contexts. Movement or traversal mechanics were identified as facilitating player interests and valuing through a process of enabling player reengagement with only the content the player deemed to be personally valuable. Similarly, Tutorials were also viewed as facilitating player interests and values. Though some tutorials were a requirement of the overall game environment, optional tutorials were revisited for explicit instruction on how to accomplish a difficult or unfamiliar task which the player found necessary or important. Strategy/Planning and Selecting/Collecting mechanics were both identified as providing support for player interest/valuing and were seen occurring in tandem across experiences within the game environment. For example, creating compounds or enacting specific element reactions required the collection of only those materials of interest. As a result, this process demonstrated the use of foresight and planning which the player undertook due to both the personally relevant task to be accomplished in game and the global relevance ascribed to the chemistry processes under study.

**Mechanics that Support Self-Organization/Self-Control**

Self-organization and self-control constructs are related to the player’s behavior, motivation, and cognition toward specific goals. Broadly, these refer to three categories of self-regulation, co-regulation, and socially shared regulation. Due to the focus and parameters of this study, there were few opportunities for regulated actions beyond the scope of self-regulation, but that does not mean co-regulation was absent entirely. Mechanics associated with self-regulation included Strategy/Planning, Selecting/Collecting, and Behavioral Momentum. Strategy/Planning and Selecting/Collecting demonstrate self-regulated actions as the player is an active participant in their own learning process, whether that exists in the domain of game and technical literacy or specific content knowledge surrounding chemistry processes. Behavioral Momentum functions as a means to have players continue performing actions they have performed in the past. As a result, this mechanic focuses on motivating the player to enact a specific outcome in their own process of learning.

Though there was only a single player within the Chemistry Lab environment, there were still several opportunities for co-regulation. Mechanics that facilitated such processes included Feedback, Questions/Answers, and Roleplay. The player was provided feedback through the game experience through processes of trial and error. When prompted to create H2O2, the player placed Hydrogen, Oxygen, and Oxygen elements onto the Lab Table. As a result, the Lab Table produced garbage, as the proper components to create a H2O2 molecule were not present. Though not explicit, this interaction demonstrates the omnipresence of the scientists in the Chemistry Lab who play a role in regulating the player’s behaviors throughout the experience. More explicitly, players were prompted to answer questions from famous scientists such as Marie (named for Marie Curie) and Alexander (named for Alexander Fleming). These interactions not only provided students with directed oversight, but also with the ability to roleplay as an apprentice of historically renowned scientists and chemists.

**Mechanics that Support Self-Perceptions/Self-Definitions**

In relation to the previous identity constructs, relatively few mechanics were linked to a player’s reflection on their own changing self-perceptions and self-definitions. Though mechanics had the potential to allow the player to see themselves in new ways in relation to chemistry content, there were little to no opportunities which prompted player reflection or acknowledgement of shifting identity within the game environment. Predominantly support for self-perceptions and self-definitions was provided through Roleplay mechanics. Through the presentation of various historical figures, players are offered the opportunity to explore possible selves within chemistry. This roleplay provided the player with the ability to gain competence in this field and “try on” the role of a chemist in approaching a number of chemistry-related tasks. Additionally, Realism played a role in allowing the player to see herself in the role of a chemist. Being tasked with “busy work” such as cleaning the lab environment, preparing equipment, and gathering resources added to the experience of roleplay which added to the exploration of a possible self.
Discussion

An analysis of the identified game mechanics illustrated the extent to which specific mechanics can facilitate identity exploration as conceptualized by Projective Reflection. As evidenced by the connections between mechanics and identity constructs in Figure 1, a majority of game mechanics demonstrated potential to facilitate change in learners across either two or three identity exploration constructs. Conversely, only a single mechanic was linked to just one identity construct, while no mechanics were linked to all four identity exploration constructs. This outcome coincides with recent findings on the use of game design mechanics for learning which suggests individual game mechanics can elicit multiple learning outcomes or, for the purposes of this study, elements of identity exploration (Ampatzidou & Gugerell, 2019). This further solidifies the need for game designers and educators to understand the potential learning outcomes afforded by the mechanics designed into game experiences.

Throughout the coding and analysis phase, a total of eighteen unique game mechanics were identified. However, only a single mechanic, Feedback (lack of), was identified as having a potential negative development for identity. Despite being the only mechanic with strong potential to hinder identity exploration, Feedback (lack of) was identified as occurring throughout several instances of gameplay. For example, when provided with tasks or quests by NPCs, the player is given prompts that describes what needs to be accomplished. Throughout the entirety of these quests, the dialogue provided by the NPCs remains the same despite the player’s level of progress. Additionally, the Chemistry Lab add-on provided the player with an infinite number of resources for building chemical reactions, though it struggles to provide specific feedback on the usage of individual elements and their general importance. These instances where Feedback (lack of) was identified have the potential to hinder students in their development of relevant knowledge and regulated actions. This finding holds particular importance when examining game-based experiences to be used for specific learning outcomes. Fundamentally, experience designers and educators should ensure that a basic minimum requirement for game mechanics are implemented into game environments to ensure that learning outcomes are not hindered by mechanics. This finding should aid in guiding designers in considerations for games with learning outcomes and in helping instructors evaluate if a game experience is appropriate for their instruction.

In addition to a focus on the game mechanics of the Minecraft EE: Chemistry Lab, it’s similarly important to note the game genre and how these findings might generalize to similar game environments. Though Chemistry Lab is equivalent to an add-on for the main Minecraft game, they share the genres of Action-adventure, Open world, and Sandbox. Similar games included in these genres include Terraria, Grand Theft Auto V, and a wide variety of simulator-oriented games including Train Simulator, Farm Simulator, Roller Coaster Tycoon, and Jurassic World Evolution. Though we cannot make direct assumptions surrounding the game mechanics and how they might facilitate identity exploration within these games, it is probable that games within the same genres enable players to interact with a similar set of game mechanics. Therefore, there is potential that a similar set of game mechanics can be ascribed to specific game genres which culminates in similar possibilities for identity exploration. Additional research is required to investigate these and similar possibilities between the interplay of game mechanics, identity exploration, and game genres.
Conclusion, Limitations, and Future Work

This paper introduced preliminary findings of a study concerning the game design features of Minecraft EE: Chemistry Lab which can facilitate learning as a process of identity exploration. The play experience of a player-researcher was observed and deductively coded by three doctoral researchers for the occurrence of game mechanics as guided by the LM-GM framework. Subsequent data analysis identified potential alignment between game mechanics and identity exploration constructs including player knowledge, interest and valuing, regulated actions, and self-perceptions and self-definitions. Findings revealed a total of eighteen unique game mechanics within the Chemistry Lab game environment which align with at least one identity construct. Game mechanics most often supported change in a player’s content knowledge and game/technical literacy, while they were least likely to support change in a player’s perceptions of self and self-definitions. This study also revealed a basic set of game mechanics within the Sandbox genre of games and their capacity to enact change in a player’s identity. These findings could be utilized to guide game environment designers and instructors in how learning is integrated into digital experiences such as games.

Though this study was able to identify connections between game mechanics and learning as identity exploration, there remained several limitations. The play session for the player-researcher was only thirty minutes in duration and occurred in a single session. This duration is problematic in two ways: First, the player-researcher was unable to experience the entirety of the game environment and the various interactions (mechanics) it provided. From this perspective, there is a possibility that a number of mechanics were missed and/or there were potential...
links to identity constructs that went unobserved. Second, Projective Reflection conceptualizes learning as identity exploration over time. A single game session is not adequate to illustrate a change in a player’s identity. As such, this study identifies the potential for alignment between game mechanics and identity exploration, but does not explicitly identify change in the player-researcher. In reference to the player-researcher, only a single player’s game data was observed and coded. An expanded study would investigate the play data of multiple participants in order to gather more in-depth insight into game mechanics.

Future studies will expand upon the findings of this paper by examining multiple players across a number of game-based environments. From this perspective, players will be provided the opportunity to experience the depth and breadth of an environment which will demonstrate the full range of potential game mechanics. Through the use of multiple game-based experiences, results will be able to be compared across similar games as well as those which differ widely to understand the extent to which a set of game mechanics can be shared within and across game genres. These findings can be analyzed in order to create a framework which can provide insights into the degree and type of identity exploration afforded by various genres of game-based experiences.

References


“History Comes Alive”: Implications for Teacher Professional Development on Place-Based Local History

Katherine L. Walters
Department of Career and Information Studies
University of Georgia, United States
klw51525@uga.edu

Theodore J. Kopcha
Department of Career and Information Studies
University of Georgia, United States
tjkopcha@uga.edu

Christopher R. Lawton
Putnam County Charter School System, United States
christopher_lawton@putnam.k12.ga.us

Abstract: Traditional textbook approaches to history education present history as a static set of dates, names, and events to be memorized. Engaging in historical inquiry in the K-12 classroom is a way to move history education beyond the recall of facts, as it requires the assessment of evidence and the construction of historical arguments and understanding. However, engaging in historical inquiry presents challenges for both teachers and students. This study presents place-based local history as a way to engage students in meaningful historical inquiry. The goal of this study was to identify best practices when preparing inservice history teachers to use technology to engage with local history as a source of inquiry, investigation, and knowledge to support historical thinking. Using case study, we examined the experiences of two teachers who engaged in place-based local history with an academic historian over a six-month period in a rural county in the southeastern US. We then used those experiences to establish a set of design principles and implications that best support teaching practice in this area of education. These design implications may be used to create professional development programs that address the specific needs and challenges related to technology, pedagogy, and historical methodology that emerge from the process of using local history as the focus for historical inquiry.

Introduction

K-12 teachers are often prepared to teach history as lists of facts and dates to remember, and students are assessed on their ability to recall those facts. This simplistic view, however, fails to account for the constructed nature of historical artifacts and narratives – that is, it ignores the way that social dynamics and individual perspectives influence the stories we tell about the past. Historical inquiry is one way to engage students in constructing understandings of history that go beyond facts and dates (Ercikan & Seixas, 2015; Levstik & Barton, 2011; Wineburg 2001). By engaging students in thinking like an academic historian, historical inquiry promotes understanding facts and information as they relate to the causes and consequences of historical events. In other words, historical inquiry engages students in understanding the social and individual perspectives that influence how we construct the stories of the past.

One way to promote historical inquiry is through place-based local history. Place-based local history blends historical inquiry with events from the local context, providing students with an opportunity to learn about the events of the past as they impact the people and places in their community (Gruenewald, 2003; Lovorn, 2012). While existing research supports the benefits of historical inquiry (e.g., Leinhardt & Young, 1996, Wineburg, 2001), an ongoing challenge is to support teachers in sustaining inquiry-based approaches to history. It requires teachers to connect school activity with the community, support experiential learning, and promote student-driven inquiry. More importantly, it requires teachers to understand the role of local history in historical inquiry and place-based
pedagogy. This can be difficult for teachers to integrate into the current curriculum, which is more often focused on achieving specific state standards in a timely fashion.

Adding to the challenge is technology. Technology supports historical inquiry by supporting access to primary sources (Hofer & Swan, 2014; Waring & Torrez, 2010), organization of content (Saye & Brush, 2002; Spoehr & Spoehr, 1994), student construction of artifacts (Hofer & Swan, 2014; Saye & Brush, 2002), and role-playing activities (Hofer & Swan, 2014). Technology also provides a personal “hook” as students use online data (e.g., ancestry.com) to make interesting connections between their families’ and communities’ histories (Lee & Molebash, 2014). Thus, an added challenge to preparing inservice teachers to conduct place-based local history is that it also requires technology preparation.

The purpose of this case study was to investigate a place-based local history program enacted by two teachers in a high school in a rural county in the southeastern United States. The goal was to identify best practices when preparing inservice history teachers to use technology to engage with local history as a source of inquiry, investigation, and knowledge to support historical thinking. While several scholars have explored the use of place-and inquiry-based approaches to history at the preservice level (e.g., Crocco & Marion, 2017; Lovorn, 2012; Waring, et al., 2015), few have focused on how inservice teachers transform their practice from traditional approaches toward place-based local history. The research questions guiding the study were as follows: (1) What were the benefits of a place-based local history program as perceived by the teachers? and (2) What challenges did teachers face and how did they overcome these challenges?

Inquiry- and Place-based History Education: A Review

In historical inquiry, students engage in the real-world task of constructing a historical narrative. This mirrors the process of historians who typically identify and analyze primary and secondary documents and images to construct a careful argument about the past. Overall, inquiry-based learning can positively affect students’ knowledge and discipline-specific reasoning skills (Hmelo-Silver et al., 2007). However, teachers face multiple challenges implementing inquiry-based lessons in history; teachers often lack of background in historical methodology (Lovorn, 2012; Keirn & Luhr, 2012), face environmental constraints including time, administration, and standards (Lovorn, 2012; Meuwissem, 2017), and lack of support throughout the implementation process (Callahan, Saye, & Brush, 2016; Keirn & Luhr, 2012; Lovorn, 2012; Neumann, 2012).

Many professional development and teacher education programs use various technologies to support historical inquiry, from the implementation process (Saye & Brush, 2002) to training teachers in historical methodology (Baron, 2013). In a pre-service teacher education program, Waring and Torrez (2010, p. 297) found that teachers perceived lessons using digital primary sources to teach historical perspective-taking as useful because it: “(a) made history real, (b) challenged assumptions, (c) helped them to understand content, (d) multiple perspectives, and (e) fostered inquiry.” For teachers to be comfortable introducing technology in the classroom, however, they must have ample opportunities to participate in inquiry, interpretation, and personal meaning-making themselves (Lee & Molebash, 2014, p. 161). Additionally, tech-specific challenges can arise for teachers, such as troubleshooting and the need for additional planning time (Hofer & Swan, 2014). Therefore, tech-specific support and experience are needed.

Inquiry-based learning in history also can connect students’ learning to their own community. It opens the possibility that historical inquiry can happen in places and spaces familiar to students. This goes beyond simply taking students out to historic spots in their community. As Baron (2013) explains, “Mere proximity to historic places does not provide intellectual access to them” (p. 167). Rather, students must make connections between their own actions and beliefs and the people who lived and experienced past events within that community (Clarke & Lee, 2004). Place-based local history can therefore provide a bridge between students’ lives and school, one that results in meaningful learning experiences.

Methods

This case study explored the experiences of two high school teachers who implemented a place-based local history curriculum in a rural county in the southeastern US. The teachers worked closely with an on-site academic historian who provided ongoing support with engaging students in the history of their community as it related to various performance standards. Their experiences were analyzed to identify challenges, if/how they overcame these challenges, and perceived benefits of the curriculum to determine potential design implications of doing place-based
local history. In this way, the teachers served as embedded units in our design, helping to reveal the design and support features that helped teachers be successful.

Participants and Context

The place-based local history program was implemented in a rural public-school system where approximately 80% of students live at or below the federal poverty line. The racial makeup of the school system is roughly 44% black, 44% white, and 9% Hispanic. The participants were two Caucasian male high school history teachers. Teacher 1 (T1) had been teaching US History and American Government for 12 years; teacher 2 (T2) had been teaching US History and dual-enrollment history courses for 23 years. Both worked closely with an academically-trained historian who serves as Director of Experiential Learning for the county. The historian provided ongoing support, helping teachers engage students in the history of their community as it related to various performance standards. The program took place in the T1’s inclusion-level US History and T2’s dual-enrollment US History courses over a 6-month period.

As described in Lawton, Kopcha, Walters, and Ocak (2020), the place-based local history program consisted of multiple, simultaneously occurring projects that connected classroom activity with the community. Technology played a critical role throughout the program. Students used online resources (e.g., courthouse archives, digitized artifacts) and photo and video editing software to create new historical artifacts that could be shared to support further inquiry. In the current study, T1’s students created a database of the names and locations of enslaved persons in their county. T2’s students collected oral histories from community members. As students participated in these projects, they were exposed to information that prompted them to ask additional questions or to the desire to create ways of sharing the information/experience with others.

Professional development provided by the academic historian supported the teachers in historical inquiry. First, teachers identified a robust and interesting set of projects that aligned with state history standards. Next, the teachers worked to develop materials (e.g., lesson plans, student materials) for engaging students in those projects; they also planned in-community field trips to local government agencies and locations. The academic historian supported this process, scaffolding the inquiry process from initial introduction to the historical topic to working with primary resources, collecting information in a systematic manner, and constructing historical narratives around the work. The academic historian regularly co-taught lessons with the teachers, modeling both the process and underlying thinking of historical inquiry over several months.

The authors of this study participated in the design and implementation of the professional development program as described, as well as current iterations of this program. The first author was a graduate research assistant in the university’s college of education and worked closely with the other authors and participating teachers to provide support for lesson development. The second author was a faculty member of the same university and lead the professional development workshops as well as provided just-in-time support to participating teachers. The third author was the academic historian, whose role is described throughout the paper; he provided regular on-the-ground support to the two teachers in this study.

Data Collection and Analysis

Both teachers participated in an hour-long interview with the first author. Interviews were guided by a semi-structured protocol that focused on the benefits and challenges of implementing a place-based history curriculum in a local context. Interviews were transcribed and imported into the qualitative analysis software program, NVivo 12. Each interview was first thematically coded using an inductive approach. The coded segments were then analyzed to determine subcategories within each theme. All three researchers reviewed the initial codes and data and made minor revisions through discussion until consensus was reached. The final code structure was then applied to both interviews.

Results

Three main themes emerged from the interviews: technology, pedagogy, and historical methodology. As shown in Table 1, each of these themes contained subcategories that identified the challenges and benefits of the place-based local history program the participants were/are involved with (Tab. 1). For example, each of the three main themes included discussion around both the benefits and challenges associated with using technology and
employing pedagogical strategies associated with historical methodology. The three themes and associated sub-themes are presented in detail below.

**Technology**

Overall, teachers found that technology was critical for locating and digitizing historical content, as well as supporting the construction of content by students. Technology also promoted collaboration between students and allowed them to share their work with a broader community. However, teachers reported not having confidence in their own technological skills beyond supporting students’ information seeking.

**Benefits of Technology**

Technology supported access to both primary and secondary historical sources for students. For example, T2 stated, “[We do] a lot of technology and family database search[es] like familysearch.com and show them how to get into the deed records…they have to find secondary sources and journal articles that have been peer-reviewed…” Students used archival materials such as probate records, deed records, and digitized 19th-century newspapers to gather information about enslaved individuals and their families. Using secondary sources to better understand the historical context, students constructed new historical narratives of past members of their local community. Students also used technology to gather and preserve their community’s history as part of an annual gathering at what was once the county's segregated school for African American students. T2 explained, “…at community events we recorded oral histories [and] document scanning so that we have a database for … future primary sources to build more projects with.” A key benefit is that the activity was student-led – they recorded and conducted oral histories, as well as scanned photos and documents that community members brought to the event.

Another benefit was that all of these artifacts were then entered into a database for future student research. This required students to collaborate using Google Docs and think about how other students might view and build upon their work in the future. For example, one group conducted initial genealogy and life history research on a formerly enslaved woman and her family, and the next group of students took this research and used it to create a short documentary (T2). In this way, technology went beyond fact-finding and created an ongoing collaborative effort to conduct place-based local history over multiple groups of students.

**Challenges with Technology**

Teacher 2 indicated considerable uncertainty about his technological competence: “Technology is certainly my weakness, but there’s a lot of technology when we are making videos and recording oral histories and editing them down to short usable clips….” His comment indicates both the importance of technology and his perceived inability to support students with audio and video recording and editing. He later noted, “I’d like to see [students] get paired with a tech person, someone who is teaching audio and video.” This suggests teachers need training, or even interdisciplinary partnerships, to develop the skills needed to conduct research and share findings. This might range from constructing a written document to more complex and challenging uses like audio/video recording and editing.

**Pedagogy**

For the teachers in this study, student discussions and reflections were viewed as critical but difficult-to-implement pedagogical strategies. However, increased agency and connections to the community were perceived as benefits for both teachers and students. These are discussed more fully, below.

**Pedagogical Challenges**

A large component of successful place- and inquiry-based education is deep student discussion and reflection – both were challenging for teachers in this study. Teacher 1 initially found it difficult to support
productive discussion, noting: “I had ground rules [before each discussion], and just I had to stop the discussion after five minutes because they weren't listening to each other, they weren't respecting other people's opinions…” One effective strategy for teaching students how to engage in a productive discussion of history was to allow them time to process the activity and then lead them through particular questions. For T1, those guiding questions were important because they helped guide the discussion “in the right direction.” Teacher 2 similarly explained, “You have to develop a structure and a plan ‘cause you can’t just jump into something like the slave database without being able to put the things first into a proper context and without proper training…” This structure was challenging for teachers to anticipate ahead of time. Both teachers found that despite their planning, it often happened in an in-the-moment fashion, in response to information that exposed the ways that specific groups of people were marginalized or unfairly treated in the past. Teacher 1 noted how students began to understand the history of enslavement not just as an event from the past, but also as a theme that was contextually relevant in the present: “So those kind of opened up some good discussions about… putting themselves in those shoes… You know [enslaved persons]… lived lives just like us, but they had different struggles, but they were still humans, and they still had feelings … and [I] try to get them [students] to reflect on… what would go through your head if you were told that … you're not gonna be seeing these people [enslaved persons’ family members] anymore?” Teacher 2 similarly explained how students began to develop an embodied understanding of segregation, both nationally and in their own community, by relating it to contemporary issues of social injustice: “You’re talking about issues like civil rights, voter discrimination, and the Klan, and this is happening to people they know, parents or grandparents, [or aunts and] uncles. It’s hard for it not to be personal.”

**Pedagogical Benefits**

For T2, place-based local history was an opportunity for students to work more closely with the community. Both teachers attributed students’ high levels of engagement in the place-based local history curriculum to (1) the fact the students’ families had lived in the area for a long time and therefore had personal interest in the research, and (2) students’ belief that they were both becoming part of and helping their community in the process. For example, students regularly engaged in research during local events, and many presented at academic conferences.

Another benefit was that place-based local history cultivated students’ sense of agency as historical researchers within their own community. As researchers, students were expected to create their own understandings and knowledge and share it with others; this contrasts the traditional role of the student learning history as de-contextualized facts and dates. Teacher 2 noted: “I don't know anywhere else in the country where we have high school students that are conducting original research that rises to the level where I am comfortable, and Ph.D. historians . . . are comfortable taking it to a professional conference and presenting it. I think that… shows the quality of work that high school students can do. A lot of people think high school students, they can’t do this. They can. Give them the opportunity…”

Both teachers also thought that implementing this place-based local history curriculum cultivated a sense of responsibility in their students. Teacher 2 commented, “I feel like they really began to feel like they [could] right these past wrongs. I think it certainly makes them aware of it.” This sense of responsibility is echoed in T1’s recollection of the words of one of his students, “’…These people didn't have a voice, and this is my turn to give them a voice, and to… not forget about them… It’s a lot easier for white people to find their ancestry, but… for African Americans it's very difficult and… hopefully with what I'm doing in this I can help.’” For this teacher, student motivation for completing their research projects was based on their real-world impact.

**Historical Methodology**

A third theme that emerged from the interviews centered on historical methodology. Historical methodology involves analyzing historical evidence and constructing narratives of the past built on focused research, careful analysis of new and existing evidence, and logical reasoning. Students in this place-based local history program were taught to engage in historical methodology by mirroring the processes of academic historians. For teachers in this study, this methodology meant they had to create authentic opportunities for research, as well as scaffold the entire process in response to students’ needs. This created both challenges and benefits for teachers and students.
Challenges with Historical Methodology

In order to guide students successfully through the steps of a historical inquiry project, both teachers recognized the importance of being knowledgeable of and comfortable with the historical content of the inquiry. In this study, both teachers had experience with graduate school history programs where they learned historical methodology, as well as the pedagogical experience of at least 12 years in the classroom. That background was important in that it helped them overcome challenges as students engaged in historical inquiry. At the same time, both noted how they personally had to reach a level of comfort and familiarity with the historical research process while finding time for activities and reaching out to the community. Addressing the sensitive nature of place-based local history required an additional level of disciplinary expertise and time for planning than traditional lessons. Teacher 2 explained, “I think to do this you really have to get confident people in their field of study...If they don’t know their content themselves, they certainly aren’t going to be able to relay it and take it that step further into conducting the research.”

One specific challenge that teachers faced was in developing the scaffolding needed to engage in historical inquiry. Some supports could be predicted and prepared for ahead of time, such as the need for context-building. As the teachers engaged with the students in historical inquiry, however, they began to see more opportunities to scaffold student understanding. For example, T1 was surprised some of his students were not aware that people had been enslaved in their county: “it just blew my mind. Like, you’re from the South, it’s just amazing… they had no idea. A lot of times they would go through 300 documents [from the mid-1870’s] and say there's nothing [about slavery] there.” In response, he developed scaffolds to support students in analyzing documents in search of enslaved persons’ names around the time of emancipation. This entailed prompting students to attend to specific historical facts (e.g., the date of emancipation) to help contextualize events of the past. Specifically, they compared census data from 1860 to 1870 (i.e., pre- and post-Civil War). Comparing the census data allowed T1 to help students recognize that most of the adults in the county were enslaved just a decade prior to the 1870’s. Teacher 1 attributed this realization to the scaffolds he developed, which helped them situate facts and knowledge (e.g., population data in the mid-1800’s) in ways that connected the present to larger events of the past (i.e., slavery).

Benefits of Historical Methodology

Both students and teachers learned to work as historians in their local community. This work engaged students in asking “so what” questions about evidence to be used in the arguments they constructed. According to T1, those “so what” questions helped students identify where to look next for evidence and begin constructing an explanatory narrative:

“So you're looking at a document, you're putting [data from it] in a spreadsheet, and from doing that you can eventually create or write history about it…. and you can start putting links together and… rationalizing that this happened during this time period . . . [The] 1870 census is really close and so maybe we can find more information because a lot of these [freed people] ... probably stayed in [the] County after they were emancipated… maybe I can find … some links.”

Teacher 2 similarly noted how this process taught students to find a relevant piece of evidence, then use it to find the next relevant piece of evidence: “[Students] are working like a historian, using the skills that a historian would use which are applicable in all the humanities…I think it’s important work.” Working like a historian, i.e., engaging in the historical research process, is an essential skill both teachers aimed to develop in their students.

Another benefit of the place-based local history program was its emphasis on the local community and applying historical inquiry in meaningful ways. Teacher 2 explained that the local connection to places and people they know is what made history “come alive” for students: “[History] becomes real to them in a way that it can’t be to them if they’re sitting there in a classroom... I can talk about [local historical] events and people. So that’s much more real, concrete thing for them.” Connecting what students read in documents to places in their own community grounded both teacher’s lessons in something concrete for the students. The teachers noted making use of the local context to connect history with their sense of community. Teacher 1 explained, “it’s in your community… [these] people have walked in the same spots you have and … they created history from the things that they did and eventually you'll be creating history from the things you did [and] maybe someday someone will be looking back at what you did and wondering…” Occupying the space of a historical event assisted students in connecting the past and present, and in seeing themselves as historical agents who were contributing members of their community.
<table>
<thead>
<tr>
<th>Theme</th>
<th>Challenges</th>
<th>Benefits</th>
<th>Design / PD Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Teachers uncomfortable supporting students’ technology use beyond fact finding and information seeking (perceived incompetence)</td>
<td>Students learned to access and locate primary and secondary historical content, collect and digitize new historical content, and construct historical content individually and collaboratively.</td>
<td>Teachers require support in technology-assisted content creation.</td>
</tr>
<tr>
<td>Pedagogy</td>
<td>Place-based learning required additional work and planning. Students struggled to engage in deep reflection and discussion. Teachers unsure about how to handle social justice issues.</td>
<td>Students developed stronger community connections/relationships. Students had greater agency and were engaged and motivated to work on the project.</td>
<td>School administration support, increased planning time and PD on sensitive topics. Provide support for building community connections/relationships. Give students time to express their thinking in different modalities (written, spoken, art, etc.).</td>
</tr>
<tr>
<td>Historical Methods</td>
<td>Teachers needed to scaffold historical methodology and engaging students in inquiry. Also needed a reactive approach to teaching, which takes time and on-the-spot pedagogical decisions.</td>
<td>Students engaged in historical thinking that related to their own community; “history comes alive.” Teachers and students learned to apply history in a way that was meaningful to them and their given context.</td>
<td>Create opportunities for interdisciplinary teams. Create structures for creating products/artifacts that incorporate perspectives on history.</td>
</tr>
</tbody>
</table>

**Table 1.** Challenges, Benefits, and Implications for Place-Based Local History Education

**Discussion**

This study strongly supports previous literature on historical inquiry. It is common for teachers to struggle with using technology to move students beyond fact-finding and information gathering (Brush & Saye, 2009; Hofer & Swan, 2014). Likewise, it is common for teachers to need support with inquiry-based methodology. Historical inquiry requires teachers to adopt practices that are often counter to their previous experiences in the history classroom and their own understanding of teaching history (Callahan, Saye, & Brush, 2016; Crocco & Marino, 2017). They need professional development and just-in-time support that helps them and their students engage in deeper reflection and make sense of the issues that emerge from the history of their community (Danker, 2005). This requires time, support, and ongoing effort in an already taxed teaching environment.

What this study contributes is insight into practices that not only engage students in doing historical inquiry, but also in making connections between their inquiry and the people and events in their community. In other words, the teachers in this study developed both the historical methods (e.g., analysis of primary sources) needed to interpret the past and the historical consciousness needed to make connections between their community’s past and present. Engaging in place-based inquiry alongside an academic historian supported teachers in this development. Teachers reported it was beneficial to visit places in the community as they learned about the historical events that created that community. Through interaction with people and the artifacts of history that remain in the community, teachers made meaningful connections between the past and present.
Broadly, historical consciousness is our ability to think in time—to imagine past, present, and future. The ability to identify connections between the past and the present, and to reflect on these connections to make sense of the present, represent what Duquette (2015) describes as a narrative level of historical consciousness (grounded in Rüsen, 2004). One teacher’s use of the phrase “history comes alive” demonstrates this advanced level of historical consciousness. In the teacher’s perspective, the past was pulled into the present by becoming “alive,” and therefore both relevant and meaningful to the lives of students now. The development of historical consciousness in teachers is important for at least two reasons. First, historical consciousness is critical to all people to expand our life view beyond our selves and is used as an asset in decision making and identity development (Ahonen, 2005). Second, teachers must be prepared to support students in their development of a reflective historical inquiry practice. This involves understanding what prompts and activities students need to move from non-reflective historical inquiry (i.e., interpretation of the past and present as separate and unrelated) towards a fuller understanding of how the past impacts the present, and therefore, how the present will impact the future (Duquette, 2015).

Making history come alive helps address ongoing issues in the teaching of history. Wineburg (2001) and others (e.g., Booth, 1983; Leinhardt & Young, 1996; Levstik & Pappas, 1992; Seixas, 2015) have long advocated for teaching history in a way that mirrors the work of academic historians: the goal is to support students in learning the facts of a historical event, the complex context in which that event took place, and the historical methods needed to construct a narrative. In this study, this understanding was developed by exploring how local history was constructed by the people who tell that history. Both teachers noted how the program engaged students in telling untold stories of their own community.

Place-based local history carried an aspect of social justice in this study. Although it may be expected that a local history lesson in the US south will incorporate discussions of racial inequity and oppression, the way these difficult topics are approached is critical. Developing students’ historical consciousness requires negotiating the complexity of social justice issues rather than presenting a simplified textbook narrative. Additionally, as historical consciousness develops, students uncover new ideas and ways to connect the past and present. Pedagogically speaking, this was challenging. Teachers were unsure how to handle the sensitive issues of racial injustice and imbalance of power associated with slavery and segregation. While exploring these issues was a powerful approach, it also required training and understanding that teachers often have not had the experience to develop. On-site support was critical in supporting teachers as these issues emerged.

In this case, the emergence of social justice issues presented a tension with which teachers needed to deal. As students connected with community, they learned that history is something that happens to the people they know in the place they live. This grounds history in a local, shared, space. However, this project often focused on the stories of people who had been marginalized and whose histories had not been told. The idea of a “shared” community history is then called into question by asking “whose stories get to be part of this history?” Although uncovering this contradiction presents an opportunity to delve deeper into historical inquiry, it also presents challenges for teachers such as how to support students in critically analyzing and reflecting on the socio-historical-cultural positions of various perspectives.

Implications

One immediate implication is that teachers need professional development and additional time to fully engage in place-based local history. In order to support their students in historical inquiry, teachers must first develop their own understanding of historical methodology. Although history teachers are trained in historical content, approaching historical questions, gathering and assessing evidence, and examining and challenging existing narratives pose a challenge. Additionally, teachers must learn to create and provide scaffolds for students throughout this process, and to engage in deep reflection about potentially sensitive issues. As well, teachers must learn how to connect with the community as a source of historical knowledge. In this study, support was provided by an academic historian, which suggests how working with a local university or community-based historical society could be a good step towards learning and practicing the methodological aspects of historical inquiry. This supports Neumann’s (2012) argument for collaboration between history teachers, historians and history faculty, and professional developers to support teachers’ historical thinking abilities. Additionally, building and sustaining relationships with community leaders is critical to conducting historical research with meaningful benefits for all involved—students, teachers, and community.

Another implication is that fact-finding and information-gathering activities should be viewed as foundational pieces of a larger, student-driven project. In this study, multiple projects grew into research papers presented at academic conferences, a documentary film, and visual displays in the community. Students engaged with the historical research critically and creatively through multimodal products shared with a broad audience (Dayton-
Wood et al., 2012). This supports student engagement and helps bridge the gap between the classroom and the community, establishing students as community members in a new way. Technology can play an important role in this process – not only in finding facts and documents of history, but also in constructing those into a meaningful narrative. This can be supported in a number of ways, including ongoing written and photo journaling (e.g., blogs), reflection prompts, and examples of telling history available from professional historical associations. Discussion and reflection are critical components of this process; they allow for critical engagement with the material. Students must learn to look at historical material to see what is and is not included, at who is writing the depiction and why (Wineburg, 2001). Discrimination and judgment are important skills for historians, and difficult for students to master; this study suggests that such skills can be cultivated with scaffolding, support, and technology.

Conclusion and Next Steps

Wineburg (2016) explained how the goal of teaching history is not to create historians but to create better thinkers who are prepared “...for the vocation of citizen” (p. 16). Historical inquiry requires students to locate and assess evidence and to consider multiple perspectives, skills they need to become informed and engaged participants in the life of their community. Place-based local history is a powerful way to engage students in developing these skills. However, it requires new practices and approaches to learning that educators and scholars have only begun to understand. This study represents an initial attempt at identifying design considerations and implications. It is our hope these design implications may help guide others looking to do similar work in their own localities.

References


Growing Up Mobile: How Do Today's Preservice Teachers Feel About Integrating Mobile Phones in Their Classrooms?

Kevin Thomas  
Bellarmine University  
United States  
kthomas@bellarmine.edu

Michael Hylen  
University of Louisiana-Shreveport  
United States  
Michael.Hylen@asbury.edu

Beth Carter  
Methodist University  
United States  
bcarter@methodist.edu

Abstract: This study examined the perceptions of 183 preservice teachers in Kentucky and North Carolina to determine their support for the use of mobile phones in the classroom, and their perceptions of phone features useful for school-related work. Based on responses from 158 participants, the results indicated that 89% preservice teachers used their mobile phones for school-related work and over half (55%) supported their use in the classroom. The preservice teachers perceived many features and functions of mobile phones as being useful. They identified access to the Internet (m = 4.26), use of educational applications (m = 4.30), and use of a calendar (m = 3.88) as the most beneficial. The researchers found that age and school policy affected participants’ perceptions.

Introduction

Preservice teachers today offer a unique perspective on mobile phones in the classroom. Many of these candidates are only a few years removed from being students in P-12 schools. As students, their perspectives on the instructional value of mobile phones have been shaped by their personal use as well as the myriad of policies at their schools regarding use of mobile phones. As teaching candidates, their perspectives on the instructional value of mobile phones in the classroom continues to be shaped by personal use as well as the knowledge, skills and dispositions learned in their teacher preparation programs. Granted, prior preservice teachers have had access to mobile phones during their P-20 education; however, increased access to mobile phones and online content, significant growth in instructional applications, and evolving school policies make current preservice teachers’ perspective on this topic unique.

Mobile phones have always had the potential to be a beneficial classroom technology, and this potential has increased over time. One reason for this is an increase in access to mobile phones. In 2011, 35% of adults (Mobile, 2018) and 31% of teenagers between the ages of 14-17 had a smartphone (Lenhart, 2012). Today, 95% of adults own a mobile phone and 77% of adults own a smartphone. For adults between the ages of 18-29, smartphone ownership is 94%. Ninety-five percent of teens have access to a smartphone (Mobile, 2018). As the ubiquity of mobile phones increases so does the potential for teachers and students to access technology for schoolwork.

Likewise, access to online content has increased over time. In 2009, 25% of mobile phone owners were accessing the internet via their phones (Smith, 2012). Today, more than two-thirds of Americans access the internet via a mobile device (Bauman, 2018), and 91% of teens age 13-17 access the internet using a mobile device (Lenhart, 2015). Increases have also been seen in the availability of educational applications. For example, in 2010 the Apple store listed 150,000 apps; by 2017, this number had increased to more than 1.5 million (Statista, 2018a)—almost 200,000 of these are educational apps. In 2018, the most popular apps on the Google Play store were educational (Statista, 2018b). The assessment app Kahoot alone has over 50 million users a month and over 830 million have played it since 2013 (Manning, 2017).
Perhaps in response to the increased ubiquity and instructional application, many schools in the U.S. are no longer banning mobile phones. According to a 2017 report by the National Center for Education Statistics (NCES), bans on mobile phones in schools have been steadily dropping since 2010 (Snyder, de Brey, & Dillow, 2019). Approximately ninety percent of U.S. schools banned mobile phones in 2010. By 2014, the number of the schools banning phones dropped to 75.9% and dropped another 10.1% (65.8) by 2016. During this same period, high schools banning mobile phones dropped from 80% to 35%.

This study examined the perceptions of preservice teachers from three teacher preparation programs regarding the use of mobile phones in the classroom. More specifically, it examined their level of support for mobile phones in the classroom and their ability to support student learning. Additionally, this study examined the impact of age and school policy on participants’ perspectives on mobile phone integration.

Literature Review

While educators have long recognized the instructional benefits of technology, including improved students’ engagement, motivation and learning (Roblyer, 2016), these benefits are contingent upon teachers and students using technologies appropriately. Mobile technologies provide teachers with a vast array of benefits including “new and enhanced learning opportunities such as personalized and adaptivity, context-awareness and ubiquity, interactivity, communication and collaboration among learners, and seamless bridging between context in both formal and informal learning” (Nikou & Economides, 2018, p. 102). However, some of the inherent characteristics of mobile technologies, specifically mobile phones, have made it difficult for teachers to manage their appropriate use and created barriers to their integration in classrooms and schools.

The primary instructional benefit of mobile devices is their ability to engage students in meaningful learning opportunities anywhere (Traxler, 2009); therefore, teachers can use mobile phones to engage students in mobile learning (m-learning). M-learning is defined as “a type of learning that enables learners to learn anywhere, anytime using wireless technologies” (Alioon & Delialioğlu, 2019, p. 656). M-learning supports personalized learning (Lindsay, 2016), scaffolding (Hung, Hwang, Lin, Wu & Su, 2013), collaboration (Jeno et al., 2019), increased engagement (Lin, Fulford, Ho, Iyoda & Ackerman, 2012), and increased motivation (Jeno, Grytnes, & Vandvik, 2017). Research has demonstrated the use of m-learning to support student learning in P-12 content areas including math (Song & Kim, 2015), history (King, Gardner-McCune, Vargas, & Jimenez, 2014), science (Kantar & Dogan, 2015), and art (Katz-Buonincontro & Foster, 2014). Nikou and Economides (2018), in a study of students participating in a mobile assisted intervention, found a significant increase in learning in low-achieving students.

M-learning has the potential to engage students in self-directed learning. Self-directed learning is a process in which the individual determines learning needs and defines the task, sets learning goals, enacts study strategies, adapts studying, and evaluates learning outcomes (Saks & Leijen, 2014). Lindsay (2016), surveyed teachers in twenty-four schools about their use of mobile technologies for m-learning. Teachers reported one of the most frequent m-learning activities they engage students in was accessing content via the internet. Teachers reported that students used their mobile technologies to access the internet to “investigate theory, ideas, concepts and to access teacher created content at school nearly every day” (p. 886).

Mobile technologies prepare students for lifelong learning because learning occurs in many places and times (Waycott, Jones, & Scanlon, 2005), and as noted by Sha et al. (2012), preparing “students with knowledge and skills for lifelong learning is regarded as a major goal of contemporary education in which mobile learning is subsumed” (p. 368).

Purpose and Research Questions

In order to prepare students to be successful for the future, schools must provide access to “mobile devices that connect learners and educators to the vast resources of the internet and facilitate communication and collaboration” (U. S. Department of Education, 2017, p. 69). The use of mobile devices facilitates the ability of educators to “personalize and customize learning experiences to align with the needs of each student” (U.S. Department of Education, 2017, p. 22) in both formal and informal learning contexts. Increased access to mobile phones and online content, significant growth in instructional applications, and evolving school policies, make mobile phones a viable option for classroom use. However, many teachers have traditionally opposed allowing mobile phones to be used in the classroom (Lenhart et al., 2010). Yet, as stated earlier, current preservice teachers bring a new
perspective on mobile phone use in classrooms. The purpose of this study was to examine preservice teachers’ perceptions regarding the use of mobile phones in the classroom.

1. Do preservice teachers support the use of mobile phones in the classroom?
2. Would preservice teachers use mobile phones for school-related work?
3. Would preservice teachers allow their students to use mobile phones for school related work?
4. Do preservice teachers think that mobile phones could/do support students’ learning?
5. What features do preservice teachers think are useful for school-related work?

**Methodology**

**Research Design**

Researchers at Asbury University and Bellarmine University in Kentucky and Methodist University in North Carolina used a quantitative descriptive research method to investigate the perceptions of preservice teachers regarding mobile phone usage in the classroom. This study utilized a validated survey (see Appendix A) for data collection (O’Bannon, Dunn, Park, 2017). Survey research was the preferred method of data collection because of its economy, rapid turnaround, and the standardization of the data (Babbie, 2012). Participants had the option of either completing the survey in a hard copy format or online. The online survey program used for this study was QuestionPro.

**Participants**

The subjects for this study who comprised this convenience sample consisted of candidates enrolled in the Preservice Teacher Preparation programs at three small liberal arts: Bellarmine University and Asbury University in Kentucky and Methodist University in North Carolina. Overall, 367 subjects viewed the online survey with a total of 183 (49.9%) providing some level of participation in the study. Of these participants, 158 (49.9%) completed the study.

The preservice teachers who comprised this sample were distributed between the states, with 126 (69%) located in Kentucky, 41 (22%) located in North Carolina, and 16 (9%) located in other states. The 16 candidates located in other states were comprised of students enrolled in an online degree program and most often lived in a bordering state (e.g. Indiana and Ohio). Of the 158 participants who completed the survey, one hundred and twenty-two participants (77%) were female, and 36 (23%) were male. One hundred and twenty-six (79.75%) were Caucasian, 12 (7.59%) were African American, six (3.8%) were Latino/Hispanic, five (3.16%) were more than one race, four (2.53%) were Asian, one (.63%) was American Indian/Alaskan Native, and four (2.53%) were other. The greatest percentage of students were between 18 and 21 years of age (N=97, 61.4%), with the overwhelming majority (N=129, 81.6%) reporting they were under the age of 30. The mean age was 24.21. All one hundred and fifty-nine participants (100%) owned smartphones.

**Data Source**

The survey used was developed by Thomas, O’Bannon, and Britt (2014). The survey gathers data on participants’ demographics, phone ownership, and mobile phone usage as well as support for the use of mobile phones in the classroom, opinion on use of mobile phones for school-related work, allowing students to use mobile phones for school-related work, and the ability of mobile phones to support student learning. Data was also collected on participants’ perceptions of the benefits and barriers associated with mobile phones in the classroom. The survey contained a variety of question types including Yes/No, checklists, open-ended, and Likert-scaled questions using 5-point scales (SD = strongly disagree, D = disagree, N = neutral, A= agree, and SA = strongly agree). Likert scaled items were classified in themes.

Participants had the option of taking the survey in hard form or online. The online survey was created using QuestionPro, and a link to the anonymous survey was shared with participants in person during class.
Data Analysis

An email requesting student participation in the study was sent to all faculty teaching initial certification courses in the education programs at each of the three institutions. Once a faculty member agreed to allow her/his students to participate in the study, the researcher at that institution attended the class and explained the purpose of the study to students. Participants then selected which format they would use to complete the survey. Students selected either a hard copy of the survey or a handout which provided the URL and a QR code to the survey. Both forms of the survey required participants to provide consent.

Accordingly, the independent variable is pre-service teacher perception of mobile phone usage in the classroom. To analyze the data in this study, a number of statistical tests were utilized. In order to characterize the data, descriptive statistics (reported below) were first generated on each question. The descriptive statistics were used to assist in describing and summarizing the data.

Results

Support for use of Mobile Phones

In this study, questions five to eight asked pre-service teachers their level of support for use of mobile phones in the classroom. Based on the responses from 158 participants who completed the survey, the results indicated that more than half (55%) of preservice teachers supported the use of mobile phones in the classroom while less than one-fourth (20%) did not support their use, and one-fourth (25%) were neutral. As stated previously, in order to characterize the data, descriptive statistics (Tab. 1) were first generated on each question. The descriptive statistics were used to assist in describing and summarizing the data.

For the purpose of testing whether the participant age correlated with participant perception response, a Pearson Correlation Coefficient was calculated for each set of responses (Tab. 2). While the results of the Pearson Correlation Coefficient did not reveal a statistically significant relationship between age and perception, they did reveal a slight correlation between the two (older candidates tended to disagree more than younger candidates).

Participants were given an opportunity to provide open-ended comments to address how they would allow their students to use mobile phones for school related work. The primary uses identified by participants were for conducting research and utilizing educational apps. Preservice teachers also identified Google tools, Kahoot, recording video and audio as primary school related uses of mobile phones. They also noted that mobile phone use was more appropriate for middle and high school.

School Mobile Phone Policy

In order to determine if school-related policy on mobile phone usage had an influence on pre-service teacher perceptions on mobile phone use in schools, participants were asked to indicate the type of mobile phone policy at their school. The category of “Use for instructional purposes throughout the day” had the largest number of participants (n=66) with “Not allowed” having the fewest (n=2). Once again, in order to characterize the data, descriptive statistics were generated for each policy type on each of the four questions for the purpose of describing and summarizing the data (Tab. 3). Mean results did not appear to reveal a direct correlation between school policy and participant perception.

For the purpose of testing whether the school policy correlated with participant perception response, based on their experiences in the classroom as a student or as a student teacher, a Pearson Correlation Coefficient was calculated for each set of responses (Tab. 3). While the results of the Pearson Correlation Coefficient did not reveal an overall statistically significant relationship between policy and perception on each question, they did reveal a small correlation between the candidates’ school policy and their response to support mobile phone use (R = 0.302). Participants who attended schools that allowed mobile phone use for instructional purposes showed the greatest level of support for use of mobile phones in the classroom.

Participants were also asked to provide open-ended comments about mobile phones being banned from schools. The majority of respondents cited the inability to manage students’ use and the resulting distraction mobile phones cause in the classroom, including in their personal experience, as their primary concern and reason why mobile phones should not be allowed in the classroom.
I find it very difficult to use cellphones in the classroom because many of the students are not using them in the instructional method that is being asked of them. I believe it serves as a major distraction between the content the teachers are trying very hard to teach. I grew up with it, so I completely agree with it. I've seen cell phone in high school classes and a lot of students don't pay attention.

Additional concerns included lack of security, cyberbullying, and student addiction to mobile phones. Preservice teachers also provide comments in support of allowing phones in schools, again citing professional and personal experiences.

I think cell phones can be highly effective for use in the classroom. I would use them for Kahoot (online, teacher created quiz), calendar, camera for notes or needed things, audio recording when I was sick or a teacher talked too fast. I know that they can be used for other things, but it contributed highly to my knowledge and high school experience. Cell phones and being connected are apart of life in 2018, and I do not feel that it makes sense, or is effective to take away a tool that can be useful in a classroom. In today's society and from personal experience, I was relieved to have my phone in class in the event of many lockdowns. With the ability to have my phone in class, I was able to notify my parents that I was safe as well as being able to find current information about our status during the lockdown.

Additional reasons given for support included student engagement, overcoming barriers like lack of access, and parents’ ability to contact their children. Again, preservice teachers noted that the use of mobile phones in the classroom is more appropriate for middle/high schools and not elementary schools.

Mobile Phone Features for School-Related Work

Eighty-nine percent of the preservice teachers reported using their phones for school-related work. As part of this study, participants were asked to specify how strongly they agree or disagree with specific features of mobile phones for use in the classroom. As with previous questions, in order to characterize the data, descriptive statistics were first generated on each question for the purpose of describing and summarizing the data. Of the 22 listed features, pre-service teachers identified ‘access to the Internet’, ‘use of educational applications’, ‘use of a calculator’, ‘use of a calendar’, and ‘watching videos’ as the five most beneficial applications for classroom usage (Tab. 4).

When descriptive data was delineated by age groups, those 18-29 and those 30+, there was one change in the top five rankings of the features. While participants ages 18 to 29 ranked the top five features exactly as those of the whole group, those thirty years and older replaced “watch a video” \( (m = 3.54) \) with “use clock/alarm/timer” \( (m = 3.57) \) as the fifth highest ranking feature. We found it no surprise those ages 18 to 29 had the same rankings as the whole group since the number of participants in this age range was over four times as large as the number in age grouping of 30 and older.

Once again, for the purpose of testing whether the participant age correlated with pre-service teacher perception response, a Pearson Correlation Coefficient was calculated for each of the top responses (Tab. 5). As in the previous case, the results of the Pearson Correlation Coefficient did not reveal a statistically significant relationship between age and perception of mobile phone usage in the classroom.

Participants also provided open-ended answers to how they use their mobile phones for school related work. Preservice teachers indicated that they use their phones to communicate, with instructors and peers, as well as collaborate on and create course work.

I record student progress and images of completed projects on my phone. I use the Google Docs app for store written papers on my phone which can also be quickly emailed from my phone if need be. I have also used my phone to create a portfolio of all my artwork over the years. I connect with other classmates to share information or work on projects when we are unable to meet in person. I access the internet very often to answer questions or look up new information. I use my calendar to remind me on important dates, when my computer cannot alert me or is not with me. I access my email on my phone.

Participants indicated that regardless of school policy or teachers’ integration of mobile phones, they used their mobile phones to engage in a variety of school related activities.
Discussion
The data suggests that there is a correlation between the age of preservice teachers participating in this study and their perception of the use of mobile phones for school-related work, with younger teachers expressing more favorable perceptions. Results indicated a small correlation between age and preservice teachers’ perceptions of mobile phone use in schools, and while not statistically significant, substantial gaps exist in the level of support between the younger and older participants. For example, fifty-nine percent (m = 3.54) of participants age 18-29 supported the use of phones in the classroom, compared to 36% (m = 2.84) of the participants over age 30. There was a 25% difference in participants’ beliefs that mobile phones support learning: 93% (m = 3.91) of the younger participants in contrast to 68% (m = 3.5) of those 30+ participants. Likewise, 86.8% (m = 4.17) of participants under 30 indicated they would use mobile phones in their classrooms, compared to 68% (m = 3.4) of older preservice teachers. An even greater discrepancy between younger and older participants was demonstrated in their lack of support.

For all but one of the survey questions about mobile phone use, older respondents were twice or more than twice as likely to oppose mobile phones. For example, when asked if they would use mobile phones for school-related work, 40% (m = 3.4) of older respondents indicated that they would not, compared to 8.5% (m = 4.17) of younger preservice teachers. Similarly, 32% (m = 3.27) of older preservice teachers opposed allowing their students to use their mobile phones for school-related work, whereas only 16.3% (m = 3.81) of younger participants did not support student use.

There are several explanations for the discrepancies in support for school-related use of mobile phones based on age. Perhaps the most obvious is the amount of use and degree of comfort younger participants feel with mobile phones. According to Pew (Jiang, 2018), Millennials lead older Americans in their adoption and use of technology. In particular, “more than nine-in-ten Millennials (92%) own smartphones, compared with 85% of Gen Xers (those who turn ages 38 to 53 this year), 67% of Baby Boomers (ages 54 to 72).” While all of the participants in this study owned a smartphone, access has increased over the last decade (Lenhart, 2012; Mobile 2018), affording younger participants access to mobile learning during more of the formative years and formal education. Likewise, mobile phones have seen a tremendous increase in access to the internet (Bauman, 2018) and educational applications (Statista, 2018b) over the last decade. Research indicates that both the internet (Lindsay, 2016) and educational applications (Jeno et al., 2019) support student engagement in m- and self-regulated learning. All of participants identified the use of educational apps and the internet as the top two tools they used on their mobile phones for school-related work; however, participants under 30 were more likely to use these tools than were their older colleagues.

Like age, the mobile phone policy at the schools attended by participants had a correlation with their perceptions on the use of mobile phones in their future classrooms. Preservice teachers who attended schools that allowed teachers and students to utilize mobile phones for school-related work were more likely to support the use of phones in their future classrooms. Furthermore, they were more likely than their colleagues who attended schools that banned mobile phones in the classroom to believe that mobile phones support student learning and indicate that they would allow students to use them in their future classrooms. Over the last decade, the percentage of high schools banning mobile phones has dropped from 80% to 35% (Snyder et al., 2019). In fact, only two (1%) of the 158 participants attended schools that completely banned phones. The majority of participants (n = 66, 41%) attended schools that allowed mobile phones to be used for instructional purposes throughout the day. One explanation for this increase in support from students attending schools that allowed mobile phones in the classrooms is the removal of the primary barrier to integration, school climate (Bitner & Bitner, 2002). Additionally, these preservice teachers had access to instructional models for appropriate instructional integration of mobile phones. Combined with their coursework in their respective TPP, participants observing and interacting with instructional models of integration in their P-12 classrooms could have assisted them in building the necessary knowledge and self-efficacy to use mobile phones in the classroom (Ertmer & Ottenbreit-Leftwich, 2010).

Implications for Practice
The findings of this study have implications for educational stakeholders and the field of teacher education/technology. More than half of the preservice teachers who completed the survey support the use of mobile phones in the classroom, and based on the research, a number of factors may have contributed to their perceptions including access to mobile phones and online content, significant growth in instructional applications, and evolving school policies. However, the school districts where they choose to teach must also see the benefits of incorporating
this technology and allow mobile phones as instructional tools. Further studies are needed to determine the perceptions of school administrators.

Another factor is the age of teachers. Findings indicate a slight correlation between age and perception; older candidates tended to disagree more with the listed uses than younger candidates did. Further studies are needed to determine if this trend will continue. The results of this study may serve as a guide for faculty in educational technology. Teacher education programs should incorporate training in how to manage the appropriate use of technologies such as mobile phones to achieve the benefits of collaboration, engagement, motivation, and achievement. In addition, the results of this study will benefit teacher educators and higher education faculty as they learn to incorporate mobile phones into their curriculum and instruction.

References


Smith, A. (2012). 17% of cell phone owners do most of their online browsing on their phone, rather than a computer or other device. Washington, DC: Pew Internet & American Life Project.


Appendix

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<tr>
<th>Questions 5-8 Responses</th>
<th>N (ages 18-29)</th>
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<th>SD</th>
<th>N (ages 30+)</th>
<th>Mean</th>
<th>SD</th>
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<td>1.060</td>
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<td>Would allow student use for school related work</td>
<td>158</td>
<td>3.72</td>
<td>1.127</td>
<td>129</td>
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<td>Believe cell phones could/do support student learning</td>
<td>158</td>
<td>3.83</td>
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<td>129</td>
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Table 1. Descriptive Statistics for Support for use of Mobile Phones

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<td></td>
<td></td>
<td>Would allow student use for school related work</td>
<td>-0.2485</td>
</tr>
<tr>
<td>Belief cell phones could/do support student learning</td>
<td></td>
<td></td>
<td>-0.2061</td>
</tr>
</tbody>
</table>

Table 2. Correlation: Support Questions and Respondent Age

<table>
<thead>
<tr>
<th>School Policy (n=158) Note: one person did not list a response to school policy</th>
<th>Support Use</th>
<th>Use School related</th>
<th>Allow for School related</th>
<th>Believe support learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not allowed (n=2)</td>
<td>Mean = 3.5</td>
<td>Mean = 5</td>
<td>Mean = 4.5</td>
<td>Mean = 4</td>
</tr>
<tr>
<td>Allowed but must be off (n=15)</td>
<td>Mean = 3.06</td>
<td>Mean = 3.75</td>
<td>Mean = 3.25</td>
<td>Mean = 3.875</td>
</tr>
<tr>
<td>Use before or after school (n=35)</td>
<td>Mean = 2.91</td>
<td>Mean = 3.68</td>
<td>Mean = 3.28</td>
<td>Mean = 3.6</td>
</tr>
<tr>
<td>Use before or after school, changes and lunch (n=30)</td>
<td>Mean = 3.3</td>
<td>Mean = 4.1</td>
<td>Mean = 3.66</td>
<td>Mean = 3.93</td>
</tr>
<tr>
<td>Use for instructional purposes throughout the day (n=66)</td>
<td>Mean = 3.89</td>
<td>Mean = 4.33</td>
<td>Mean = 4.1</td>
<td>Mean = 3.95</td>
</tr>
<tr>
<td>Other (n=8)</td>
<td>Mean = 3.25</td>
<td>Mean = 3.5</td>
<td>Mean = 3.44</td>
<td>Mean = 3.33</td>
</tr>
</tbody>
</table>
School Policy (n=158) Note: one person did not list a response to school policy

<table>
<thead>
<tr>
<th>Support Use</th>
<th>Use School related</th>
<th>Allow for School related</th>
<th>Believe support learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>R = 0.302</td>
<td>R = 0.138</td>
<td>R = 0.219</td>
<td>R = 0.026</td>
</tr>
</tbody>
</table>

Table 3. Descriptive Statistics for School Mobile Phone Policy

<table>
<thead>
<tr>
<th>Top Features for School-Related Work</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>N (Ages 18–29)</th>
<th>Mean</th>
<th>SD</th>
<th>N (Ages 30+)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to Internet</td>
<td>157</td>
<td>4.27</td>
<td>0.710</td>
<td>128</td>
<td>4.44</td>
<td>0.626</td>
<td>29</td>
<td>4.08</td>
<td>0.935</td>
</tr>
<tr>
<td>Watch a video</td>
<td>157</td>
<td>3.85</td>
<td>0.946</td>
<td>128</td>
<td>3.95</td>
<td>0.855</td>
<td>29</td>
<td>3.54</td>
<td>1.272</td>
</tr>
<tr>
<td>Use calendar</td>
<td>157</td>
<td>3.88</td>
<td>0.918</td>
<td>128</td>
<td>3.98</td>
<td>0.937</td>
<td>29</td>
<td>3.77</td>
<td>0.863</td>
</tr>
<tr>
<td>Use calculator</td>
<td>157</td>
<td>3.86</td>
<td>0.949</td>
<td>128</td>
<td>3.99</td>
<td>0.904</td>
<td>29</td>
<td>3.65</td>
<td>1.129</td>
</tr>
<tr>
<td>Use educational apps</td>
<td>157</td>
<td>4.30</td>
<td>0.653</td>
<td>128</td>
<td>4.41</td>
<td>0.616</td>
<td>29</td>
<td>4.19</td>
<td>0.801</td>
</tr>
<tr>
<td>Use clock/alarm/timer</td>
<td>157</td>
<td>3.67</td>
<td>1.004</td>
<td>128</td>
<td>3.75</td>
<td>1.009</td>
<td>29</td>
<td>3.57</td>
<td>1.026</td>
</tr>
</tbody>
</table>

Table 4. Descriptive Statistics for Mobile Phone Features for School-Related Work

<table>
<thead>
<tr>
<th>Mobile Phone Feature</th>
<th>Pearson r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to Internet</td>
<td>-0.279</td>
</tr>
<tr>
<td>Watch a video</td>
<td>-0.194</td>
</tr>
<tr>
<td>Use calendar</td>
<td>-0.128</td>
</tr>
<tr>
<td>Use calculator</td>
<td>-0.194</td>
</tr>
<tr>
<td>Use educational apps</td>
<td>-0.136</td>
</tr>
<tr>
<td>Use clock/alarm/timer</td>
<td>-0.132</td>
</tr>
</tbody>
</table>

Table 5. Correlation: Mobile Phone Usage and Respondent Age
Abstract: One important goal of engaging young students in computational problem solving is to build and assess their understanding of foundational computing concepts. Abstract concepts, such as iterative control flow, are known to be hard for novices, and misunderstandings are common even in block-based programming environments. In this study, we present the instructional design and formative assessment strategies on physical computing platforms that allow learning through hands-on computing media. From our experience working with elementary level students, we have created content materials appropriate to the young learners’ cognitive ability and instructional strategies that are effective in teaching abstract concepts. We have also designed a novel game-based formative assessment method to gain insights into students' learning in a playful and low-stake setting. A case study of a weeklong robotic program for grades 3-5 students is presented to illustrate how these design strategies are applied in the teaching of the abstract concept of loops and how a game-based assessment are utilized to determine student understanding quantitatively.

Background

Programming exposes students to computational thinking that involves problem-solving with computer science concepts (Grover & Pea, 2013; Lye & Koh, 2014). Constructionist pedagogies coupled with block-based environments are currently the dominant approach of teaching computing at the elementary school level. Young students are often encouraged to explore and experiment in open-ended projects on their own (Brennan & Resnick, 2012; Wolber, Abelson, & Friedman, 2015) It is hoped that, as the graphical drag-and-drop blocks remove the obstacle of program syntax, students face a less steep learning curve in mastering computational problem solving compared to traditional text-based environments (Dwyer et al., 2015; Tabet, Gedawy, Alshikhabobakr, & Razak, 2016).

Many computational concepts, however, involve complex cognitive challenges (Garner, Haden, & Robins, 2005; Winslow, 1996). Robins, Rountree, & Rountree (2003) suggests that the teaching of abstract concepts should rely on an explicit focus on building the mental models of a conceptual “notional machine”. While open-ended free-choice projects often work well in motivating interests and creativity, they lack the explicit teaching structure necessary for learners to construct their knowledge and mental models. Block-based languages reduce the syntax burden on the learners. Nonetheless, the semantics meaning of the programming logic, as well as the underlying conceptual model, remains a hurdle for young students.

For example, misconceptions about simple loop iterations are common even in block-based environments. Grover & Basu (2017) shows that 30% of the 100 6-8th students from an introductory programming course using Scratch couldn't correctly trace a counting loop that repeats three times. Another large-scale study of existing Scratch projects shows only 14% of the students have used conditional loops in their program (Aivaloglou & Hermans, 2016), while most of the students’ programs do not demonstrate meaningful use of control flow or logic programming blocks. Teachers and students need effective instructional design strategies and formative assessments to improve the quality of learning. Passey (2017) suggests that the open-ended approach be integrated with more structured instruction. New assessment rubrics and methods have also been adopted to evaluate the learning of computational concepts at elementary and middle school levels (Basu, 2019; Fagerlund, 2018).

Content knowledge assessments evaluate computational thinking in terms of how knowledge accumulates during learning. A common approach uses code analysis, which analyzes students’ open-ended projects through the frequent of use of language construct and the level of sophistication of such use (Basu, 2019). This approach relies on code analysis of student projects, which might be insufficient when students are given scaffolding code. Román-González (2015) uses regular tests to evaluate students’ understanding of certain computational concepts. These
tests resemble traditional programming or algorithm tests, e.g., tracing a code snippet to determine the screen output, and can be stressful for young learners or even detrimental to the overall learning experience. Hadad, Thomas, Kachovska, & Yin (2019) applied formative assessment to guide student’s learning.

Physical computing platforms such as robotics have been widely used in educating elementary and middle school students (Bascou, 2016; Xia & Zhong, 2018). However, research has been limited in the areas of strategies of instructional design and formative assessment on physical computing platforms. Thus, we hope to address the following two questions in this paper:

1. How to use physical media’ capacity to enhance students’ understanding of abstract concepts?
2. How to design hands-on formative assessment with physical computing media to monitor student learning?

Introduction

Toward the goal of improving the learning of essential computational concepts at the elementary school level, it is important to recognize that building computational thinking capacity for young students should not be mistaken as merely teaching them how to code (Tedre & Denning, 2016). The emphasis should not be placed on teaching them how to programming but rather on helping them build computational concepts and problem solving skills. Moreover, being able to complete an open-ended project does not equivalent to a solid conceptual foundation, as shown in recent studies (Grover & Basu, 2017; Grover, Basu, & Schank, 2018). Our experience in teaching elementary students’ computing problem solving indicates that explicit instruction and structured learning activities are effective ways to build young students’ conceptual understanding.

Physical computing involves interacting with physical devices in addition to a screen. Students can build computing artifacts on tangible media such as robotics and micro-controllers, and learn both software and hardware related concepts. Over the past decade, we have designed teaching content and activities for elementary students on a wide range of physical computing platforms, including robotic (e.g., Mindstorms EV3 and VEX IQ), mobile computing (e.g., MIT AppInventor) and micro-electronics devices (e.g., Micro: bit, Circuit Playground and Raspberry Pi). This paper presents some of the strategies we have adopted to teach essential abstract concepts rather than language constructs with physical media. With a theoretical foundation rooted in cognitive load design principles (Sweller, van Merriënboer, & Paas, 2019), our approach focuses on young learners’ cognitive ability so that the instructional design aims to reduce overload associated with learning abstract concepts. Simple programming language constructs are preferred to explain concepts through tangible programming examples. Hands-on computational artifacts, e.g., a piece of circuitry or a robot on physical computing platforms, provide students with a mental “hook” to grasp abstract ideas. Meanwhile, scaffolding helps students engage in deep conceptual understandings, as well as in building a larger project with smaller sub-modules.

This paper also discusses using hands-on formative assessment to monitor student’s learning. The goal of formative assessment is to evaluate student learning in a low-stake setting to provide ongoing feedback that can be used by the teacher to improve their teaching. It is often difficult to assess students’ learning with hands-on devices such as robotics since the underlying computing platform involves both computing software and hardware components. That is, a program needs to be executed on hardware pieces rather than simply producing a result on a computer screen, which makes it more complex to design instruments to evaluate the learning of a particular concept. Moreover, the traditional paper-based assessment could also create additional stress during the learning process. Our strategy is thus designed to alleviate such stress and evaluate students’ learning through a low-stress and game-like approach.

In the following sections, we present our instructional design and formative assessment approach while using a case study to show how these strategies may be implemented. In the case study, we address the challenge of teaching the abstract concepts of loops to elementary school students on the EV3 robotics platform. The quantitative results of our game-based hands-on formative assessment confirm that our three instructional strategies are both developmentally appropriate and effective in student learning.

Instructional Design Strategies

The Neo-Piagetian theory (Knight & Sutton, 2004) has been adopted in the analysis of the cognitive development of novice programmers’ ability to reason about code (Izu, Pope, & Weerasinghe, 2017; Voogt, Knezek, Cox, Knezek, & ten Brummelhuis, 2013) and as guide to map teaching and assessment activities to trance the
development of abstract concepts (Szabo & Falkner, 2014). The Neo-Piagetian framework suggests that the development of programming skills is sequential and cumulative, and novice programmers pass through at least three stages of reasoning behaviors: sensori-motor, preoperational, and concrete operational. From our experience working with elementary and middle school students, we have identified difficulties in teaching abstract computing concepts and problem-solving skills with physical computing media, and designed instructional design strategies that promote skills building through these stages.

**Instructional Design Strategy 1: Focus on Concepts, not Language.**

This strategy focuses on the senori-motor understanding that is foundational to programming. Teaching that leads to strong conceptual foundations should focus on computational concepts, not the program language constructs that implement these concepts. Adams & Webster, 2012; Brennan & Resnick, 2012 have identified seven concept groups on the Scratch platform - sequences, loops, parallelism, events, conditionals, operators, and data. These concepts are universal, but they are implemented as various language constructs across different programming platforms. For example, a conditional loop can be supported by the `while-do` or `do-while` loop language construct in various languages. It is thus important to identify these concepts and present them explicitly, rather than simply covering the language constructs. Knowing how a particular concept is supported natively in a programming environment is also important. For example, Scratch language is a better fit to teach the concept of event handling than in a procedural-oriented environment such as Mindstorms EV3.

Moreover, language implementation options should be limited to reduce the risk of overwhelming young learners with choice overload. That is, the teaching examples and activities for demonstrating a certain abstract concept should be limited to a particular construct, even though there exist multiple ways to implement the same concept through different language constructs. For example, when students are first introduced to a conditional loop, a single loop-related language construct, e.g., `do-until`, is sufficient to demonstrate the concept of conditional iteration. Being exposed to other similar constructs, e.g. `do-while`, `while-do` can be very distractive and confusing to novice learners. Such a limited scope is particularly important for young students so they can establish the correct initial understanding of the basic concept. The teacher must make a careful decision of the abstract concepts as well as the selected language constructs in designing the teaching content.

**Instructional Design Strategy 2: “Tell and Show” Abstract Concepts**

This strategy helps the learner to progress from sensori-motor to pre-operational stage of skill building. Compared to a traditional screen-only programming environment, tangible physical media have the advantage of having young students see and interact with the abstract concepts in the real world. The explanation of abstract concepts should be conveyed with concrete demonstrable examples. These examples should be described with simple language that corresponds to the pseudo-code of the underlying program logic. For example, Figure 1 shows a simple code snippet written to illustrate the concept of `do-while` loop, and this code can be expressed in plain English as “The robot will continue to make ‘Dog Bark’ sound until it sees red color.”

![Figure 1. Code example using a do-while loop.](image-url)
The teacher can then run the code in a visual or tangible context. Here this piece of EV3 code can be loaded into the robotic brick that is connected to a color sensor to show the actual behavior of the program. These types of “Tell and Show” examples provide opportunities for the students to connect the abstract idea to the verbal language and then to the actual embodiment of the execution, thus reinforcing their understanding of how concepts are translated into the behavior of a computing system.

Tangible examples also give teachers a good way to show the bigger picture. Young learners often lack the capability of discovering the connectivity between different conceptual elements. It is necessary to explain how concepts relate to each other to help the students build a complete mental model. An example could be controlling a flashing LED light alternatively using a counting loop and a conditional loop with a simple decreasing counter. Students can visualize the concept of loop controls and also see the relationship between the two kinds of loops such that the former is just a special case of the latter.

**Instructional Design Strategy 3: Apply Scaffolding and Proper Context Management**

This strategy reinforces students’ preoperational understanding and guides them toward concrete operational skills. Hands-on learning can engage students in effective concept building only when the cognitive demand originated from the highly complex programming and construction activities are properly managed. Reducing cognitive overload is crucial on physical computing platforms since dealing with multiple types of media stimulus, e.g., sound, image, or physical media, may potentially cause a level of cognitive load that interferes with learning. A general instructional approach to alleviate this problem is scaffolding (Van Merrienboer, Kirschner, & Kester, 2003), and we extended from this approach in teaching computational concepts in terms of different stages of learning and different learning objectives. During the early stage of learning, scaffolding can direct young students to work on activities in a focused context - start with more straightforward examples and progress to more sophisticated versions of activities within the same context. For example, adding more logic into an if statement or a conditional loop.

As students move on to increasingly complex activities in a larger project, scaffolding also allows students to build modular pieces of some sub-tasks, and then integrate them together, such as the building of different structure modules of a robotic. These sub-tasks should be sequenced in a way that introduces a minimal number of changes in the learning context. For example, activities on the physical computing platform may have different subtasks relative to software programming, hardware construction, or both. Desirable activity sequencing is to have similar tasks in the same context grouped in a chuck, such as completing the building of a LED light connection. As the students work on a larger chunk of work in the same context, students can avoid the number of context switches that cause distraction and cognitive overload.

**Instructional Design - A Case Study**

Our instructional strategies are suitable for designing a wide range of computing curriculum for elementary students on different computing platforms, e.g., robotics, physical computing, and mobile computing. This case study shows an example of teaching the concept of loops on the Mindstorm EV3 platform, in a setting of a weeklong summer camp. The notion of control flow is among the most foundational computational concepts. We identify three types of loops to be covered - infinite loops that repeat a set of instructions forever, counting loops that repeat a given number of times, and conditional loops that iterate based on a logic condition. Compared to both infinite loops and counting loops, conditional loops have more expressive power and are, potentially, much harder to learn. Applying our design strategies, we create structured learning activities with scaffolding to help 3rd-5th graders learn three types of loops - infinite, counting.

A simple robot with several input sensors is pre-constructed so students can focus on learning computational concepts rather than building with the blocks. Although the EV3 environment provides several options to implement loop iterations, the instruction is limited to only the do-until loop block that repeats the instructions, as long as the break condition is not satisfied. Moreover, the do-until block consists of a broad range of possible logic conditions (i.e., a total of 16 different conditional types supported on EV3), and only a limited set of condition types is included. These two restrictions allow students to be focused on the essential concept and not get overwhelmed by the language constructs.

The tangible robot is an excellent media with which to demonstrate abstract computational concepts. For example, the concepts of infinite and counting loops can be explained with a robot that repeats the specific motion. A
conditional loop uses a logic condition to control the repetition, and this condition must be carefully selected so the program can implement interesting robotic behaviors, but still not be too complex for young students to comprehend the concept. For example, one can set the logic condition of a do-until loop to the input of a color sensor, which allows the students to observe how a robot "does" the driving "until" it sees a specific color.

While learning more difficult concepts, students benefit from scaffolding in a focused subject matter. For example, students are provided with examples to understand how conditional loops work. Figure 2 (a) shows an infinite loop followed by a simple conditional loop that makes the robot move left and right for 5 seconds. Figure 2 (b) shows a later activity that requires students to test in what ways a more advanced condition using the color sensor input works to control the sound of a T.Rex roaring sound. These activities build students' content knowledge in the specific concept of loops through scaffolding.

![Figure 2. Scaffolding of learning activities to teach the concept of loops: from infinite loops to conditional loops.](image)

Scaffolding is also integrated to help students apply their knowledge in problem-solving. In this case, modular pieces of sub-tasks are first given as warm-up exercises. Students then incorporate these modules into a larger task. For example, several mini-projects are designed to help students practice their understanding of how to apply loops in different settings. Students practice with "mini-tasks" that required them to solve a problem using simple conditional loops individually.

Sample Mini-task 1:
Let the robot move forward and stops 5 inches in front of an obstacle.

Sample Mini-task 2:
The robot starts in a stop position. Whenever the robot sees something close up, it will back up and stop to maintain a distance of 5 inches.

Students then apply these sub-modules to more complex projects such as a maze track where the robot needs to be programmed with loops to navigate the path and avoid obstacle walls.

**Game-based Formative Assessment**

The goal of formative assessment is to monitor student learning to provide ongoing feedback during instruction. More specifically, formative assessments help the teacher to recognize where students are struggling and address
problems immediately. Formative assessment is particularly helpful in teaching computing concepts on physical computing devices. However, effective learning assessment is nontrivial since the learning process is highly integrated with both programming and hardware topics.

Our novel assessment strategy is designed to assess students’ understanding of abstract computational concepts through game-based activities. This approach focuses on how to isolate the target concepts within an integrated system for the assessment and on how to create a gamified instrument suitable for young students. Such an assessment instrument utilizes the multi-media or physical features of a computing platform, assess young students through their interaction with tangible physical artifacts. For example, students may be asked to identify which of a robot’s pre-load movement corresponds to a given type of loop among several choices. This approach can effectively evaluate individual students’ knowledge of a particular topic while maintaining their interests through playful interactions. The design of such an assessment consists of the following three steps.

Step 1 – identify the target computing concepts
Step 2 – identify supporting physical components
Step 3 – refine and gamify the instrument

Such a game-based approach is designed for assessing students’ learning of abstract concepts in a low-stake setting. This allows teachers to gain insight into the students’ understanding and learning difficulties while reducing the stress that is often associated with traditional content knowledge assessments. These steps of designing a formative assessment are applied in the following case study using the EV3 robotic platform.

Formative Assessment – Our Case Study Continued

Continuing our previous case study, we present the assessment of elementary students' understanding of abstract computing concepts – the control flow logic. Three types of loops are included - infinite loops that repeat a set of instructions forever, counting loops that repeat a given number of times, and conditional loops that iterate based on a logic condition from sensor input. Compared to both infinite loops and counting loops, conditional loops have more expressive power and are known to be much difficult. Students were only introduced to the "do-until" loop block using our instructional design strategies discussed previously.

Assessment Design Process

Step 1 - Identify Target Concepts
We first target concepts or skills to be measured and developing assessment arguments targeting the loop concept-related items as
- Identify the repeating pattern within a single counting loop
- Identify the continuous pattern within an infinite loop
- Identify that a conditional loop will terminate under a specified condition
- Describe what a given loop is doing
- Describe how to using sensor input as the conditions to control the repetition of a loop

Step 2 - Identify Supporting Physical Components
Once the target concepts are identified, we design the required peripheral supporting components for the assessment. In the EV3 robotic environment, the supporting components for assessing these concepts including the EV3 brick, sensors, motors, etc. We design a standard base bot as the supporting component. This robot includes motors for movement, a color sensor facing down, and an ultrasonic sensor facing forward. All motor sensors are connected to standard ports on the brick. Show the image of robots.

Step 3 - Refine and Gamify the Instrument
Initially, the instrument is designed as the traditional code-tracing style question. A set of block-based code written with the variation of the three loop types are loaded on the robotic brick, and students are asked to run the program and match it to its corresponding code snippet. However, unlike paper and pencil based code tracing commonly used in traditional programming environments, our assessment involves running the code physically on the robotic hardware system.
Considering the age factor of our participants and the nature of formative assessment, we continue to refine the assessment and add the game element. Instead of original multiple-choice tracing questions, we design a find-the-match activity. Each student is given a standard pre-built robot, which is pre-loaded with short programs constructed with two groups of loops - one group for infinite and counting loops, and the other group for conditional loops. Students run the program on the robot to observe its behavior, and then try to match the robot’s behavior to the corresponding block-based program code printed on paper. In the end, the assessment turns into a game that can be played with individual students or students in groups. Figure 3 shows four of the short programs used in the assessment.

![Game-based assessment of the concept of loops - four sample programs used in the find-the-match game.](image)

**Using the Assessment**

Forty students in grade 3-5 participated in a week-long summer program designed to teach introductory programming concepts on the LEGO Mindstorms EV3 environment. No prior programming experience was required to enroll in the classes. This assessment was conducted after the module on the loop concepts. In addition, a paper-and-pencil questionnaire consisting 6 multiple-choice questions on loops is given to the students in order to evaluate the validity of the game-based assessment.

The quantitative results from the game-based assessment indicate that students demonstrated a good understanding of infinite and counting loops. Eighty-eight percent of the 40 students found all the matches correctly in the first six-question group, with a mean score of 5.68 out of a max score of 6. Students’ performance on the question group for conditional loops was much lower: only 20% of students correctly answered all questions, with a mean score of 3.18. The Wilcoxon test was used to determine the score difference between the two groups. A significant statistical difference between them (p-value = 4.17e-10) resulted.
Discussion

The formative assessment results of the case study indicate very positive results in teaching elementary-aged students the basic concept of loops using our instructional design strategies. Compared to the 30% of the 100 6-8th students who could not correctly trace a counting loop that repeats three times (Grover & Basu, 2017), 88% of the younger 4-5 graders in our program were able to demonstrate the correct understanding of infinite and counting loops. Instructional time related to the subject was approximately 4-5 hours spread over the five days. Results indicate that young students were able to increase their content knowledge of the basic computational concepts over a short period of time, even with limited prior experience in programming. On the other hand, concepts like conditional loops are significantly harder to learn. It is not surprising that young students have much more difficulty grasping the concept compared to the two more straightforward loop types.

The assessment results suggest that abstract concepts such as the logic condition and conditional loops could be beyond the abilities of this age group. The case study also indicates that our game-based assessment approach produces consistent results compared to the traditional paper-based instrument. We have also observed during the assessment that students had a more positive attitude toward the “find-the-match” game and were more excited to complete the tasks compared to taking the paper-and-pencil questionnaire. These results can help the teacher to evaluate student learning in a low-stake setting.

Conclusion

Learning abstract computing concepts is essential in forming a conceptual foundation transferrable to other programming environments. The contribution of our work includes strategies for instructional design and formative assessments that can effectively build elementary students’ understanding of abstract computing concepts. A case study of teaching the concept of loops on a robotic platform is presented to show how practices based on our approaches are used in non-formal settings over a short weeklong program. Through the usage of a hands-on physical computing platform with a small set of language constructs, abstract concepts can be explained through tangible programming examples. The technique of scaffolding is applied in different contexts. This not only allows students to build their understanding of a specific concept over a progressive sequence of activities, but it also helps students solve more complex tasks using smaller modules. The game-based formative assessment is user-friendly and provides insights into students’ learning of abstract concepts. The results of our case study indicate that, while some elementary students can grasp some simple abstract concepts well, specific concepts, e.g., conditional loops, are difficult for young learners likely due to their limited cognitive capacity. It is thus crucial for teachers to identify such concepts and consider their appropriateness in earlier grades. Subsequent research on additional computing platforms and the

Figure 4 shows the score distribution for the two test groups - the infinite and counting loop test group vs. the conditional loop test group, with the score of each question ranging between 1 – 6.

The findings from the game-based assessment are consistent with that from the traditional paper-and-pencil assessment, in which 80% of students correctly answered the infinite loop and counting loop questions, while 18% of students answered the conditional loops questions correctly.

Figure 4. Game-based
A game-based assessment approach is necessary to evaluate our design strategies in improving students' computational competence beyond content knowledge.

References


Mapping Identity Exploration of Science Careers using Epistemic Networks

Amanda Barany  
Aroutis Foster  
Drexel University School of Education, United States  
amb595@drexel.edu  
aroutis@drexel.edu

Abstract: This paper reports findings from a research project designed to test and refine Projective Reflection (PR) as a theoretical and methodological framework for facilitating learning as identity exploration in virtual learning environments. PR structured the design, implementation, and refinement of three sessions of Virtual City Planning, a play-based course that supported the exploration of environmental science identities mediated by a virtual learning environment (Philadelphia Land Science), and supportive classroom experiences. Epistemic Network Analysis was used to visualize different processes of identity exploration enacted by each session. Visualizations of class data by time period illustrated similar trajectories of identity exploration across sessions as an increase in personal interest and valuing of the domain over time, while paired-sample t-tests found chronological differences to be statistically significant across all sessions. Results develop theoretical knowledge of the ways virtual learning environments can support both identity exploration and the future acquisition of science careers, and illustrate the value of epistemic networks for illustrating identity exploration processes over time.

Introduction

Educational research has increasingly emphasized ways to develop learner skills in identity exploration, or a student’s “deliberate internal or external action of seeking and processing information in relation to the self” (Kaplan, Sinai & Flum, 2014, p. 250). This process of self-directed learning can promote identity change in targeted directions over time, such as taking steps to attain a future career in science, technology, engineering, or mathematics (STEM) (i.e. Foster, 2014). Curricular interventions that support learning as identity exploration are therefore of particular value in a 21st century context in that they can support adaptive skill development and career preparation for emerging and under-accessed STEM careers (Callahan, Ito, Campbell, Wortman & Wortman, 2019). Facilitating identity change toward STEM careers among underrepresented minorities becomes an even more pressing imperative, given workforce statistics that illustrate limited gender and racial diversity in these fields (US Congress Joint Economic Committee, 2012).

Games and virtual learning environments have been increasingly identified and researched for their potential to support 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, theoretical and pedagogical frameworks are vital to inform the use and design of virtual learning environments (Mikropoulos & Natsis, 2011; Fowler, 2015). The intentional design and inclusion of real-world supportive classroom curricula (Hanghøj, Lieberoth & Misfeldt, 2018) also remains a necessary and important feature. Finally, emerging research on games and identity exploration will benefit from the use of methodological approaches that can illustrate the nuances of student identity exploration as it unfolds across a designed game-based learning experience.

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 that can be found in many games and game-based learning environments (Foster, 2014). PR was used to design three consecutive iterations of a Virtual City Planning (VCP), a course that leveraged a virtual learning environment (Philadelphia Land Science) and supportive in-class curriculum to promote identity exploration of urban planning and environmental science careers. VCP was implemented in a museum classroom context with a diverse sample of high school students (N=57). This paper examines group identity exploration trajectories over time in VCP sessions 1-3 using Epistemic Network Analysis, which is a quantitative ethnographic technique of modeling the structure of connections in student data. Findings (a) illustrate how VCP1-3 supported statistically significant shifts in
student conceptualizations of self over time as defined by PR and (b) reveal similarities and differences in how identity exploration was supported and enacted in each session. Implications of these findings for games and education practitioners, designers and researchers are discussed.

The research question asks: What is the nature of students' processes of identity exploration over time (as defined by Projective Reflection) in sessions 1-3 of Virtual City Planning?

Games and Identity Exploration

Digital environments such as video games have designed potential to expand participants’ social networks and help them perform and develop specific identities (Gee, 2000; Merchant, 2001). Shaffer (2006) posits that learning to think like a member of any given profession first requires learners to learn to think of themselves as members through reflection in action (Schön & Rein, 1994). For example, epistemic games, which include complex, non-routine problems solved through authentic professional practice (Bagley & Shaffer, 2015) have been found to support identity change by encouraging increasing individual affinity for the social identities within that community of practice (depersonalization) (Arastoopour & Shaffer, 2013). Becket and Shaffer (2005) also examined eleven high school students’ experience using a designed augmented reality environment, and found that participants deepened their understanding of the complexity and interdependence of variables in ecological systems and were able to connect the authentic virtual experiences to their real-world contexts.

Immersive virtual environments such as games can also afford opportunities for shaping students’ long-term interests in academic or career-specific domains. As semiotic spaces (Gee, 2005), games can shape identity exploration and change processes by providing socially safe spaces for players to explore new roles (Squire & Barab, 2004; Steinkuehler, 2004), and can connect in-game activities to real-world meanings to foster increasing personal relevance of a domain (Foster, 2008; Silseth, 2012). Miller and colleagues (2011) demonstrated these processes through their formal learning implementations of the game CSI: The Experience with over 700 middle school students in a repeated measures mixed methods study, which illustrated how the designed game experience offered authentic professional play that not only developed students’ science content knowledge, but allowed players to explore identities and develop interests related to forensic science careers.

Despite the affordances of games, few empirically tested theories currently exist to operationalize processes of identity exploration along the complex, interconnected, and evolving cognitive/affective features related to learning and self. Research on games and identity has addressed this gap through the use of the Projective Reflection theoretical framework to structure assessments of student identity exploration. For example, studies of classroom interventions using commercially-popular games illustrated how game-based learning experiences can be designed to optimally support identity exploration and change if the affordances and constraints of a game environment are first assessed and then supplemented using external curricular activities (Foster & Shah, 2015; Shah, Foster & Barany, 2017).

Methodological approaches are consequently needed to complement emerging theories such as Projective Reflection by structuring assessment of learning as identity exploration in game-based interventions. Quantitative ethnography (Shaffer, 2017) offers one valuable method for exploring patterns of activity nested in situated discourse. Quantitative ethnographic techniques such as Epistemic Network Analysis (ENA) involve the quantification of qualitative data to generate visualizations that can represent the associations individuals establish across a network of constructs (i.e. identity exploration constructs). ENA has previously been used to characterize what players learn from gameplay in terms of knowledge, skills, values, and habits of mind (Shaffer, Collier & Ruis, 2016), further highlighting the potential of this methodology for illustrating processes of identity exploration as they are enacted by learners using games or virtual environments in formal learning settings.

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 virtual learning environments, with the potential to engage in domain-specific self-transformation over time (i.e. environmental science and urban planning) (Foster, 2014). 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 (see Table 1). Conceptual definitions for each of the four PR constructs were developed from reviews of literature on 21st century learning, motivation, self-regulation, and identity.
<table>
<thead>
<tr>
<th>PR constructs</th>
<th>Definitions</th>
<th>Sample literature</th>
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</table>
| Knowledge          | Shifts in what a player knows about environmental science, urban planning, and urban planning systems from the beginning to the end of an intervention:  
  ● *Foundational knowledge*: awareness of complex and domain-specific content and processes that includes the ability to access information using digital technologies  
  ● *Meta-knowledge*: awareness of how to use foundational knowledge in relevant socially situated contexts  
  ● *Humanistic knowledge*: awareness of the self and one’s situation in a broader social and global context | Kereluik, Mishra, Fahnoe & Terry (2013)               |
| Interest and valuing | Caring about environmental science and urban planning issues and viewing them as personally relevant or meaningful  
  ● Shifts in identification with environmental science  
  ● Viewing environmental science/urban planning as relevant to the community or world  
  ● Seeing the need for environmental science for self and for use beyond school contexts | Wigfield & Eccles (2009)  
  Hidi & Renninger (2006) |
| Self-organizatio n and self-control | Shifts in behavior, motivation, and cognition toward a goal:  
  ● *Self-regulated learning*: goal setting and goal-achievement conducted independently  
  ● *Co-regulated learning*: regulation processes supported by more knowledgeable real/virtual mentors  
  ● *Socially shared learning*: regulation is socially negotiated in collaboration with peers | Vygostky (1934/1986)  
  Hadwin & Oshige (2011) |
| Self-perceptions and self-definitions | Shifts in how a participant sees herself in relation to (environmental) science:  
  ● *Self-efficacy*: confidence in one’s own ability to achieve goals and future roles  
  ● *Self-concept*: awareness of current aspects of self (i.e. skills, preferences, characteristics, abilities, etc.)  
  ● Specific roles one wants or expects to become in future | Kaplan, Sinai & Flum (2014) |

Table 1. Projective Reflection constructs to frame identity exploration and change in science games

The Play, Curricular activity, Reflection, Discussion (PCaRD) pedagogical model offers one way to design and implement a virtual learning environment that supports targeted, intentional, and situated student reflection on aspects of their identities as they shift through engagement with the game and curriculum. 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 virtual environment. These curricular augmentations draw upon students’ academic, personal and in-game knowledge and experiences to make the identity exploration personally relevant to each student (Silseth, 2012).

To assess learner identity change over time, researchers and educators may leverage the four PR constructs as an analytical tool to compare a learner’s starting self at the beginning of a designed experience to their new self at the end of the experience. Processes of identity exploration as defined by Projective Reflection are most valuable when students can enact them in an integrated fashion. In VCP, integration increases when students can begin to regularly connect their Knowledge gains, emerging personal Interests and Values, the enactment of Self-organization and Self-control strategies, and specific Self-perceptions and Self-definitions related to urban planning and environmental science. Given that identity exploration is conceptualized as a developmental process of change over time, it is vital to examine identity integration as not only co-occurrences in a single piece of student data (integration in that moment), but also as a longitudinal relationship between the way a student conceptualizes her “self” in one moment to the next across a meaningful unit of time (the course). As such, Epistemic Network Analysis is a valuable tool to visualize the intricate longitudinal relationships that emerge between PR constructs as students are encouraged to enact identity exploration of environmental science careers over time.
Methodology

This research was conducted as part of a 5-year NSF CAREER project awarded to develop theory and research on promoting student exploration of science identities using game-based learning experiences (Foster, 2014). Researchers designed and implemented three iterations of Virtual City Planning (VCP), which featured weekly use of the virtual environment Philadelphia Land Science (PLS) and supportive real-world curricular activities (see Foster, Shah, Barany & Talafian, 2019). Fifty-seven Philadelphia high school students participated in VCP1-3 from September, 2016 to May, 2017. Students were selected for participation by a science museum that coordinated weekly STEM career-related opportunities. Design-based research (Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003) informed the development and implementation of VCP1-3 to (a) develop analogous urban planning experiences given different course lengths offered by the museum and (b) refine game and curricular design to more comprehensively support student identity exploration. Though each iteration provided an analogous chronological student experience, (1) VCP1 relied heavily on the use of PLS with fewer external augmentations, (2) VCP2 balanced the use of PLS and external augmentations, and (3) VCP3 relied almost entirely on in-class gamified activities (for more information on VCP design choices and iterations, see Barany, Foster & Shah, in press). Design changes made from VCP1 to VCP3 are summarized below.

<table>
<thead>
<tr>
<th>Course context</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-week course</td>
<td>Weekly 90-minutes</td>
<td>Weekly 90-minutes</td>
<td>4-week course</td>
</tr>
<tr>
<td>● Iteration 1 of VLE</td>
<td>● Iteration 2 of VLE</td>
<td>● Weekly 90-minutes</td>
<td></td>
</tr>
<tr>
<td>● Primarily virtual activities</td>
<td>● Balance between virtual and in-class activities</td>
<td>● Short class – no VLE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Classroom activities offer analogous experiences</td>
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</table>

| Philadelphia Land Science (PLS) Setting of PLS matched to player context: | Session 2 changes: | PLS not implemented |
| ● Stakeholder groups champion city issues | ● Game structure streamlined (i.e. third round of virtual design replaced with in-person discussion) | ● Paper-based collaborative in-class activities designed to replicate process of designing a city design proposal (see below) |
| ● More diverse nonplayer characters | ● Game narrative simplified (i.e. text revised for clarity) | |
| ● Environmental/ economic issues match real-world | ● PLS use limited by connectivity issues; increased reflection, discussion, collaboration | |
| New identity exploration opportunities: | | |
| ● Written self-reflections | | |
| ● Pre/post survey | | |

| Curricula For Sessions 1-3, students, preservice teachers, and mentors met in museum space; one-to-one laptops | More in-class augmentations: | Expansion of existing activities: |
| ● Mentors roleplayed as urban planners for socially shared and self-regulation | ● Ex. players redesign the city based on their own interests and values using paper maps | ● Ex. students a) designed individual paper maps based on their interests, and b) negotiated city design in small groups on poster-sized maps |
| ● Virtual chat replaced by in-person roleplay, collaborative city design in professional meetings | ● Ex. room was divided by tapelines, economic/environmental issues read aloud; students stepped left/right from neutral center based on values | In-class curricular activities added to mirror VLE city zoning proposal: |
| ● Curricula informed by PCaRD (i.e. mentors led reflection/identity discussions) | ● Personalized work binders with paper resources, notes, records of growth | ● Ex. students read about issues, generated questions, researched answers |

Table 2. Summary of design changes from sessions 1-3.

In VCP, groups of students were synchronously guided by online and in-person mentors to change zoning districts applied to downtown Philadelphia. As structured by the PCaRD model, each weekly class involved one or
more periods of uninterrupted play. Using the virtual learning environment *Philadelphia Land Science* (Sessions 1 and 2) and analogous paper map design activities (Sessions 1-3), students role-played as urban planning and environmental science interns in a fictional design firm. They learned about the process of creating a rezoning proposal for the city of Philadelphia that addresses the competing and complementary needs of citizens. Students researched specific environmental and/or economic needs of the city as advocated by a single stakeholder group, then rezoned the city to best meet the needs of that group. In later weeks, students were jigsawed to include at least one student representative for each stakeholder group to design a new plan that met the needs of all groups. This simulated the real-world scenario of multiple interests and expertise coming together to address social issues.

Real-world curricular augmentations were designed to leverage affordances of classroom context to further support identity exploration. For example, museum staff asked students to wear lab coats and act as science professionals, so researchers role-played as urban planners to more immersively support individual, small group, and large group reflection and discussion. Another class activity involved group negotiation of city zones on paper maps that allowed learners to reflect on their values and discuss zoning merits with peers (See Figure 1).

![Figure 1. The city design tool in Philadelphia Land Science (left) and in-class supportive roleplay (right)](image)

**Data Collection**

Qualitative and quantitative data was obtained through in-game (e.g. written reflections as urban planning interns) and classroom artifacts (e.g. survey responses). Text data was organized chronologically for each student to track changes in identity exploration processes from beginning to end of VCP. After each class, researchers collaborated to write detailed memos of interactions with students; memos were segmented by discussion of student and organized chronologically in each individual’s data file. Player data was collected 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 *PLS*, framed as professional emails to the design firm.
- Written posts made on an online forum website as a curricular activity.
- Written researcher memos on student interactions, discussions, and activities.
- Screenshots and images of student map designs, from the virtual internship tool and from in-class design activities using paper maps. Images were examined for qualitative analyses but not ENA.

**Data Analysis**

Once data collection and organization was completed, researchers then engaged in a deductive or directed coding process for each case (Krippendorff, 2004) in which each line of data was coded for self-reflection on or demonstration of one or more aspect of identity exploration (as defined by PR), with agreement reached by two graduate-level coders. Lines were coded for the occurrence (1) or non-occurrence (0) of the four PR constructs to prepare for visualization of identity exploration patterns using Epistemic Network Analysis (ENA). For example, a student’s reflection reading, “the big ones [issue] I care about is pollution,” was coded (1) for interest and valuing.
We applied ENA (Shaffer, 2017) to our data using ENA1.5.2 Web Tool. ENA is a quantitative ethnographic technique for visualizing the connections between constructs. ENA assumes: (1) that it is possible to systematically identify meaningful features in data (codes); (2) that the data has local structure (conversations); and (3) that an important feature of the data is the way that codes are connected to one another within conversations (Shaffer et al., 2016; Shaffer and Ruis, 2017). For example, a single piece of student data (written, observed) may be representative of individual change in one or more codes (the four PR identity constructs).

ENA generates network visualizations of the co-occurrence of codes within a moving stanza window, which means that codes applied to one line of student data are connected to each other and to codes applied to the previous 3 lines of chronological student data (as recommended by Siebert-Evenstone et al., 2017). This process is appropriate given the conceptualization of identity exploration as a developmental process of change. Epistemic networks for code relationships were generated for the first half (Time 1) and second half (Time 2) of class for VCP 1-3 to explore how student identity exploration shifted over time as supported by each iteration. ENA also analyzes all chronological networks simultaneously so that they can compared visually and statistically. To achieve this, ENA models normalize the networks for all units of analysis before they are subjected to a dimensional reduction, which accounts for the fact that different units of analysis may have different amounts of coded lines in the data (see Shaffer et al., 2016). Epistemic networks were generated for Time 1 and Time 2 for each session to compare differences and similarities within and across them over time. In addition, paired-samples t-tests were completed to test whether changes from Time 1-2 in each session were statistically significant along the X and Y axes. The results also reference themes we identified from qualitative studies of the data (i.e. Foster et al., 2019) to close the interpretive loop and provide deeper understand the phenomena visualized in the models.

Findings and Discussion

To answer the question “What is the nature of students’ processes of identity exploration over time (as defined by Projective Reflection) in sessions 1-3 of Virtual City Planning?” the overall centroids (mean association of constructs) for Session 1-3 are presented as squares to illustrate design or cohort differences across sessions. The different locations of the 3 summary means for sessions 1-3 are illustrative of differences between cohorts in terms of how they enacted their identity exploration processes (which may have been influenced by some elements of curricular design). Figure 2 serves as a map for interpreting the direction of mean differences by session. For example, compared to the overall means for Sessions 2 and 3, the overall mean for Session 1 is skewed toward the Knowledge construct and the Self-organization and Self-control construct, suggesting that students in Session 1 more regularly discussed or demonstrated knowledge-related growth and reflected intentionally on their regulation strategies. This finding is supported by prior examinations of the curriculum elements in VCP1, which featured more student use of the virtual city zoning tool and more reflections on their emerging understanding of the role through professional emails. For example, there were a greater number of ‘professional email’ prompts in Session 1 that prompted students to synthesize or summarize the activities they completed each week (i.e. researching a stakeholder, map design negotiation with peers, etc.). This encouraged writing in which students used their emerging knowledge of urban planning to describe their design process and reflect on strategies for success.
Figure 2. Network centroids (mean of construct associations) by overall session (square). The positions of each centroid can be interpreted in relation to each other using the location of the four Projective Reflection constructs as a visual map. Arrows are included to help illustrate directionality of difference by session. For example, compared to Session 3, Session 2 students made more connections to self-perceptions and self-definitions.

Characteristics of the cohort of students also had potential to shift the overall mean of a session. For example, a qualitative review of Session 2 student data revealed that more members of this group were able to explicitly discuss their self-perceptions and self-definitions as they related to their urban planning identities over time. For example, Bethany reflected early in the session that this was the first time she had been prompted to think about future careers or roles, while students such as Mateo were thinking about looking for jobs near the end of the course itself or potentially after, while others remained unsure of what future roles they might pursue, but did not rule out urban planning. Students such as Elijah recognized how urban planning was valuable topic for him to understand as a future business owner. While the ways in which students in Session 2 described their self-perceptions and definitions differed in content, the group was more able to explicitly engage in reflection and discussion on the topic, as demonstrated by the skewing of the Session 2 overall mean toward this construct.

The overall mean for Session 3 is more centrally-located than those for Session 1 and 2, which suggests that students' discussions of and connections to the four PR constructs may have been enacted in a more balanced or integrated manner. Quotes like the following from Emil (pseudonym) suggest that students were able to more readily connect emerging knowledge, strategies for success (i.e. self-organization) and self-perceptions/definitions as active participants for change over time: “I’m very scared for the health of not only our city, but our planet. We destroy natural ecosystems to create businesses and heat up the Earth just to run our cars. I’m hoping by adding more green open spaces, we will create a better Philadelphia.”

Centroids for Time 1 and Time 2 for each session (circles) are presented in Figure 3 to illustrate chronological trajectories of identity exploration enacted by each cohort over time. An examination of shifts in mean positionalities from Time 1 to Time 2 for each session reveal striking commonalities with regard to the trajectory of identity exploration that students enacted over time. Movement from Time 1 to Time 2 across the X axis can be understood from a visual examination of the network means as a universal shift across sessions toward deeper and more frequent student connections to their interest and valuing around urban planning and environmental science careers. This shift in means towards the Interest and Valuing construct suggests that regardless of differences in cohort or in the design and implementation of VCP, each iteration of the course encouraged deeper, more frequent, and more integrated student reflections on the value and relevance of urban planning and environmental science roles for themselves and their communities, as well as usefulness of the science domain across a variety of contexts and identities. This shift is evidence that virtual environments and supportive curricula whose design was informed by Projective Reflection can support domain-specific identity exploration as Kaplan and colleagues (2014) defined it: the “deliberate internal or external action of seeking and processing information in relation to the self” (p. 250). This change is evident in the final reflections of students such as James, who wrote that “My interest in learning about my Philadelphia's
environment is really [of concern], because I live here and it's not a pretty site to live in quite frankly, and I think that 
should change,” and of Ali, who wrote “i can see myself being a construction worker, on the urban planning things 
that i know that i can change, it would be easy for myself to create the open space for the people in my neighborhood.”

**Figure 3.** Network centroids (mean of construct associations) by overall session (square) and by time period (circle). 
The positions of each centroid can be interpreted in relation to each other using the location of the four Projective 
Reflection constructs as a visual map. Arrows are included to help illustrate directionality of change. For example, 
compared to the Time 1 centroids, Time 2 centroids are all positioned closer to the Interest and Valuing construct, 
suggesting that students made more connections to their interests and values in the second half of each course.

To determine whether student changes from Time 1 to Time 2 were statistically significant for each session, 
three paired-samples t tests assuming unequal variance were conducted between the X and Y axes of Time 1 and Time 2. 
Along the x axis for each session of VCP, a two-sample t test assuming unequal variance showed that Time 1 was 
statistically significantly different from Time 2 at the alpha=0.05 level. Along the y axis for each session of VCP, a 
two-sample t test assuming unequal variance showed that Time 1 was not statistically significant from Time 2 at the 
alpha=0.05 level (See Table 3). ENA typically maximizes variance across one axis, so statistical significance across 
the X-axis is representative of the full extent of each cohort’s change. This suggests Sessions 1-3 encouraged student 
connection-making processes (i.e. identity exploration) that were different to a statistically significant degree from the 
beginning to the end of each intervention, serving as a testament to the potential of the course for promoting valuable 
changes in learners’ conceptualizations of self in relation to environmental science over time.

<table>
<thead>
<tr>
<th>Session</th>
<th>X-axis</th>
<th></th>
<th></th>
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Table 3. Paired sample t-test statistics.
Conclusion and Implications

Results illustrate the utility of educational experiences designed to facilitate Projective Reflection (Foster, 2014) and the Play Curricular activity Reflection Discussion (PCaRD) model for supporting students’ increasingly-integrated processes of identity exploration related to STEM domains (i.e. environmental science and urban planning). Curricular designs that emphasize synthesis of activities performed may be more likely to encourage reflection on emerging knowledge and self-organization and self-control strategies (as demonstrated in Session 1), and individual cohorts’ affinities for a desired career or role (such as the high affinity for environmental science in Session 2) can influence the capacity of the group to reflect more frequently or meaningfully on the identity explored in the course. Though characteristics of a specific designed experience or student cohort may result in some differences in the overall identity exploration process, trajectories of identity exploration over time manifested as increasing and statistically significant change toward student discussions of their interest and valuing of a topic. Over time, students used science knowledge to achieve personally-relevant learning goals in the situated environment, and demonstrated more detailed awareness of the relevance and value of the topic for themselves in the present and future. Given these findings, designed virtual learning environments such as Virtual City Planning serve as particularly valuable avenues for promoting the exploration (and potential future acquisition) of STEM identities across a more diverse group of students based on the capacity of such environments to adapt to individual and contextual needs and connect learning to the self. While this work illustrates general trends by session in terms of design, cohort and identity exploration over time, further work is essential to help identify which specific features of curricular design (such as the use of Philadelphia Land Science) contribute to situated, targeted, and intentional processes of identity exploration across the four Projective Reflection constructs. Findings suggest that Session 3 promoted the most balanced processes of identity exploration processes in learners, though whether this is a result of iterative refinements, cohort features, or shifts in the mode of receipt (virtual versus analogous in-person activities) warrant further inquiry.

Quantitative Ethnographic (QE) (Shaffer, 2017) techniques such as Epistemic Network Analysis (ENA) (Arastoopour et al., 2015) served as a valuable and innovative approach for understanding whole-group trajectories of identity exploration as operationalized by Projective Reflection. The use of ENA not only allowed researchers to examine large quantities of student data related to identity exploration by providing a nuanced view of the relationships between identity constructs (integration), but also supported comparison of group characteristics over time (Time 1 to Time 2). Future reports will expand on this inquiry to interpret and compare the weighted connections (line thickness) between PR constructs across different times and sessions. Future studies will test and refine new virtual learning environments that can facilitate Projective Reflection in different contexts, and also incorporate methods such as Social-Epistemic Network Analysis (See Gašević et al., 2018) to examine identity exploration as both an individual/developmental and collective/situational process of change over time.

References


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