On Your Marks, Handset, Go: An Illustrative Case Study of a Professional Development Initiative about Mobile Learning

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ON YOUR MARKS, HANDSET, GO: AN ILLUSTRATIVE CASE STUDY OF A PROFESSIONAL DEVELOPMENT INITIATIVE ABOUT MOBILE LEARNING

A Dissertation
Submitted to the School of Education

Duquesne University

In partial fulfillment of the requirements for
the degree of Doctor of Education

By
Nichole Scarlett

May 2022
ON YOUR MARKS, HANDSET, GO: AN ILLUSTRATIVE CASE STUDY OF A PROFESSIONAL DEVELOPMENT INITIATIVE ABOUT MOBILE LEARNING

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ABSTRACT

ON YOUR MARKS, HANDSET, GO: AN ILLUSTRATIVE CASE STUDY OF A PROFESSIONAL DEVELOPMENT INITIATIVE ABOUT MOBILE LEARNING

By

Nichole Scarlett

May 2022

Dissertation supervised by Dr. Rachel Ayieko

Technology is shaping our personal and professional lives every day, yet many educators struggle with its implementation and therefore are not using it to the fullest potential. The purpose of this single-case study was to analyze how a teacher’s participation in a Professional Development (PD) initiative influenced the implementation of mobile technology in teaching and learning mathematics. Using the Teaching for Robust Understanding (TRU) framework (Schoenfeld et al., 2016a) and the Substitution, Augmentation, Modification, Redefinition (SAMR) model (Puentedura, 2006) in this qualitative research, I employed a case study approach to understand the challenges faced by a teacher and ways of overcoming barriers to technology implementation in teaching mathematics. Using a thematic analysis of the multiple data
sources, I was able to examine how a PD experience shaped a teachers’ practice and how this initiative provided opportunities for agency, ownership, and identity. Three thematic findings were teacher workload, shaping teacher technology implementation, and opportunities for learner control. Participating in this PD initiative allowed the teacher to take the role of a facilitator and have a more balanced workload. The findings suggest that mobile technology implementation makes learner control possible. This study paves the way for opportunities for a teacher to promote a more robust understanding of selected mathematics topics. Implications for theory, research, and practice are discussed.

Keywords: [technology implementation, learner control, robust understanding, problem-solving]
I dedicate the following to my husband, Jim, who made a vow to marry me in the middle of my doctoral journey. It was then when I adopted a new family who encouraged and supported me. To the one who encouraged me to hide in my office to write in the evening and on weekends, read and proofread my dissertation many times, asking questions to make it clearer, and always encouraging me to keep moving forward. It will be nice to plan our lives around something other than my writing schedule and deadlines. To my in-laws, Art and Sherry, and their support and understanding as I progressed throughout this journey. You have been my greatest support behind your son. Finally, I cannot forget my closest friends, who I also call family, who took the time to listen to the stress and frustration and continued to encourage, support, and pray for me. This dissertation was made possible by everyone’s support, and I thank our Heavenly Father every day for you.
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This academic work would not be possible without my committee. They went above and beyond to help me finish even through difficult times during a pandemic. To my chair, Dr. Ayieko, who always provided suggestions and guidance throughout the dissertation process. I continue to share the guidance you have given me with my colleagues working on their dissertations. After working in the Numeracy block, I knew our ideas and efforts would come together nicely, and I could not be happier to have you as my dissertation chair.

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To Dr. Carbonara, who chose to stay on my committee after retiring [congratulations!!]. This showed how much you care for your students and means so much. Additionally, your background in instructional technology and leadership provided a great deal of feedback that truly strengthened this study.

To my committee, your support and help as I talked through my ideas with you meant so much to me and I am so fortunate to have worked with you. I cannot express my gratitude enough.
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Chapter 1

Introduction

Technology is shaping our personal and professional lives every day, yet many individuals struggle with technology acceptance and use to reach its fullest potential. Though the world of knowledge is at our fingertips, there is still a struggle with employing instructional technologies in different learning environments. Consequently, new, innovative approaches to learning must be considered as educators prepare learners for the 21st century (Collins & Halverson, 2018; Lang et al., 2017; Watson et al., 2020; Yang, 2016).

In 2001, Cuban recognized the assurance of computer use to transform teaching and learning, however these devices were being oversold and underused as they were not being implemented into a transformational learning experience. In modern times, Crompton et al. (2018) claimed that the rise of mobile technology in the past decade has led to promises of mobile learning to transform a learner’s experience. Research indicates that mobile technologies can be used in new, transformative ways, however, studies have also shown that many instructional methods use technology to enhance the learning environment, leaving little room for creativity and critical thinking (Al-Mashaqbeh, 2016; Bryant et al., 2015; Crompton & Burke, 2020). In addition, younger generations use technology daily. With a lack of development of instructional technology materials, educators make it difficult for these younger generations to connect to the presented material. As a result, teachers are challenged to use technology to its fullest potential.

Likewise, since technology is a part of students’ lives, educators should learn how to use technology to connect with students allowing for more diverse skills they can use
in the 21st century workforce. Yang (2016) contended that students expect technology to be a part of the learning environment so their perceptions should be considered in the design and evaluation of lessons. This does not mean our quest as instructional leaders is meant to reinvent the wheel, but rather find new ways to redefine the learning using readily available tools in ways that can be best utilized to reach scholars (Fullan et al., 2018). Conclusively, technology alone may not motivate student learning, so it is essential for lessons to be designed with different teaching strategies in mind.

In addition, Yang (2016) claimed that a technology-rich environment allows for more change from teacher-centered learning to student-centered learning. In other words, technology enables switching the educator’s role from teacher to facilitator (Hanson & Kutorglo, 2019). As Bear and Skorton (2019) elucidated, when students can understand and make connections across a diverse array of knowledge and skills, they will embark on a path to more rewarding lives and employment opportunities. This study demonstrates a Professional Development (PD) initiative to offer other educational institutions a groundwork in integrating mobile technology.

**Framing the Problem**

Professional Development (PD) rarely prepares teachers for best practices to reach students with new technologies. Patterson and Han (2019) supported this claim as instructional leaders are unlikely to find meaningful PD to support their ideas for technology usage in lessons. Though traditional teaching methods are slowly being phased out with different technologies, most technology is used to simply replace older, more traditional methods (Crompton et al., 2018). This results in lower levels of thinking
and/or cognitive development when accomplishing tasks (Barlow et al., 2020; Blackwell et al., 2013; Savignano, 2017).

There is a need for studies to investigate how mobile learning is being utilized to engage students’ higher-level thinking (Crompton et al., 2018; Koszalka & Ntloedibe-Kuswani, 2010). Recommendations in literature call for teacher education programs to integrate technology effectively in their own classes, illustrating best practices (Dias & Victor, 2017; Watson et al., 2020). According to Bryans-Bongey and Rosen (2019) and Collins and Halverson (2018), there is an increasing emphasis on the need for schools and teachers to provide curricular content that will prepare K-12 students for the workforce of the future. Though there is increased access to technology, there is a consistent under-use of its integration in classrooms (Blackwell et al., 2013; Cuban, 2001). In conclusion, teachers lack preparedness to use technology effectively to promote higher-order thinking (Bryans-Bongey & Rosen, 2019; Collins & Halverson, 2018).

Students struggle with relating to content taught with archaic instructional methods. Accordingly, Collins and Halverson (2018) compared student preparation for the 21st century with 19th-century skills to teaching people to fly rockets by having them ride bicycles. In addition, teachers experience many time constraints that prevent them from learning how to effectively implement technology into their curricula (Bryans-Bongey & Rosen, 2019). Thus, academic institutions must prepare their educators to unearth how technology usage best meets the needs of their students. Doing so could prevent institutions from settling for quick fixes to modern problems that result in student failure of gaining a deeper understanding of material.
Students’ understanding of a discipline is shaped in fundamental ways by their classroom experience. Mathematics, for example, is a subject full of wonder and beauty but students at the secondary level rarely experience this in such a design (Taylor, 2018). As Schoenfeld et al. (2016a) acknowledged, this is caused by relying on rote memorization techniques resulting in minimal chance of appreciation of the discipline or understandings that students will need. Moreover, limited time and the addition of extensive standards accompanied with increased testing has led to the construction of a curriculum that is narrow in scope and technical in character (Blair, 2012; Fullan et al., 2018; Ting et al., 2019). As a result, few opportunities for transformative learning are presented.

Supplementarily, research has indicated that technology can change the mathematics learning environment as it provides opportunities for learners to spend time understanding ideas conveyed rather than practice procedures without meaning (Menekse et al., 2018; Saundarajan et al., 2020; Webel & Otten, 2015). By understanding the material deeply, students may become more resourceful thinkers and problem solvers, developing competency, and promoting learner control (Collins & Halverson, 2018; Schoenfeld, 2020). Considering this, teachers should reflect on the best ways to implement technology to best engage diverse learners in more problem-based learning activities, rather than using drill-and practice approaches (Barlow et al., 2020). In conclusion, understanding the meaning behind the mathematics through technology use develops better thinkers and problem solvers which, in turn, prepares students for their future.
**Theoretical Framework**

This study intends to use a theoretical framework known as Transformation-Agency, Ownership, Identity (T-AOI), which is built from Schoenfeld and team’s (2016a) Teaching for Robust Understanding (TRU) framework and Puentedura’s (2006)—Substitution, Augmentation, Modification, Redefinition (SAMR) model. As a scholarly practitioner, I developed a Professional Development (PD) initiative in which curriculum could be redesigned to implement mobile technology into teaching and learning, transforming the learning environment, promoting learners to take control. The T-AOI framework aims to promote learner control through technology use resulting in an increase of critical thinking and problem-solving skills; skills that are much-needed in the present technology era. This would be an attainable solution to show how other schools could adapt and create approaches best suited for their institution.

**Statement of the Problem**

Present Professional Development (PD) initiatives have not been adequate for technology support when integrated in teaching and learning. Though there have been increased information and communication technology developments allowing mobile technology to shift the learning environment, there is still a lack of integration (Sulisworo & Toifur, 2016). Due to the nature of teaching and learning practices, pedagogy is difficult to change as educators would have to adjust the current curricula and teaching practices on top of an already demanding job (Cohen, 1988; Collins & Halverson, 2018). Consequently, Gainsburg (2012) argued that adapting lessons to 21st century learners, results in teachers becoming beginners again, learning with new conceptual tools.
The standards movement encourages a linear approach in teaching and learning, limiting the opportunity for students to have a transformational learning experience. This works against the type of learning that computers facilitate: learning by doing. More so, Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) scores show high standards are not being met in current American education (DeSilver, 2017; Geiger, 2018; National Assessment of Educational Progress [NAEP], 2019; National Center for Education Statistics [NCES], 2018, 2020; Roser et al., 2013). Noting this, Carter and Crichton (2014) suggested that best practices for lesson development may be determined by repurposing daily planners filled with traditional, outdated content when designing resources relevant to 21st century learners. Further, Crompton et al. (2018) contended that providing time to explore concepts using technology helps students reach higher levels of learning. By incorporating technology into the instructional design process, opportunities for higher levels of learning can be possible.

Likewise, studies have shown there is less research in changing mathematics curricula at the secondary level than in primary and post-secondary levels (Callaghan et al., 2017; Shernoff et al., 2017; Taylor, 2018). It is challenging to meet the needs of diverse students along with time pressures and standardized tests, leaving little time to develop ideas and spend time creatively engaging students (Taylor, 2018). While the primary level allows for students to explore the mathematics and reach creative solutions when problem-solving while developing their mathematical thinking, Taylor reminds us that little improvement has been made at the secondary level. To further this claim, Shernoff et al. emphasized that many teachers are interested in integrating different
approaches, but they do not believe they are well prepared to implement them. In addition, Callaghan et al. observed that few teachers sought PD assistance for integrating different approaches but desired such support. Thus, the intent of this study was to provide a model for removing roadblocks and lowering the barriers that keep teachers from integrating emerging mobile technologies into curricula.

**Purpose of the Study and Research Questions**

The purpose of this study is to analyze how teacher participation in a PD initiative influenced mobile technology implementation in teaching and learning. This model serves as a groundwork to integrating mobile technology in other courses and/or educational establishments. My study answered one primary research question and two secondary questions:

1. How does teacher participation in a Professional Development (PD) initiative influence (or shape) teacher implementation of mobile technology in teaching and learning?

2. How does a mathematics classroom teacher use mobile technology in the classroom before and after the PD initiative?

3. What is the teacher’s interpretation of their integration of mobile technology in building students understanding of mathematics?

**Significance of the Study**

This study is significant in many ways. It complements existing literature as it addresses overcoming first- and second-orders barriers teachers face, to increase student engagement and higher-level thinking. Additionally, it provides a deeper understanding of a teacher’s journey through a PD initiative with regard to readily available
technologies (i.e., mobile technology). More so, it bridges the gap in literature as mobile technology was used in ways to improve instructional practices and learning outcomes. These occurred through which a PD initiative took part in redesigning the curriculum to make it more technology focused and promote higher-order thinking. The findings from this study can inform future PD about integrating mobile technology in secondary mathematics instruction by removing roadblocks and lowering barriers that keep teachers from integrating these emerging technologies.

**Delimitations**

This study covered a six-and-a-half-week period from April 2021 through May 2021. Only schools interested in improving their secondary mathematics programs were considered. Likewise, this study included only the educator who matched the selection of criteria established for the study. The criteria for selection included educators who: actively taught secondary mathematics, had open mindsets, technology acceptance, and flexibility with trying a new project at the end of the school year.

**Assumptions**

The teacher-participant in this single-case study was willing to serve as a representative of all the mathematics educators employed at the selected school. In addition, responses received from the participant accurately reflected his professional opinions. Likewise, the teacher-participant answered all the interview questions openly and honestly.

**Definition of Terms**

- **agency, ownership, identity (AOI):** the degree to which students support what they say through their actions contributing to conversations about disciplinary
ideas, building on other’s ideas and have others build on their ideas, in ways that contribute to theory development of agency (the willingness to engage), their ownership over the content, and the development of positive identities as thinkers and learners (Schoenfeld et al., 2016a).

- **critical thinking, creativity, collaboration, communication (4 C’s):** the four essential skills to prepare young people for citizenship and the global workforce (National Education Association [NEA], 2012).

- **bring your own device (BYOD):** allowing students to utilize their personal technology in the educational setting rather than using a school-owned device to perform education related tasks (Welsh et al., 2018).

- **instructional design and technology (IDT):** the “analysis of learning and performance problems, and the design, development, implementation, evaluation and management of instructional and non-instructional processes and resources intended to improve learning and performance in a variety of settings, particularly educational institutions in the workplace” (Reiser, 2018, p. 4).

- **mobile learning:** “learning across multiple contexts, through social and content interactions, using personal electronic devices” (Crompton, 2013, p.4)

- **learner control:** placing learners in charge of their learning as much as possible encouraging learners to take ownership and follow interests while learning (Collins & Halverson, 2018).

- **professional development (PD):** the collaboration with colleagues and commitment to ongoing learning as a continuum toward support of student learning as well as the learning of colleagues (Darling-Hammond et al., 2017).
• substitution, augmentation, modification, redefinition (SAMR): a framework developed by Dr. Ruben R. Puentedura in 2006 that organizes technology integration for learning activities into four different levels including enhancement levels of technology integration—substitution and augmentation—as well as transformational levels—modification and redefinition—of technology integration (Romrell et al., 2014).

• science, technology, engineering, mathematics (STEM): teaching and learning that focuses on authentic content and problems, using hands-on, technological tools, equipment, and procedures in innovative ways to help solve human wants and needs (Brown et al., 2011).

• transformation-agency, ownership, identity (T-AOI): a framework integrating the transformation levels of Puentedura’s (2006) SAMR model into Schoenfeld’s et al. (2016a) AOI dimension of the TRU framework to promote learner control.

• teaching for robust understanding (TRU): a framework for characterizing powerful learning environments to support researchers in developing deeper understanding of teaching and how to enrich it in professional preparation and professional development. (Schoenfeld et al., 2016a).

Organization of the Dissertation

This dissertation is organized into five chapters, references, and appendices in the following manner. Chapter 2 presents a review of relevant Instructional Design and Technology (IDT) literature with a particular focus on a Professional Development (PD) initiative promoting opportunities for Agency, Ownership, and Identity (AOI) through mobile technology. Chapter 3 delineates the research design and methodology of the
study. Procedures for data collection, instruments used to gather the data and conduct the analysis, along with assumed ethical challenges are discussed. A thematic analysis follows in Chapter 4 with a discussion on implications; connections to theory, research, and practice, and recommendations for future theory, research, and practice presented in Chapter 5. This dissertation concludes with references and appendices.
Chapter 2

Literature Review

Professional development in the academic world has proven to be an effective opportunity in which to utilize Instructional Design and Technology (IDT). To conduct a meaningful professional development, it is essential for scholars to consider the historical background and contributors to the field. The following sections describe a brief history and definition of IDT, along with important theorists’ ideas found in recent research. The sections will also incorporate recurring patterns of expectations and outcomes providing a better expansion of our most basic understanding of modern learners needs. The literature will then focus on the qualities and skills needed for the 21st century scholar followed by an example of a model that results in students taking control of their own learning through mobile technology use. Finally, mobile learning incorporated into instruction to make education relevant for the 21st century learner is discussed.

Instructional Design and Technology: Changing the World

In modern academia, many burdens have been placed on educators, making it difficult to create rich experiences for 21st century learning. There is an increasing emphasis on schools and teachers to provide curricular content that will prepare students for the workforce while following the standards-based curriculum (Bryans-Bongey & Rosen, 2019). Additionally, curriculum materials have expanded as knowledge has grown, resulting in curricula becoming a mile wide and an inch deep, leaving teachers with little time for creativity when covering the plethora of material experts consider important (Collins & Halverson, 2018). This often results in uninspiring content and often increased difficulty, to the point of creating fear-inducing, classes (Clements &
In conclusion, educational environments are loaded with information, but not enough time is available to allow unique instruction for present day learners.

Given Instructional Design and Technology (IDT) developments, there is increased demand for new 21st century skills. Recent reports indicate that future workforce needs are changing, as we adapt to new innovations, transforming the way we use and interact with our computers and mobile devices (Bryans-Bongey & Rosen, 2019; Collins & Halverson, 2018; World Economic Forum [WEF], 2016). In the world of education, an obstacle remains: the lack of instructional design to address educational needs. Educators lack IDT preparation to teach 21st century learners, thus adopting old teaching methods (Budoya et al., 2019; Huang, 2005). For this reason, demand for implementing new technologies that specifically address the educational needs of our future workforce is not met.

Effective technology practices can be accomplished through professional development sessions, resulting in more collaboration between colleagues throughout the instructional design process. For example, Moore and Smith (2014) emphasized the importance of professional development as it prepares teachers and administrators for integrating topics into learning environments. Further, studies have found that teachers working in small groups, learning from their peers is the most powerful predictor for increased student achievement (Darling-Hammond et al., 2017; Jackson & Bruegmann, 2009; Nebel et al., 2017). Additionally, researchers have explored the benefits of workshops designed to address challenges regarding unfamiliar concepts and technology in an academic setting (Bryans-Bongey & Rosen, 2019; Kehoe et al., 2018). In
conclusion, technology integrated into modern instructional design techniques allows educators to create opportunities for effective collaboration in professional development.

**What is Instructional Design and Technology (IDT)?**

The field of IDT is often described as a broad, meta field embedded across many disciplines, including psychology, learning sciences, curriculum development, and educational technology, thus making it difficult to define (Bodily et al., 2019; Hill et al., 2004). The Association for Educational Communications and Technology’s (AECT), however, provided a definition, which aims to facilitate learning. Supporting the AECT, a renowned scholar, Dr. Robert Reiser (2018) defined IDT as follows:

The field of instructional design and technology (also known as instructional technology) encompasses the analysis of learning and performance problems, and the design, development, implementation, evaluation and management of instructional and non-instructional processes and resources intended to improve learning and performance in a variety of settings, particularly educational institutions and the workplace. Professionals in the field of instructional design and technology often use systematic instructional design procedures and employ instructional media to accomplish their goals…. (p. 4)

This definition recognizes both instructional and non-instructional training courses and materials, performance support, informal learning, social media, and mobile learning on improving human performance in the workplace (Reiser, 2018). Educators can use this definition to understand how to approach the instructional design process when collaborating on best practices for implementing technology, thus transforming the learning experience.
**Historical Aspects of Modern Instructional Design**

Historical studies can be used to uncover recurring patterns of expectations and outcomes, guiding the instructional design process. Rabel (2019) reported that using prior knowledge and past experiences in the design process aid in decision making. Reiser (2018) claimed that in the field of IDT, scholars whose work is influenced by the lessons learned from history and instructional design are well positioned to positively influence future developments. Therefore, an understanding of prior knowledge, past experiences, and history of IDT expands our most basic understanding of 21st century learner needs.

**The First Paradigm Shift of Instructional Design.** Instructional design dates back to World War II, as a means to rapidly prepare a large number of people for a wide variety of jobs (Dick, 1987; Kurt, 2016; Reiser, 2001). It was at this time the term “Instructional Technologist” was born. After this period, the 1950s brought several factors that changed theoretical thinking as views of learning shifted from cognitive to behavioral. Additionally, the role of the teacher was to arrange conditions that naturally sparked students to make the correct response (Ertmer & Newby, 2008). Ultimately, this paradigm shift focused on the underlying assumptions of a theory rather than discovering a new fact or tool.

B. F. Skinner (1958) is most associated with the birth of this paradigm shift. Skinner developed an instructional design process that focused on behaviorism to solve educational problems (Azimi & Fazelian, 2013). As behavior could be directly observed and measured, the role of educators shifted. Trial and error became the focus of learning as students made their own path toward the objective. Many steps found in current
instructional design models are a result of this trial and revision procedure, today known as formative evaluation (Reiser, 2001).

The instructional design process soared to prominence after the launch of the Sputnik satellite in 1957 (Azimi & Fazelian, 2013). One of the most influential individuals in the field of instructional design is Benjamin Bloom (1956), whose highly respected taxonomy spawned ways to align goals, curricula, and assessments, correlating with Skinner’s objectives. Educators have focused on Bloom’s hierarchy of skills involving six levels of cognitive complexity: knowledge, comprehension, application, analysis, synthesis, evaluation (Hoque, 2017). Bloom’s taxonomy was revised in 2001 by Anderson and Krathwohl as they claimed it to be more relevant to 21st century work, thus meeting the needs of curriculum designers, teachers, and students (Darwazeh, 2017). The levels transitioned from noun to verb form providing students with clearer objectives for what is expected of them: remember, understand, apply, analyze, evaluate, create.

Studies have shown the importance of applying Bloom’s taxonomy to encourage higher order thinking skills as we continue to prepare 21st century learners with mobile technology, projects, and games that promote active learning. As an example, Crompton et al. (2018) conducted a systematic review of mobile learning and student cognition, finding that when researchers develop activities requiring higher levels of cognitive processing, it increases. Lowrance and Rogers (2019), likewise, developed and analyzed a robotics project using Bloom’s taxonomy, demonstrating higher order thinking skills. Atlanis et al. (2018) also conducted a study using an interactive game-based lesson where self-directed learning aided in the development of enhanced thinking skills and increased
motivation among learners. These studies emphasize that higher levels of Bloom can be reached by incorporating technology in carefully planned instruction.

While Bloom’s focus was to promote higher order thinking, Mager (1962) popularized the use of learning objectives in the early 1960s. Many current-day advocates of Mager’s ideas for the instructional design process prepare learning objectives and criteria, or standards, by which the objectives are met (Reiser, 2018). In a study employing Virtual Reality (VR), Patterson and Han (2019) emphasized that a customized learning experience based on learning goals with the instructor’s own class was more effective than inserting a premade lesson into an existing curriculum. Furthering this, Jaiswal (2019) conceded that careful design of learner-centered instructional approaches significantly boosted deep learning as the focus was on the needs and development of scholars. This study also demonstrated Robert Gagné’s Nine Events of Instruction and how these objectives catered to a variety of learning styles and facilitated the learning process significantly.

Robert Gagné (1965) was influenced by both the cognitive and behaviorist approaches, expanding upon Bloom’s ideas. Gagné recognized the mindfulness of humans and developed the notion of both internal and external conditions of learning (Hill et al., 2004). The external processes Gagné described are incorporated into his Nine Events of Instruction and are designed to engage the internal processes. These processes are: gaining attention, informing the learner of the objective, stimulating recall of prior learning, presenting the stimulus, providing learner guidance, eliciting performance, providing feedback, assessing performance, and enhancing retrieval and transfer (Richey, 2000).
Recent studies show the implementation of Gagné’s ideas using technology as a learning aid. Hanson and Kutorglo (2019) reported improvement for both instructors and students utilizing Gagné’s Nine Events of Instruction through digital education technology. Moreover, Azizan et al. (2019) argued when teachers use innovative instruction using a well-designed digital educational game corresponding to Gagné’s nine events, both they and their learners are positively impacted. As the instructor now acted as a facilitator, these designs implementing digital educational technology resulted in more collaborative learning environments among the students.

**The Second Paradigm Shift of Instructional Design.** A second paradigm shift occurred during the 1970s, when the number of instructional design models greatly increased in many fields. Academic instructional design began to incorporate multimedia resources, while new materials were developed for military and workforce training, and instructional problems were solved worldwide for fields including business and industry (Reiser, 2018). The instructor still played a role in the learning process, however learning was now generated by the student and not dispensed by the teacher, making it more meaningful (Hanson & Kutorglo, 2019). Specifically, learning began to be constructed by the individual, based upon existing knowledge and previous experiences.

Research has shown the importance of designing experiences that allow individuals to construct their own learning using technology. Shipley et al. (2018) argued that this shift in philosophy is key in outlining the blocks that supported learners’ knowledge construction. Similarly, Blair (2012) argued that a new mindset of teaching through technology must emerge, depending on a vital shift in teacher and student roles where the teacher becomes the facilitator. Further, Johnston et al. (2018) reported that a
constructivist environment where students take control of their learning, provides opportunities, and supports them in applying their knowledge. In other words, Johnston et al. believed learners are actively experimenting within a rapidly changing environment, constructing new skills and understandings generated within the virtual environment, which transfer to real-life contexts. Hands-on experiences are critical as students learn through their minds and through their behaviors in contextual environments.

The birth of e-learning in the 1980’s is generally attributed to the use of microcomputers. While there was a rising interest in how the principles of cognitive psychology could be applied in the instructional design process, actual effects were small (Reiser, 2018). Along with an increased interest in computer-based instruction, microcomputers began to be used as tools to automate some instructional design tasks (Reiser, 2018).

Following the production of computer-based instruction, the use of electronics and learning systems began to flourish in the 1990s. Interest in constructivist views of teaching and learning rose, laying a new foundation for the authentic learning tasks that reflect the expectations of the real-world (Reiser, 2018). New emphasis prioritized on-the-job performance broadening the instructional design field (Reiser, 2018).

Instructional designers played a vital role beginning in the 2000s: the rise of online learning. Reiser (2018) argued that we are in the age of learning technology where the workplace has turned innovations such as social media, mobile devices, and performance into support tools to help employees perform their job. This reduced the need for formal training and provided designers the opportunity to promote alternate means of skill acquisition (Reiser, 2018). Throughout history, these theorists and design
processes have taken us from simple inventions such as the teaching machine in Skinner’s day, to a technological revolution where our 21st century learners thrive.

**The 21st Century Learner**

Most teenagers today have access to mobile technology. The Pew Research Center (2019) reported at least 96% of households, including minorities, own a cell phone while at least 79% own a smartphone. According to the Global Education Census Report (2018), 74% of American students use a smartphone in the classroom, while 85% of students use a laptop when doing their homework. Young people are more than twice as likely as they were four years ago to report that they use computers for homework every day (Rideout & Robb, 2019). A report from the Common Sense Census stated 53% of children own their own smartphone by age 11, while an even greater percentage of teenagers, 84%, have their own phones (Rideout & Robb, 2019). Technology is used to enhance learning, but given the availability of mobile devices, it should be used to blend with other tools (Global Education Census Report, 2018).

**Connecting the 21st Century Learner with Technology**

It is imperative for scholars to take control of their own study and become engaged in exploration to have a deeper understanding of a topic. Blair (2012) emphasized that students of the 21st century are highly relational, want to explore, design and create their own materials, and demand quick access to new knowledge. Additionally, Fullan et al. (2018) stated when students care about the topic they are learning and are given the opportunity to design their own education, deeper learning and change occur. Further, Jonassen et al. (1998) argued when using computers as mindtools—computer applications used by learners to engage them to think critically
about the content they are studying—computer systems can facilitate learning. This occurs when used in ways to promote student reflection, discussion, and problem-solving. These studies emphasize that students need opportunities to explore topics so they can find ways to connect with the material, and in the process obtain conceptual understanding.

Likewise, students yearn to make connections through technology, as it is their world. Therefore, it is essential for educators to find ways to integrate technology into their instruction. Collins and Halverson (2018) insisted that one way to meet student needs is by providing opportunities using familiar technology where they can create an interest-driven space, taking guided command of their own learning. Moreover, Walsh (2019) claimed this could develop digital heirs who would be best placed to mediate between real and virtual environments, possessing skills for the 21st century. As a result, students would develop more interest in the subject matter and be better prepared with skills needed for the present-day workforce.

Supplementarily, traditional assessment techniques are not as effective as evaluation methods that encourage the learner to be a part of the experience. Lessani et al. (2017) reported that students who learned by problem-solving and discovery learning methods were more active when compared with students who experienced traditional, teacher-centric methods. Supporting this claim, Barkhand (2017) demonstrated that increased interaction, feedback, and instructional tools promoted significant change in the learner environment. However, Ting et al. (2019) believed that powerful instructional methods and active learning pedagogies remain relatively rare due to the passive nature of learners’ involvement in traditional, teacher-centric courses. Furthermore, Ahmad et
al. (2020) acknowledged that traditional assessments did little to inform educators of the difficulties their learners encountered. These studies show the importance of training educators to effectively change pedagogy and assessment techniques.

The mindset for teaching through technology requires a shift in roles between the student and teacher. Mobile technology allows students instantaneous access to a world’s worth of knowledge, shifting traditional teaching methods in the classroom by facilitating learning in new ways (Dias & Victor, 2017; Sulisworo & Toifur, 2016). Ting et al. (2019) insisted that active learning strategies are designed to shift traditional teaching methods to facilitation methods, promoting problem-solving and collaborative learning, resulting in more positive academic outcomes. Technology should play a vital role in the modern learner’s education, just as it does in their everyday lives.

Teaching through technology requires educators to shift their approach, learn new skills, and find innovative ways to reach their students. Carter & Crichton (2014) believed these shifts will require professionals to develop new skills, core concepts, and curate dynamic network systems of learning artifacts and group activities. More so, Shipley et al. (2018) acknowledged that, as educational technologies continue to shift more towards self-directed learning, design tools should strategically identify opportunities to embed scaffolding within academic technologies. Rather than adhere to currently accepted best practices, educators should consider next practices: finding innovative ways to relate to the digital world in which students are maturing.

**Modern Skills for the 21st Century Learner**

Various frameworks for 21st century learning agree that critical thinking, creativity, communication, and collaboration are vital skills for a technology-infused life
(Beswick & Fraser, 2019; Blair, 2012; Fullan et al., 2018). Fullan et al. urged us to normalize failure to create opportunities for reason and improvement, resulting in deeper learning. This, in turn, allows for more creativity, thinking, communication, and collaboration.

Beswick & Fraser (2019) argued that critical thinking, creativity, communication, and collaboration are central to STEM disciplines: Science, Technology, Engineering, and Mathematics. Many jobs rely on digital and Information and Communications Technology (ICT) literacy, seeking assistance and collaborating with others to create new, innovative ideas as technology continues to advance. Accordingly, Artificial Intelligence (AI) has begun to shape our everyday lives, so understanding and designing machines are important skills necessary to complete 21st century jobs. Students need to ask why an outcome occurred so they can learn how to interpret the outcome of an algorithm.

**Critical Thinking for the Modern Learner.** Critical thinking is an essential skill for the present-day learner. However, educators struggle to create lessons encouraging students to question claims and seek the truth. Tondeur et al. (2017) found past efforts to change lessons to better connect with the modern learner were unsuccessful due to the outdated nature of teaching and learning practices. For teachers open to changing their practices, studies have acknowledged that they spend countless hours adapting curricula to meet new standards, but lessons still lack opportunities that promote critical thinking and inquiry in the time allocated (e.g., Collins & Halverson, 2018; Jaffe et al., 2019). Thus, teachers struggle incorporating critical thinking into lessons expected from the teaching standards, with time constraints and static teaching and learning practices.
There is an increasing interest in using mobile technology to promote critical thinking. Examples of mobile technologies that have been used more recently to promote critical thinking include Augmented Reality (AR) and Virtual Reality (VR) (Johnston et al., 2018; Papanastasiou et al., 2019; Patterson & Han, 2019). Crompton et al. (2018) revealed that mobile learning encourages higher level thinking. Additionally, Pifarré (2019) agreed that interactive technologies draw learners into open communication, promoting ways of thinking together. Students can use technologies to explore ideas with one another, stimulating higher levels of thinking.

It is crucial for educators to foster innovative ways to develop thinking skills using technology to meet the needs of the modern learner. Crompton et al. (2018) insisted there are still unfulfilled opportunities for using mobile technology to promote higher level thinking in courses such as mathematics. To address this issue, Darling-Hammond et al. (2017) emphasized that teachers engage in collaborative professional learning and research to promote 21st century competencies. Similarly, Levin-Goldberg (2012) noted that the global market is driven by creativity and innovation, and problem solvers must work together to produce stellar products. Creativity and problem solving borne of higher-level thinking is integral to the future success of 21st century learners as they graduate into the workforce.

Creativity to Encourage Innovation. Creativity encourages innovative ideas, individual uniqueness, and an eagerness to share ideas which encourages others to try something similar. Henriksen and Mehta (2016) found that creativity allows students to embrace their inner strengths, and find fresh ways to explore topics, reaching a “beautiful mindset” (p. 87). Further, Fullan et al. (2018) argued that a strong sense of identity based
on a purpose or passion, creativity, and mastery of a valued pursuit, along with connection to the world gives meaning to life. Essentially, if students do not embrace what is being taught, they are not working towards their lifelong goals and are disconnected from the real world.

Effective technology use can nurture creativity in an academic environment. For example, Papanastasiou et al. (2019) illustrated strong evidence for significant improvement of students’ learning, social, and creative skills. Pifarré (2019) furthered this claim by stating the role of interactive technologies to promote thinking together creatively. Likewise, Papanastasiou and colleagues suggested that allowing students to explore using interactive technologies promotes cooperation, builds collaborative ideas, and allows for performing complex and unique tasks. In general, even if a student is not yet utilizing the correct strategy, they can learn from their mistakes and find a better approach.

**Communication to Convey Ideas.** Students are consistently using their personal devices to connect with others through text-based communications, emails, or social media, making it essential to create a learning environment fostering open communication. Pifarré and Li (2018) noted when students interact around computers, they display communicative traits such as thinking through writing. By the same token, Jaffe et al. (2019) found ideal learning environments allow for interpersonal connections creating relational elements of trust, respect, and empathy when time permits. Overall, communication teaches students how to efficiently convey ideas to one another.

It can be difficult to support peer learning through technology because text-based communications lack vocal tone, so it is imperative to carefully design lessons utilizing
technology that help students practice interpreting communication. Lang et al. (2017) believed that adopting a pedagogy supporting peer to peer learning is beneficial. Capturing multi-modal communication, Pifarré (2019) argued, helps us better understand how creative processes emerged in a technology-enhanced learning context. In conclusion, educators must collaborate to carefully design lessons fostering better communication in the classroom.

**Collaboration to Promote Teamwork and Reduce Cognitive Load.**

Technology can connect learners by encouraging active, collaborative learning and reducing cognitive load. Nebel et al. (2017) demonstrated how collaboration teaches students how working in groups allows them to join forces to create something beyond what they could produce on their own. In addition, findings revealed insight into the experimenting and learning process, which increased task interdependence and efficiency while reducing cognitive load (Nebel et al., 2017). Thus, working in small groups allows for increased productivity and time to connect to material.

Students will likely experience teamwork most of their lives, making preparation for active learning essential for their success. Ting et al. (2019) reported that active learning levels the playing field, and students with less prerequisite background knowledge are more inclined to close the performance gap to students with stronger background knowledge. However, as Pifarré (2019) noted, when students are given interactive opportunities through technology, collaborative thinking is encouraged. Complementarily, Levin-Goldberg (2012) concluded active learning not only advocates a collaborative environment, but also requires critical thinking to solve problems. All four of these skills (critical thinking, creativity, communication, collaboration) are necessary
for success when reaching the 21st century learner. As educators, we need to find ways to structure our lessons that are best designed for our learners.

**Professional Development in IDT**

Collaboration is not only an important skill for 21st century students, but also a mandatory consideration when designing ways to integrate technology. Studies have shown that teachers are unlikely to find meaningful professional development to support their planned-for use of emerging technologies (Liu, 2012; Patterson & Han, 2019; Yang & Liu, 2004). Complimentarily, research suggests technology is most effectively integrated into the curriculum when teachers are involved in a collaborative process of designing new lessons (Cviko et al., 2014; Patterson & Han, 2019; Sharif & Cho, 2015). Consequently, Okumuş et al. (2016) believed that teachers should be given considerable time for collaborative efforts among teachers to become familiar with latest educational technologies. This is because, like students, educators learn by doing, investigating, and sharing. In general, professional development can be meaningful when institutions have a shared vision, take advantage of the collaborative process, and have ample time in which to accomplish these tasks.

Conjointly, teachers cannot affect change alone when it comes to transforming the learning experience through technology as a shared vision must exist in the institution. Enhancing lessons or designing new ones utilizing technology is a complex process, requiring a great deal of thought about content, context, students, and the technology itself (Matuk et al., 2015; Patterson & Han, 2019). To do this, Fullan et al. (2018) argued that a leading transformation comes from a whole system change, a shared definition of understanding about the nature of work. Likewise, Atkinson (2019) insisted that to be
effective, teachers need time to develop collegial relationships as well as explore, plan, and play with technology. Thus, effective leaders who support emerging technology provide time and opportunities for collaboration.

Studies have shown how effective professional development can be accomplished by colleagues taking risks together, resulting in an open community of learning when integrating technology into instructional practices. Learner-centered professional development is an important factor for supporting technology integration (Callaghan et al., 2017; Okumuş et al., 2016). Bryans-Bongey and Rosen (2019) developed a blended instructional design, leading to a successful professional development project within the parameters of limited time, money, and low teacher participation, resulting in high levels of student engagement. Likewise, Atkinson (2019) emphasized that risk-taking comes more easily when teachers could rely on peers for real-time support, leading to less resistance to technology. Overall, successful professional development relies on collaboration and peer support.

**Overcoming Barriers to Effective Professional Development**

Barriers must be overcome for educators to collaborate and design effective instruction using technology. Factors limiting teacher participation in professional development include first-order barriers such as constraints of time, budget, technology resources, and miscellaneous materials (Blair, 2012; Bryans-Bongey & Rosen, 2019; Ertmer, 1999). Furthermore, educators and learners often fail to adopt technology as originally intended. These failures and barriers to effective instruction can be attributed to second-order barriers such as challenges in determining how to assess student learning, time spent governing workarounds to administer lesson plans, challenges in navigating a
user interface, and usability design flaws (Earnshaw et al., 2018; Ertmer, 1999; Jou et al., 2016; Rodríguez et al., 2017; Straub, 2009). As a result, teachers struggle to effectively implement technology.

Attitudes about technology use in the classroom influence educators’ views of professional development. Blackwell et al. (2013) reported attitudes towards technology tend to be the dominant reason for resistance to technology in the classroom. In addition, Carter and Crichton (2014) proclaimed the design and development of curriculum is viewed as a superfluous waste of resources as educators encounter and balance an overcrowded curriculum. Carefully designed professional development where academics, software developers, and researchers are all involved, would give teachers an opportunity to consider technology an agent of change (Carter & Crichton, 2014). This would encourage a more positive attitude and increase adoption of technology to meet students’ developmental needs.

Educators need a support system to gain knowledge of cohesive educational technology solutions to design courses rich in engagement and active learning. Carter and Crichton (2014) found that educators required awareness, reflection, and the support of their peers to differentiate between technologies, policies, and practices that are cutting edge or just trendy. Nevertheless, Ting et al. (2019) suggested that many teachers may need more knowledge and experience to design classes that are rich in engagement and active learning. In general, teachers need to be actively engaged in professional development, and given time to work with other scholars in design and technology.

The gap in the literature regarding technology in different content areas points to the urgent need for professional development to redesign curriculum (Black-Fuller, 2016;
Millen & Gable, 2016; Okumuş et al., 2016; Vgoot et al., 2013). This gap in information prevents educators from gaining the knowledge that would improve instructional practices and learning outcomes using technology (National Education Technology Plan [NETP], 2017). As the NETP highlights, this transformed learning experience can occur when technology is carefully designed and thoughtfully applied, working collaboratively on a shared vision, taking full advantage of technology-rich learning environments. Thus, educational leaders should set sound policies incorporating technology into instructional design processes and provide the essential tools that support learners to thrive.

Peer support structures and real-time assistance aid teachers’ professional growth through collaboration in all subject areas. Ting et al. (2019) claimed that active learning methods including problem-based, discovery-based, and inquiry-based learning have not typically been applied, so examples of powerful instructional methods and active learning pedagogies remain relatively rare. Accordingly, courses such as mathematics are not meeting the necessary standards (Roser et al., 2013). Considering this, Taylor (2018) argued the main challenge appears to be the knowledge and experience of many teachers and calls for better training and time to explore and play with new resources. The theoretical frameworks by Schoenfeld et al. (2016a) and Puentedura (2006) help us find ways to actively involve the 21st century learner in the mathematics classroom.

**Theoretical Framework**

Research suggests that careful design prompting interdisciplinary connections in STEM disciplines can provide the opportunity to transform the learning experience. Bear and Skorton (2019) suggested interdisciplinary learning would help prepare students for the workforce. English (2009) urged professionals in mathematics-related fields to draw
upon interdisciplinary knowledge in solving problems and communicating their findings. These findings draw upon teacher knowledge in a flexible and creative manner—contrary to the way mathematics is taught in school (English, 2009).

Furthermore, Beswick and Fraser (2019) argued for mathematics teachers to contribute to STEM and 21st century competence agendas in which they must use content knowledge and teaching strategies as a foundation to build their capacity to integrate mathematics with other disciplines. Therefore, careful design incorporating STEM disciplines such as technology and mathematics, will transform the academic experience giving students the opportunity to take charge of their own learning, making math relevant to them.

**Teaching for Robust Understanding (TRU)**

Instruction can always be enriched by a focused attention on the different dimensions of teaching. Taylor (2018) insisted that to change curriculum in substantial, challenging ways, we need writers with an artistic core in addition to mathematical and pedagogical skills. Schoenfeld et al. (2016a) claimed that there is no single correct way to teach, and though improving pedagogy is not easy, knowing the focus can be extraordinarily helpful in enhancing instruction. Teachers must be able to reimagine the mathematics classroom and spend time in workshops to explore promising activities with students who are excited to embark in mathematical exploration (Taylor, 2018). Consequently, this shift in thinking could transform the learning experience, providing robust learning opportunities.

Schoenfeld (2013, 2014, 2016a) is most associated with the development of the Teaching for Robust Understanding (TRU) framework. This framework focuses on the
opportunities the environment provides for students to experience deep engagement with mathematical content. These opportunities target qualities that make up powerful classrooms, rather than focus on what the teacher does. The TRU framework provides a straightforward and accessible language for discussing what happens in classrooms, in professional preparation, and in professional development (Schoenfeld, 2016a). There are five dimensions to the model: The Content; Cognitive Demand; Equitable Access to Content; Agency, Ownership, and Identity; Formative Assessment. This study focuses on Agency, Ownership, and Identity (AOI), acknowledging that the other dimensions can be met with teachers, when the environment supports AOI.

**Agency, Ownership, and Identity.** Given the lack of research in secondary mathematics classrooms, while much literature focuses primarily on cognitive demand (Crespo & Harper, 2020; Smith & Stein, 1998), there is a need for focus on student Agency, Ownership, and Identity (AOI) in the instructional setting (Schoenfeld, 2016a). This dimension establishes an environment providing students opportunities to develop a sense of agency. Students also can take ownership of content and build positive identities where their contributions are encouraged, recognized, supported, and built upon (Schoenfeld et al., 2016a; Schoenfeld, 2019). Furthermore, Langer-Osuna (2017) observed that agency and identity have given students opportunities to conjecture, explain, make arguments, and build on one another’s ideas.

Agency is the capacity to engage content which occurs when learners share what they think about the problem rather than feeling pressured to match some other authority, such as textbook answers or the instructor (Schoenfeld, 2016a; Schoenfeld, 2019). Moreover, Langer-Osuna (2017) observed that as students formulate ideas, decide and
justify whether particular mathematical ideas are reasonable or correct, and discuss, they take on forms of intellectual authority that fuel collaboration. Therefore, lessons should be carefully designed, allowing room for students to explore and share ideas, making learning their own personalized experience.

Schoenfeld (2016a) found there was little room for students to present their thinking for refinement through classroom discourse. Educators must find new, innovative ways to reach learners and allow students to make the content their own. Schoenfeld (2019) believed that students who have told themselves they are bad at math have already formed their own negative identities as mathematical thinkers. Further, Schoenfeld concludes student identities play a role in what they see the mathematical enterprise to be, how they own the mathematics they produce, and how they fit in that larger picture, shaping their lifelong view of math.

Opportunities for students to present their thinking is a widespread hindrance, preventing learners from coming up with answers on their own, causing them to regurgitate information whether they agree. Ownership refers to the sense that one has control of their disciplinary ideas rather than imitating or memorizing those of others (Schoenfeld, 2016a). Additionally, Fellus (2019) argued that understanding where learners stand opens space for educators to learn student identity which can in turn guide learners’ future learning paths in mathematics.

One way to meet learners’ need for agency, ownership, and identity is through the world in which they are growing; one filled with technology at their fingertips helping them feel connected. Langer-Osuna (2017) acknowledged that, when authority was shared between the teacher and student, opportunities to take ownership of ideas arose,
leading to greater conceptual understanding and identification with mathematics. In addition, Sulisworo and Toifur (2016) found cooperative mobile learning strategies influenced improvement in students’ learning performance and achievement, and found motivation was the key to success. Further, Sanabria and Arámburo-Lizárraga (2017) conducted a study changing the traditional math classroom with mobile technology using AR and suggest technologies to be used to transform the learning experience. AOI can be better reflected and transform the learner's experience when technology is brought into the modern classroom, leading us to the next theoretical framework by Puente dura (2006).

**Substitution, Augmentation, Modification, Redefinition (SAMR)**

Digital technologies are constantly evolving and can take shape in many forms, making them generally unpredictable in use and design (Hamilton et al., 2016). Rather than reading and carrying hard copy texts and notebooks, technology has allowed us to store and access everything on one portable device. Smartphones have given us the world of knowledge at our fingertips and virtual simulations have given us an opportunity to explore places and artifacts that were once unreachable. Ruben R. Puente dura (2006) emphasized the importance of transformation using the Substitution, Augmentation, Modification, Redefinition (SAMR) model which encourages teachers to move from lower to higher levels of teaching with technology. This promotes higher levels of thinking as described previously in Bloom’s hierarchy of learning. Figure 1 shows a comparison of the levels of SAMR to Bloom’s hierarchy of learning. This study compares technology in ways that simply enhance the learning experience through
substitution and augmentation to ways that transform the learning experience through modification and redefinition.

![SAMR Model and Bloom's Taxonomy](image)

*Figure 1. SAMR model and Bloom's Taxonomy (PuenteDura, 2014).*

**Technology Usage (Enhancement and Transformation).** Though instructional technology has developed opportunities for higher order thinking, it is often used at the ‘enhancement’ levels of technology use. Participants in a study by Savignano (2017) agreed that the higher up the model educators integrated digital tools, the greater the learning outcome. However, Savignano conceded that educators most commonly integrated technology at the substitution level due to ease of swapping traditional tools for digital tools. Teachers struggled with reaching higher levels of integration, pointing to the need for further education and professional development as higher levels of technology integration force teachers to think differently about their practice and lesson delivery (Savignano, 2017). Improved professional development can aid in preparing teachers to design transformative lessons, giving students opportunities to achieve AOI.
Mobile technology can foster AOI in many ways. Bray and Tangney (2016) observed that the use of mobile technology has the potential to have a transformative impact on task design as it permits a more realistic, interactive, genuine problem-solving learning environment. Technology enables students to take ownership of their work, create knowledge, collaborate with others, and engage in the learning process (Savignano, 2017). Barlow et al. (2020) presented an example of this as technology was used to reaffirm student’s mathematical identities, allowing them to share their knowledge and achievements in mathematics. Providing students with the opportunity to develop and share their ideas, allowing for AOI, is important for the 21st century learner.

Transforming learning environments with mobile technology develops more interactive classes. Sulisworo and Toifur (2016) concluded that changes in learning environments and interactive learning applications affect the strategies and approaches to students’ learning, facilitating student success. Nonetheless, Savignano (2017) questioned whether all learning with technology should occur at the redefinition level of SAMR as the substitution level is appropriate for learning vocabulary and other basic knowledge. In conclusion, transforming the learning experience with mobile technology should be implemented where deemed most appropriate.

**Developing a Framework for Learner Control (T–AOI)**

The aforementioned studies stress the importance of purposeful integration to reach the highest level of SAMR. Technology can transform the learning experience through modifying and redefining the learning experience resulting in higher chances of incorporating student AOI (Bray & Tangney, 2016; Savignano, 2017; Sulisworo & Toifur, 2016). It follows then, SAMR (Puentedura, 2006) promotes a transformed
learning experience creating AOI (Schoenfeld, 2013), and allowing students to use the mobile technology most personal to them and their interests to expand far outside the classroom (Dias & Victor, 2017; Jou et al., 2016). This provides learners with an opportunity to take control of their own learning.

Collins and Halverson (2018) define learner control as placing students in charge of their learning as much as possible, so they take ownership and can follow their interests. Figure 2 shows the relationship between transformation with technology; agency, ownership, and identity; and learner control.

![Figure 2. A framework for learner control.](image)

Once the learning environment has been transformed with technology, students are given the opportunity for Agency, Ownership, and Identity (AOI) encouraging them to take control. When learners take control, different approaches to problem-solving through mobile technology can transpire.
What are Mobile Learning Benefits?

Some research suggests that mobile devices can be effective tools for learning by piquing students’ interest (Masterson, 2019; Sulisworo & Toifur, 2016). Studies have shown cooperative mobile learning improves student learning performance and allows educators to generate digital learning solutions that can be used anytime and anywhere, while remaining highly effective (Danka, 2020; Johnston et al., 2018; Jou et al., 2016; Sanabria & Arámburo-Lizárraga, 2017; Sulisworo & Toifur, 2016; Suparman & Sangadji, 2019). Thus, mobile learning motivates a student and enhances their experience and achievement both in and out of the classroom.

Jou et al. (2016) emphasized that developments in cloud technology have made it possible to utilize the Internet and smart handheld devices for performing various tasks (e.g., reading e-books and using apps). Mobile technology has positioned itself as a valuable tool for transforming traditional curricula and learning techniques in many ways through its accessibility, flexibility, and portability. Likewise, research has shown this technology supports effective learning, lower educational cost, improved retention, and performance-based assessment with rich technological resources (Blair, 2012; Johnston et al., 2018; Jou et al., 2016; Nikou & Economides, 2018; Sanabria & Arámburo-Lizárraga, 2017; Suparman & Sangadji, 2019). In conclusion, mobile devices are reaching students in ways never previously experienced.

With the rapid growth of mobile technologies, learning has developed in new ways, not only in the educational setting, but also in the workforce. Nikou and Economides (2018) insisted that with the rapid growth of mobile technologies and the extensive usage of mobile devices, there is a continuously increasing adoption of mobile
learning in educational settings. Further, Bring Your Own Device (BYOD) policies are
gaining popularity in both learning and working environments (Adams Becker et al.,
2017; Nikou & Economides, 2018; Welsh et al., 2018). Perhaps the greatest added value
of mobile versus desktop computer-based assessments lies in the ability to extend
classroom interaction to other locations while providing interactive, mobile, timely, and
integrated multimedia elements anytime and anywhere (Blair, 2012; Jou et al., 2016;
Suparman & Sangadji, 2019).

Conclusion

Around the world, teachers collaborate to develop curriculum and school-based
assessments in various ways including research projects and technology applications to
evaluate student learning (Darling-Hammond et al., 2017). Darling-Hammond and
colleagues acknowledged that teachers become more effective when they work in
collegial environments, resulting in the most powerful predictor of student achievement
over time. In a review of literature, Nikou and Economides (2018) reported more
research is needed with participants from secondary education, professional lifelong
learning, and teacher training. To further this claim, Dias and Victor (2017) argued that
teachers already deal with substantial challenges, but when provided with adequate
training and support, the challenges become less significant. Careful design in
professional development can transform the learning experience providing more
opportunities for student agency, ownership, and identity in the learning experience.
Educators must collaborate and teach the students of today in ways designed to best
prepare them for the future. Perhaps, then, students will begin to appreciate the beauty of
learning.
Chapter 3

Methodology

Barriers have interfered with the execution of technology in teaching and learning. Nevertheless, with increased availability of technology, personal relevance, and ongoing research on how to best utilize it in an educational setting, scholars are learning how to identify and overcome these obstacles (National Education Technology Plan [NETP], 2017). Transcending these impediments would, in turn, transform the learning experience, making course content more relatable to the 21st century learner (Periennen, 2020; Puentedura, 2006). The execution of technologies in the classroom can provide more opportunities for young scholars to achieve a sense of Agency, Ownership, and Identity (AOI).

I begin this chapter with a description of the research and a rationale for the chosen design. Following this description, I provide a brief overview of the selected case. In the subsequent sections I provide a detailed explanation of the instruments, explaining how these measures were used to provide valid and reliable data, while addressing the corresponding research questions. This section also outlines how I used the data sources to examine how mobile technology can transform the learning experience. Details of the data collection process are provided thereafter. Additionally, I provide a detailed review of the data analysis process. Finally, I conclude with ethical issues that I faced. I end the chapter with a summary of the research methods.

The Purpose and the Research Questions

This study analyzed how a Professional Development (PD) initiative influenced a secondary teacher’s technology use in mathematics. The PD encouraged collaboration
with the teacher and I, as the scholarly practitioner, to promote a high-performing system where we took advantage of each other’s knowledge and skills (Darling-Hammond et al., 2017). This illustrative single-case study was designed to answer the following primary question along with two secondary questions:

1. How does teacher participation in a Professional Development (PD) initiative influence (or shape) teacher implementation of mobile technology in teaching and learning?
2. How does a mathematics classroom teacher use mobile technology in the classroom before and after the PD initiative?
3. What is the teacher’s interpretation of their integration of mobile technology in building students understanding of mathematics?

The Design of the Research

An illustrative single-case study was chosen as the most appropriate design, offering a description of the process, granting more flexibility when working with the institution, and making changes where appropriate. A case study is an empirical inquiry used in many situations to investigate a phenomenon, or case, within its real-life context, and is prevalent in the research method in the field of education (Merriam 1998; Yin, 2014). Further, the boundaries between phenomenon and context may not be evident. Therefore, the case study is the examination of the particularity and complexity of a single case, where the case is an integrated system, coming to understand its activity within important circumstances (Merriam, 1998; Stake, 1995; Yin, 2014). Accordingly, the goal of this study was to understand how to make math relevant to the 21st century
learner through a teacher-centered PD initiative, promoting technology use, and providing a real-world perspective on its implementation in the classroom.

Yin (2014) expressed that the single-case design allows the researcher to have a deeper understanding of the exploring subject. Similarly, Stake (1995) advocated the emphasis on the uniqueness of the case itself by coming to know it well primarily as to how it is different from others. Further, Yin argued that a single-case design gives the researcher the opportunity to observe and analyze the phenomenon that is difficult to access for social science inquiry. Likewise, Merriam (1998) argued that the reader’s understanding of the phenomenon under study could bring about the discovery of new meaning, extend the reader’s experience, or confirm what is known. Considering the time constraint of this study, it would also have been difficult to align schedules and set up PD sessions for several teachers with different teaching approaches among the schools. Therefore, the single-case study enabled me to undertake a deeper investigation.

Another reason for conducting this single case study was to capture the teacher building upon and applying the skills discussed in the PD. Also, I had the opportunity to study the same single case at two or more different points in time (Yin, 2014). Studying the case at different points in time throughout the project as Merriam (1998) argued, allowed for more inquiry through our reflective process to better focus on the end result based on the opportunities the teacher provided. Yin considers this reflective process the common case as my investigation occurs in the real-world context to gain a deeper understanding of something that may not be readily apparent. I had hoped to see trends of this over time after the PD initiative had been implemented. In the future, the school and I plan to use this framework to improve the programs for all subjects, not just mathematics.
In this study, the problem to solve was the previous inability to redesign lessons to transform the learning experience with technology. Supporting Yin’s (2014) claim about the longitudinal case when a case is studied at different points of time, I reviewed recordings to help with discerning best practices necessary to improve the learning environment. It would have been difficult to uncover particulars transforming the learning experience with several participants so focusing on one case made this manageable. In addition, Tessier (2012) claimed recordings do not get damaged with time and backups are easily accessible. It may also be noted that software such as ATLAS.ti has been developed making it easier to find specific excerpts of interest to the researcher. Additionally, Tessier acknowledged that the data collected can be recycled for further analyzation in the context of this illustrative case study if deemed necessary. Considering my intention to continue working with the school, I could also use the data to revamp other courses within the school.

**The Limitation for the Research Design**

This study also came with its limitation: one participant. Though it may be difficult to generalize results from one participant, this study was designed for a single teacher in one school to gain a deeper understanding of the influence the PD had on his teaching practice (Queirós et al., 2017 & Yin, 2014). As single-case studies may not always follow a set of established procedures or may allow ambiguous evidence to influence the direction of the findings, it may be presumed this study needs greater rigor (Yin, 2014). To overcome this limitation, I ensured my findings related back to the impact of the PD through the different artifacts and field notes collected during the observed lessons. Additionally, field notes from the PD compared to the recorded
sessions confirmed the triangulation of findings. Further, the conversation guides that proceeded or followed an observation provided a path where necessary changes were made to help me, as the researcher, meet established procedures.

**Context of the Study**

The participating school in this study was a private institution in southeastern Ohio. According to Niche ([https://www.niche.com](https://www.niche.com)), there were 134 students in grades K-12 with a student-teacher ratio of 11 to 1. White students made up 97% of the population and African American students made up 3%. The population for the small town in which the school was located is 4,097, where 91.5% of the total population was white, 4.3% was black or African American, 0.1% was recorded as American Indian and Alaskan Native, and 4.0% is reported to be two or more races (United States Census Bureau, 2019). The median household income for the town was $26,729, and 31.9% of families were below the poverty line (United States Census Bureau, 2019). Consequently, the school did not have extensive technology resources. Given this limitation, this study serves as a model for other schools, to use available resources, promoting a more powerful classroom.

**Historical Context.** Prior to this study, the school had been working on new ways to enhance the mathematics learning experience for the students. My intention was to work with an educator who was a collaborator and willing to integrate technology into their curriculum. This educator did not have to be familiar with the technology discussed because the PD initiative allowed for time to learn and use the technology in their educational setting. As a former private school mathematics educator, I predicted this teacher had limited time to develop a mobile technology plan on their own. Thus, the participant would have benefitted from someone who could help research best and recent
practices for implementing mobile technology, promoting a transformed educational experience resulting in opportunities for students to achieve AOI.

**Selecting the School Site and Participant.** This study utilized a purposefully selected site sampling method including descriptions of the findings to analyze patterns within the data. I selected a school where technology was scarce, where teachers were willing to improve on their practice and work with readily available resources. The school I selected for my study was undergoing many changes as they were building from the ground-up during the COVID-19 pandemic. The school provided a favorable context for establishing a Professional Development (PD) initiative with the mathematics director to whom most of the mathematics responsibilities fell. My intention was to support the teacher to expand his knowledge on technology integration after engaging in one-to-one PD.

From the three potential participants available in the selected school, I chose to work with Mr. Fred Beasley—name chosen to maintain anonymity in this dissertation—because he not only taught the higher levels of mathematics in the secondary setting, but also had been working on a plan to improve the mathematics program. He had 16 years of IT experience connecting to his 14 years in STEM and was interested in developing instructional methods that employed smart devices with available technology tools. Also, as found in the literature, he had experienced PD that was not adequate in finding ways to implement technology tools, though he desired the support. Additionally, Mr. Beasley was willing to participate in PD toward the end of the school year. He was ready to provide attainable artifacts such as lessons plans, and schedules directly related to the
project, and in accordance with IRB protocols and procedures, signed a consent form after discussing expectations.

I developed a PD initiative promoting collaboration with Mr. Beasley regarding one of the courses he taught. Considering this, I studied the technology and improvements to which he had access to improve student learning. Focusing on one course allowed for more flexibility and reflection time to make changes where appropriate (Yin, 2014). Informing Fred’s journey on implementing higher levels of mobile technology, this study promotes opportunities for learners to achieve AOI and serves as a model for other schools to follow. Therefore, this examination could help other institutions by viewing this school’s approach to how to build a mobile technology initiative in mathematics.

**The Modern Learner.** The 21st century learner is surrounded by mobile technology. By age 11, 53% of students have their own smartphone (Rideout & Robb, 2019). Additionally, the PEW Research Center reports that 93% of low-income teenagers have or have access to a smartphone at home while 75% have or have access to a desktop or laptop computer at home (Anderson & Kumar, 2020). Even more, the United States Census Bureau (2019) divulges that 89% of households own a computer. Considering the availability of students owning mobile phones and computers, I anticipated the students in this private school also had access to mobile technology. I encouraged Mr. Beasley to implement a Bring Your Own Device (BYOD) policy as one had not already been established, so technology was readily available throughout the project. Since it is difficult for a teacher to change curricula on their own due to the pressures of the job as Carter and Crichton (2014) pointed out, I facilitated a PD initiative to reach the goal for
teacher-provided opportunities of using mobile technology to promote opportunities for AOI.

**Instruments**

Scholars at UC Berkeley and Michigan State developed the Teaching for Robust Understanding of Mathematics (TRU Math) suite of tools for teacher professional development and research. These tools, in addition to collected artifacts such as lesson plans, triangulated the data sources by providing insight to how the learning experience was transformed. Moreover, the data examined how the mobile technology transformed the learning experience promoting opportunities for AOI in the mathematics classroom (Bray & Tangney, 2016; Sulisworo & Toifur, 2016). Furthermore, I adopted instruments that had already been tested for validity and reliability (elaborated upon under “Validity and Reliability of the Data Sources”) and have been used by other researchers.

**Data Sources**

**Data Source #1: Conversation Guides.** This study used the Teaching for Robust Understanding (TRU) Conversation Guide to facilitate coherent and ongoing discussions in which Fred and I brainstormed together (Baldinger et al., 2016). These guides aimed to support educators with different strengths and experiences to work together collaboratively improving instruction and better supporting students to develop robust understandings (Baldinger et al., 2016). Also, the guides helped the educator to highlight the different dimensions of teaching that together build a strong classroom in which conversations were intended to promote reflective practice thus informing Research Questions 1 and 2.
The objective for the Conversation Guides were to highlight the Agency, Ownership, and Identity (AOI) dimension of the TRU framework while including questions that promoting the use of mobile technology in the classroom. Questions in the Conversation Guide (Baldinger et al., 2016) included what Mr. Beasley planned to do, my observation of what he transformed into practice, and finally my notes on what I observed. Herein, the teacher provided ideas on how he planned to implement the skills discussed in the PD initiative and how he utilized those skills. Considering this, the guides served as a reflective tool for the educator on his teaching to determine if he also believed he implemented the skills taught in the PD. Meanwhile, as Mr. Beasley reflected on his instruction to determine how he implemented the technology considered in the PD initiative, we also examined why he may have changed something from what was established in the PD to the execution of ideas in the lesson, furthering an answer to Research Question 2.

**Data Source #2: TRU Math Rubric.** In addition to Conversation Guides, a TRU Math rubric (Schoenfeld et al., 2014) was used to score observations of Mr. Beasley’s performance and the opportunities he provided in his mathematics classroom. The rubric was used for the AOI dimension of the TRU framework. This rubric aided Fred and me in building teaching practices, resulting in opportunities for him to create a more powerful learning environment for students. The more powerful the AOI, the more powerfully students emerged as thinkers and problem solvers (Schoenfeld, 2015) thus satisfying Research Questions 1 and 3. Additionally, this rubric was a scoring guide for me to determine how the educator in his mobile technology use in teaching and learning was influenced (Research Question 1). It was also used as a tool to measure the
opportunities Mr. Beasley provided in comparison to his interpretation of mathematics performance (Research Question 3).

**Data Source #3: Field Notes.** Field notes are an essential component of qualitative research. Qualitative research is often time-consuming and produces copious amounts of data useful to other researchers, so field notes were needed to preserve and organize observations and context (Phillippi & Lauderdale, 2018). Correspondingly, researchers are encouraged to take field notes to enhance data and provide rich context for analysis (Creswell, 2013; Lofland et al., 2005; Mulhall, 2003; Patton, 2002; Phillippi & Lauderdale, 2018). Thus, I took handwritten field notes during PD sessions and teacher observations which addressed Research Questions 1, 2 and 3.

**Data Source #4: Video Recordings.** A study has shown that nearly half to two thirds of data is lost when using field notes alone (Kieren & Munro, 1985; Tessier, 2012). Field notes cannot be replayed and are often incomplete or biased leading to a loss of information and valuable details (Tessier, 2012). In conjunction with field notes, video recordings were used to ensure my observations aligned with what the recording captured. Given this, the data sources complemented one another, once again, addressing Research Questions 1, 2 and 3.

Field notes and video recordings were used to answer the research questions to ensure the data collected from teacher reflections and researcher perceptions correlated. These were utilized in teacher observations when the educator taught his lessons. Additionally, field notes and video recordings were used during the PD sessions to develop the skills necessary to promote AOI through mobile technology. Furthermore, the notes and recordings confirmed the data collected from the conversation guides,
rubric, and artifacts while also providing valuable details that were not possible to collect through the guides, the rubric, and artifacts alone.

**Data Source #5: Physical and Virtual Artifacts.** Mr. Beasley’s project plans, curriculum, and examples were collected to add an important component in the overall case (Yin, 2014). In addition to teacher interpretation, this component demonstrated the difference the PD had on student learning through the opportunities Fred provided. He reported his class consisted of students of various levels which not only aided in determining the influence of the PD on provided opportunities for learning, but also informed the next instruction. Further, a thematic analysis was used to determine the influence of the PD on student learning in which the collected artifacts confirmed, thus answering Research Questions 1 and 3.

**Validity and Reliability of Data Sources**

Due to involvement with the field of work, the process of data collection and interpretation may have been potentially biased. Several criteria were considered for this study to ensure its validity and reliability. By fulfilling these criteria, it can be guaranteed that the research methodology was planned in a logical way, where all components related to each other allowing the investigation to be effective and the desired results to be achieved (Quintão et al., 2020). Additionally, recordings, observations, and tools already tested, ensured the validity and reliability of this study.

Accordingly, to ensure this study was reliable and valid, I recorded all sessions of the PD and took field notes when watching the recordings and while observing the teacher. I then reviewed the recorded PD session to ensure the notes taken during the PD initiative matched what I had observed. Specifically, I sought to find how Mr. Beasley
was applying the skills learned in the PD that promoted opportunities for AOI through the use of mobile technology.

A frequent criticism associated with case studies is their validity and reliability. The empiricism and subjectivism of the researcher, namely through their emotional involvement with the field of work, means that the process of data collection and interpretation may be potentially biased (Quintão et al., 2020). Since I was an active participant in the PD, it was important that I was not in solitude when scoring the observations. As Gold and Windscheid (2020) conceded, external observers often shed light on different dimensions of teaching quality and promote validity and stability of observer ratings. Given this, I asked another scholar of similar age and STEM experience in the same doctoral program, to grade Mr. Beasley’s lessons using the TRU Math rubric. Prior to grading, I provided a brief tutorial on how to use the rubric and the scholar determined the amount of Agency, Ownership, and Identity (AOI) opportunities promoted using mobile technology. Having another scorer in the same instructional technology program eliminates this bias and ensures the study was reliable as they could focus on the technology implementation.

To supplement recordings and observations, I used available tools that had been tested for reliability and validity by the developers of the tools. These tools were developed and refined through an irritative process involving a team of researchers to ensure the validity and reliability of the instruments. Also, the tools have been used in different studies and provided reliable and valid results (Coles, 2019; Karsenty & Arcavi, 2017; Menanix, 2015; Sayavedra, 2018).
Finally, I was not employed at the institution leaving little to no bias for or against the school. Further, interpretation of field notes and transcripts promoting insight into the meaning-making process may have been gained in the collaborative research (Paulus et al., 2010). Understanding the meaning may have helped unfold the qualities necessary to promote an effective teacher-centered PD initiative that provided opportunities for a more powerful classroom with mobile technology.

**Data Collection Process**

As the scholarly practitioner, I employed a thematic analysis to answer the research questions. Prior to implementing the PD initiative, I briefly met with the teacher to discuss his current practices and observed him in his traditional setting using the Teaching for Robust Understanding (TRU) Math rubric. Afterwards, I facilitated three PD sessions throughout the course of a six-and-a-half-week period. The goal of the PD initiative was to combine the Agency, Ownership, and Identity (AOI) dimension of the TRU framework (Schoenfeld et al., 2016a) and the transformation levels of the Substitution, Augmentation, Modification, Redefinition (SAMR) model (Puentedura, 2006) by mobile technology. Having this in mind, at each successive PD, the teacher-participant and I reflected upon the former training and implementation of ideas from the PD initiative to inform the next instruction. By doing this, an opportunity for me to determine if Mr. Beasley’s participation in the PD initiative influenced mobile technology use in his practice was created.

During the PD, handwritten field notes were taken in addition to a video recording. Specifically, I recorded the lesson and took field notes on what I observed. The purpose of the recordings was to note what I may not have addressed in the field
notes. I compared the field notes to the recording to ensure all details necessary for the study were included. Additionally, the teacher was shown the aforementioned rubric I used when observing each lesson to give him a better idea on practice. Ultimately, the field notes, recording, and rubric further demonstrated the implementation of the skills taught in the PD and whether the technology usage influenced opportunities for student learning.

This study exploited the use of TRU Math Observation Guides (see Appendix A) to support collegial observations of teaching by me, the researcher. The guides provided me with what to focus on in the AOI dimension of the TRU Framework (Schoenfeld & the Teaching for Robust Understanding [TRU] project, 2016b). Furthermore, this guide facilitated planning, observation, and collaborative reflections on instruction after each time the PD initiative was implemented.

Conversation Guides (Baldinger et al., 2016) were used before and after the observed lesson in the next phase of the study. This served as a basis for teacher reflection and assisted me in examining why there were discrepancies between what was established in the PD and the execution of the ideas in the lesson. Additionally, the Conversation Guides were used to determine if Mr. Beasley’s lesson plan aligned with how he and I interpreted the skills taught in the PD. Moreover, the guides were used to highlight the AOI dimension of the TRU framework while including questions that promoted mobile technology use in the classroom.

Furthermore, the Conversation Guides (see Appendix B) consisted of questions that guided me to prompt Mr. Beasley to reflect on his practice. I would ask him these questions and how he was changing his practice, giving him time to respond. These
reflective conversations would help us determine if the intended transformative technology practice discussed in the PD sessions occurred. Thus, through these guides, I could see how Fred intended to transform the learning experience with mobile technology.

In addition, the field notes I took were then be compared to what Fred reported, confirming the results provided from the field notes in the observed lessons. I had the project plan (see Appendix C), which was one of the collected artifacts, to consider where changes had been made and to serve as a source to how he planned to implement the skills taught in the PD. The rubric was then used to analyze the observed lesson and information provided by the educator from the Conversation Guides.

Following the initial Conversation Guide, Mr. Beasley then instructed the lesson utilizing the skills learned in the PD. Video recordings and handwritten field notes were also taken during the teacher observation. I ensured the notes followed a classificatory system so they could easily be used by an outside party (Yin, 2014). The field notes were documented following the main categories: Enhanced or Transformative use of technology tools, and the opportunities given to promote AOI in the lesson. These notes contained more information that a recording may not have captured including body language, drawings on the whiteboard, or technology used.

Once the lesson was complete, I then met with Mr. Beasley and used the Conversation Guide, again, as a means for him to reflect on his instruction. This provided a debriefing session with him to ensure I understood the objectives of the lesson, the purpose of the enacted activities, and his initial response to the lesson. This started the process as Fred would explain his rationale to the changes he made from the previous
conversation. It also addressed how well he was able to provide opportunities for AOI using mobile technology. In addition, physical and electronic artifacts such as lesson plans, curriculum, and examples were collected. Once the data were analyzed, the process was repeated twice.

As an active participant in the study, I aided the teacher in developing the math tasks. As a scholarly practitioner, I have received a depth of training in the thoughtful selection and implementation of technologies that I could use to support the teacher. I collaborated with the teacher to redesign lessons and assessments. Also, I supported the teacher to determine best practices for mobile technology use for his students.

In conclusion, each PD session was recorded and analyzed by me to ensure all details were captured. The recordings served as a source for researcher reflection for the next session. Additionally, I observed one lesson before the follow up PD session to inform the next instruction. Consequently, this provided an opportunity for me to interpret the decisions of the teacher in order to find the special meaning behind the progress in the students learning experience.

**Data Analysis Process**

Classroom observations were used to investigate if the teacher was reaching higher levels of Substitution, Augmentation, Modification, Redefinition (SAMR). This aided in determining if he was implementing the skills taught in the PD and how technology was being used to transform the learning experience. To analyze the classroom observations, I used a coding approach to determine if the level of technology usage was Enhancement (E)—a combination of Substitution (S) and Augmentation (A) levels—or Transformative (T)—the combination of Modification (M) and Redefinition
(R) levels. For example, if Mr. Beasley reported students were simply using their phones as calculators, the level would be recorded as an (E) level of technology implementation whereas a phone used to collaborate in different rooms to solve a problem dealing with map locations would be recorded as a (T).

These observations of the opportunities the teacher provided and learned from the PD initiative addressed Research Question 1 as they showed me how Mr. Beasley’s mobile technology usage in teaching and learning may have been influenced as a result of the PD. It also demonstrated how he was applying the mobile technology in the classroom after the PD satisfying Research Question 2. Thus, the coding approach on the TRU Rubric exposed the technology usage to provide opportunities for AOI, and whether the skills taught in the PD impacted Mr. Beasley’s technology practice.

In addition, the TRU Math rubric (Schoenfeld et al., 2014) was used to analyze the classroom videos and notes taken during classroom observation. Adaptations to the rubric were made to meet the theoretical framework used for this study, including the technology usage to transform the learner experience. Consequently, this rubric was used to inform Research Question 1 as I could see the changes in the opportunities provided to promote student Agency, Ownership, and Identity (AOI) with mobile technology throughout my observations (see Appendix D for TRU Math Rubric Results for Observations 1–3).

I also observed the recorded lectures. Further, to address interrater reliability, I sought an independent view of an additional scorer who already had basic knowledge of technology use and mathematics. This scorer participated in the same technology program as me and was involved in STEM education. To provide more specific
knowledge about the project, I provided a brief tutorial on how to grade the recorded teacher lesson using the TRU Math Rubric to avoid researcher bias. This scorer also coded the technology usage. Likewise, I looked at the different parts of the scores that I obtained from the classroom observation notes and recordings to see if the scorer selected the same results as me. Finally, the scorer and I discussed our results and discussed the discrepancies; thus, demonstrating reliability.

To gain an overall picture of the data collected in the Conversation Guides—the primary data source—I conducted a thematic analysis where I utilized a holistic coding approach, lumping the data (Saldaña, 2013). The approach helped me to become more familiar with the data and see overarching ideas that connected the data. I would consider entire paragraphs as I lumped the data to provide an initial summary of each paragraph. It also revealed gaps that needed to be addressed in the PD so Mr. Beasley and I could adjust our approach for the next instruction while revealing how technology was being used before and after each session. In conclusion, the lumping approach aided me with finding major ideas to start, prior to transitioning to a line-by-line approach that I used once my data collection was finished.

To further analyze the data, I used a splitting approach (Saldaña, 2013) for line-by-line coding using the ATLAS.ti program as a tool for a computer assisted qualitative analysis. This line-by-line approach gave me a deeper understanding of the data allowing me to map concepts, splitting the data into categories. I continued to revisit the data, connecting the categories until I could establish themes. The data is displayed through text and narratives (see Chapter 4). Additional data displays are included in Appendix D and Appendix F.
ATLAS.ti was the program chosen for its roots in grounded theory in qualitative research as a tool to support text interpretation (Muhr, 1991) and was used for coding the multiple forms of data collected. First, ATLAS.ti was used to code the information collected through the Conversation Guides. This informed me if Mr. Beasley was implementing the skills taught in the PD, informing Research Question 1. Additionally, ATLAS.ti was used for the TRU math rubric, video recordings, field notes, and artifacts collected to further confirm the themes uncovered from the conversation guides. This thematic analysis of the data confirmed an emergent pattern disclosing how the skills taught in the PD were being utilized and whether they were promoting a transformative classroom encouraging opportunities for AOI.

**Ethical Considerations**

To protect human subjects, I stored all collected data electronically in an approved university data repository. Approved university file storage, locations providing appropriate data security controls including encryption, authentication, and authorization were implemented to secure the collected data. Data was not stored on university owned nor personal owned computing devices. Apart from that, when transmitting the data, it was saved as an encrypted file. Further, the data was protected and accessed by the universities secure authentication methods approved by Computing and Technology Services (CTS). These approaches taken by me ensured that the data was secured and deleted after a three-year period.

**Research Methods Summary**

Thinking forward drove this study. The plan to achieve success in the classroom using mobile technology was intended to work beyond this dissertation. Many iterations
would be necessary to promote success among the different courses in the school, however, this study was designed to serve as an initiative to build upon with an illustrative, single-case study design. I began with a conversation followed by an initial observation of a teacher in a secondary mathematics classroom to shed light on his current practices. Then, the participant and I met to determine what was needed to meet the objective of the study: promote opportunities for AOI using mobile technology.

Observations, recordings, collected artifacts, and tools previously tested for validity and reliability by the developers were used as data sources for the study. After each observation, the teacher and I met to inform the next, best practices to apply. We met four times during a course of six-and-a-half weeks to provide a time of reflection. Used as a form of reflection and discussion of preliminary results, the final meeting was used to prepare for the next academic year.
Chapter 4

Thematic Findings

This chapter presents the findings of the illustrative case study. Prior to the discussion of the themes, I first provide a participant profile followed by a discussion of the themes that emerged after the data analysis process (see steps in Appendix E). For clarity and cohesion, I organize the results using the themes in relation to the research questions. Within each theme, I discuss how they relate to the research questions and the objectives of this study. The first theme is the most general as it describes the barriers the teacher faced when attempting to implement new technologies to reach his modern learners. The second theme describes the Professional Development (PD) initiative’s influence on the teacher’s practice. The final theme describes what occurred as a result of implementing mobile technologies to promote opportunities for Agency, Ownership, and Identity (AOI). Finally, I will end the chapter with a summary of how each theme relates to the research questions.

Participant Profile

Mr. Fred Beasley had been teaching courses in STEM for 14 years in private K–12 schools and was serving as the acting mathematics director. Most importantly, he had extensive Information Technology (IT) experience over the past 16 years. Accordingly, he considered himself an early adopter of new technology. I took advantage of his varied educational background as it aided in creatively integrating the ideas from our conversations to reach his modern learners. Also, as the mathematics director, he was centrally placed to build the mathematics program from the foundational level.
I held an initial conversation with Mr. Beasley and the school leaders to determine the current atmosphere of the school’s teaching practices, and to share the goals of the study. The conversation focused on Fred’s teaching approach, technology integration, and types of activities utilized in the classroom. Informed by Puentedura’s (2006) SAMR model, I provide a categorized summary of the applications and hardware discussed throughout the data collection process (see Table 1).

**Table 1**

**Technologies Discussed**

<table>
<thead>
<tr>
<th>Technology or Application</th>
<th>Type</th>
<th>Intended Use</th>
<th>Report of Use</th>
<th>Level of SAMR</th>
<th>Enhance or Transform</th>
<th>Was the Technology Observed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desmos</td>
<td>Application</td>
<td>Graphic Calculator</td>
<td>No</td>
<td>A</td>
<td>E</td>
<td>No</td>
</tr>
<tr>
<td>Open Boards</td>
<td>Application</td>
<td>Exporting Class Notes</td>
<td>No</td>
<td>S</td>
<td>E</td>
<td>No</td>
</tr>
<tr>
<td>Jamboards</td>
<td>Application</td>
<td>Virtual Collaboration</td>
<td>No</td>
<td>M</td>
<td>T</td>
<td>No</td>
</tr>
<tr>
<td>iPads</td>
<td>Hardware</td>
<td>Mobile Application</td>
<td>Tried</td>
<td>R</td>
<td>T</td>
<td>No</td>
</tr>
<tr>
<td>Tynkercad</td>
<td>Application</td>
<td>3D Design</td>
<td>Tried</td>
<td>R</td>
<td>T</td>
<td>No</td>
</tr>
<tr>
<td>Smartboard</td>
<td>Hardware</td>
<td>Whiteboard</td>
<td>Used</td>
<td>S</td>
<td>E</td>
<td>Yes</td>
</tr>
<tr>
<td>Google Classroom</td>
<td>Application</td>
<td>LMS</td>
<td>Used</td>
<td>A</td>
<td>E</td>
<td>Yes</td>
</tr>
<tr>
<td>Chromebook</td>
<td>Hardware</td>
<td>Word Processor, Remote Learning</td>
<td>Used</td>
<td>S</td>
<td>E</td>
<td>No</td>
</tr>
<tr>
<td>Technology or Application</td>
<td>Type</td>
<td>Intended Use</td>
<td>Report of Use</td>
<td>Level of SAMR</td>
<td>Enhance or Transform</td>
<td>Was the Technology Observed?</td>
</tr>
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</tr>
<tr>
<td>Google Suite</td>
<td>Application</td>
<td>Remote Learning</td>
<td>Used</td>
<td>A</td>
<td>E</td>
<td>No</td>
</tr>
<tr>
<td>Chromebook</td>
<td>Hardware</td>
<td>Search Engine, Sketchup</td>
<td>Used</td>
<td>R</td>
<td>T</td>
<td>Yes</td>
</tr>
<tr>
<td>Sketchup</td>
<td>Application</td>
<td>3D Design</td>
<td>Used</td>
<td>R</td>
<td>T</td>
<td>Yes</td>
</tr>
<tr>
<td>Smart Phone</td>
<td>Hardware</td>
<td>Mobile Application</td>
<td>Will Use</td>
<td>R</td>
<td>T</td>
<td>No</td>
</tr>
<tr>
<td>Sketchup Mobile Viewer</td>
<td>Application</td>
<td>Augmented Reality</td>
<td>Will Use</td>
<td>R</td>
<td>T</td>
<td>No</td>
</tr>
</tbody>
</table>

*Note.* This table demonstrates the data to suggest the different types of technology the considered (top), reported to be used throughout the project (middle), and planned to use after our last conversation (bottom).

a Puenteurda’s (2006) hierarchy model of technology usage in the learning environment: Substitution (S), Augmentation (A), Modification (M), Redefinition (R)

b Enhancement: First two levels of SAMR (Substitution, Augmentation)

c Transformation: Last two levels of SAMR (Modification, Redefinition)

According to Mr. Beasley, not all technologies discussed were implemented in lessons. Instead, the plans were selected and adjusted to meet the needs of his students. Furthermore, I include a column to show the technologies I anticipated him using as he continued the project after the final exam period.

**How do the Thematic Findings Answer the Research Questions?**

The data, which includes conversations with the teacher, classroom observations, and teaching artifacts were examined to determine themes, patterns, and relationships. These findings are organized using the TRU (Teaching for Robust Understanding) Math
and SAMR (Substitution, Augmentation, Modification, Redefinition) models to analyze the influence of a PD initiative on one teacher’s technology implementation in teaching and learning mathematics. After the analysis process, the three major themes in this study are presented in this order: teacher workload, shaping teacher technology implementation, opportunities for learner control. These themes aided in answering this study’s research questions: (a) How does teacher participation in a Professional Development (PD) initiative influence (or shape) teacher implementation of mobile technology in teaching and learning? (b) How does a mathematics classroom teacher use mobile technology in the classroom before and after the PD initiative? (c) What is the teacher’s interpretation of their integration of mobile technology in building students understanding of mathematics?

**Theme 1: Teacher Workload**

Theme 1, Teacher Workload, highlights barriers teachers are likely to face when designing lessons emphasizing time constraints, changes in technology, and this teacher’s challenge in finding ways to engage learners. This school was starting from the ground-up and learning new approaches to teaching and learning that worked for them. When asked about schedule changes, Mr. Beasley stated, “…we’re a new school to some degree…so we’re just learning the vibe and trying to figure things out here.” Learning new methods during the COVID-19 pandemic made it difficult for him to utilize his intended teaching approach. This leads to the first theme that emerged from the data—the size of the workload the teacher must balance, which speaks to two of the questions I was exploring.
The question I will answer first in relation to Theme 1 describes how Mr. Beasley used mobile technology before and after the PD initiative (Research Question 2). This question was answered through our reflective conversations, TRU math rubric scores, and my observations.

**The Reality of Time Constraints.** Mr. Beasley conveyed that the obstacles he faced caused time constraints for using technology effectively. In our initial conversations, he described his full schedule and how one of his IT periods became a study hall, occupying time normally used to complete his duties. He described his envisioned lessons, but due to time constraints, he could not focus on improving his approach to teaching and learning. Consequently, he stated, “That’s the plan, but I can't be the IT guy and do that, so I am trying to find the grounds to not be the IT guy anymore.” Further, he mentioned on multiple occasions that “schedules would change in less than a minute’s notice.” With little time to explore, Fred struggled to find ways to use mobile technology in a transformative way that appropriately challenged his learners.

Given the demanding schedule of balancing his multiple roles in the school, Fred stated, “I can’t fully devote on what needs oversight.” He found himself struggling to find time to carefully plan lessons and address student needs. He expressed that it was more difficult to get to know his students in times of remote learning, so he tried to schedule meetings with them individually. Mr. Beasley would also survey his students frequently to gauge his lessons’ difficulty and effectiveness. With his different roles and balancing the additional workload that accompanies a pandemic, he expressed how much he wished he could have challenged his learners more by stating, “Project-based learning is good fun; I’ve done very little of that this year, though I wish I could have done more.” This
aligns itself with research demonstrating that teachers have demanding schedules and may have difficulty balancing multiple roles due to competing demands and time constraints (Merritt, 2016; Snyder & Bae, 2018; Teig et al., 2019).

**Technology Integration Before and After the PD.** In our preliminary discussions on mobile technology use, Mr. Beasley expressed his concern for his current technology integration practices challenging his diverse audience as “It wasn’t hitting up as far as their abilities, their skills.” I was able to confirm current technology usage in rubric scores (see Appendix D) and my observations, recording how the technology was used to perform calculations (i.e., replacing calculators) and the electronic whiteboard (i.e., replacing the chalkboard) resulting in lower levels of Blooms: Remember, Understand.

During times of remote learning, Mr. Beasley indicated his class’ technology use did increase, but he struggled to engage his learners. He mentioned he “tried some hybrid things” and flipped classroom approaches but “sometimes they [students] tend to be a little bit less responsive.” Though technology promoted more availability when it came to viewing lessons, by posting them on YouTube and allowing time to schedule meetings with the teacher, Fred reported “most of them [students] just didn’t really respond. If forced, they would reluctantly show up.” When planning on his own and keeping an open mind to alter his approach to teaching and learning, he found himself struggling to reach his students.

After discussing the importance of technology to reach modern learners, Mr. Beasley reflected on how to alter his approach to engage his learners. We considered ways to use the project-based approach he wished he could utilize, especially in the
current era requiring much flexibility and patience. Our conversations centered on ways to integrate readily available technology that students could take home with them. We speculated these mobile opportunities would have allowed students to continue what they started in the classroom in the event of another shutdown.

The curricula Mr. Beasley used was not customized to his learners, which led to reflective discussion in finding ways to use available mobile technology. We started our discussion on projects for the iPad as students could easily transport this hardware home. With this in mind, we discussed the geometry concepts his learners were approaching and how TynkerCAD would have been a perfect application, as it contained a user-friendly interface with an Augmented Reality (AR) feature. We discussed how AR would promote opportunities for AOI in student projects and make the mathematics come to life for them, making it their own.

After the project was underway, we found that Mr. Beasley could not implement the 1:1 iPads as initially intended. To transform the learning experience, Mr. Beasley wanted to include the Augmented Reality (AR) portion of the project to bring the mathematics to life. However, he found the iPads were too old to be updated to run TinkerCAD; yet another obstacle he needed to overcome. Considering this was a Google School, we examined the Google Suite.

After reflective discussion, we chose to use Google’s application, SketchUp. This application was more cognitively demanding than TynkerCAD but it could be used on Chromebooks, another piece of hardware available to each student, and it included an AR component accessible on a smartphone. Given this, Mr. Beasley and I considered approaches to use this to our advantage and reach the goals we set. In addition, being a
Google school, Fred acknowledged it was “free, so the price is right.” Finding free applications to transform the learning experience while not adding additional frustrations can be daunting for teachers (Collins & Halverson, 2018; Ertmer, 1999). So, we decided it was the perfect technology to use for our purpose to promote AOI. In conclusion, though Fred was able to adjust his approach with researcher intervention, he added to his workload by scheduling time with me to alter his approach in hopes of better engaging his students while still balancing changing schedules, different roles, and overcoming new obstacles in planning ways to use available technology. This change in utilizing available technologies after the PD initiative aligned with Research Question 2.

**Learner Centered Technology Integration.** The first theme, Teacher Workload, also informed the research question that stresses the teacher’s interpretation of how his mobile technology integration aided in building student understanding of mathematics. Understanding students’ backgrounds and interpreting how they responded shaped Mr. Beasley’s plans for future lessons, resulting in a higher workload.

Getting to know students had been a challenge throughout the school year. Mr. Beasley expressed early in our conversations, “I’m trying to assess a little bit. I haven’t really had enough time to really assess individual learning…this year is kind of a downer, it’s the nature of the year but just trying to see where things are.” In addition, his students came from a mathematics background of “see, get, repeat, done.” He could not simply focus on teaching the topics at hand as he would find himself reviewing content with which students should have already been familiar. He reported that when he would challenge his students to think critically and apply the mathematics concepts, “it’s a big step for some of those kids…with word problems, they can’t conceptually analyze, they
can’t put words into numbers and proceed.” Mr. Beasley relayed in our second conversation that his students did not view themselves as mathematical thinkers. However, he noted in our fourth conversation that this started to change once students were given opportunities to create their own projects and use technology in a meaningful way.

Scores from the TRU Math observation rubric revealed that Mr. Beasley provided more opportunities for AOI. Technology was not only being used to “aid in building students’ knowledge in application and analyzation,” but was also used to “pay explicit attention to accuracy, catch mistakes…and correct errors resulting in the highest levels of Bloom’s (1956) hierarchy of learning”. I noted how he would “prompt his students to explain their ideas and reasoning further” and “encouraged students to help one another.” Mr. Beasley recognized that the students were beginning to view themselves as mathematical thinkers as they were the ones “doing all the learning.” Although technology made this possible, it was still burdensome on him as he tried to find different ways to engage the learners. However, allowing for teacher reflection made possible a transformational learning environment which Mr. Beasley believed aided in building student understanding of mathematics complementing Research Question 3.

**Theme 2: Shaping Teacher Technology Implementation**

The second theme that emerged from the data was the shaping of the teacher’s technology implementation through the Professional Development (PD) initiative. Theme 2 discusses enhanced and transformative uses of technology integration followed by technology uses before and after the PD initiative. This theme aligns to the first two
research questions posed in this study. The following will describe the findings from this study, joining the second theme with these questions.

The first research question related to shaping of a teacher’s implementation of mobile technology in teaching and learning through a PD initiative. As the goal of the PD was to find ways to change a teacher’s technology practice to promote Agency, Ownership, and Identity (AOI), this question was answered through reflective conversations, observation rubric scores, and my observations which included field notes and recordings.

**Technology to Enhance the Learning Experience.** Mr. Beasley had expressed interest in using mobile technology to meet the diverse needs of his students, however he could not research new approaches on his own. Given the additional demands of the COVID-19 pandemic, Mr. Beasley had little time to find new, innovative ways to integrate mobile technology into his lessons. Initially, when asked about his usage and acceptance of mobile technology, it was evident that technology was generally used as a form of enhancement in his classroom as it merely substituted or augmented the learning experience (Puenteđura, 2006).

We just got them [Chromebooks] out to high school and things like that, so Google Classroom is where the most integration is right now. English class, primarily papers, research, things like that. In math, not yet because I’m trying to find some decent extension things to use.

Even throughout other course work, students were using technology as a means of simply enhancing the experience through word processing and search engines, rather than using technology to transform their learning endeavors.
Mr. Beasley made various attempts to implement technology, but encountered frustrating obstacles, sometimes forcing him to give up due to limited time. He revealed in our conversation that his students were “more of the social type” as they enjoyed face-to-face communications combined with social media on their devices. Given this, we discussed how he had tried to use communicative technologies, especially in times of social distancing, but encountered much frustration.

Provided this was a Google school, Jamboards were discussed, and Mr. Beasley expressed his frustrations: “I just don't like the way Jamboard works in real time. I find it [the lag in real time] immensely frustrating…” However, he acknowledged that some form of chat feature would be of great use in the classroom by continuing, “…but in sharing information, thoughts, ideas, it’d be very useful; people doing things at the same time.” Communicative technologies may have frustrated Fred in the past, but our discussions helped him reflect upon and think about better ways to reach his social learners.

Mr. Beasley expressed a desire to further explore other communicative technologies (i.e., Open Board) he has tried in the past. In our second conversation, he stated, “I liked the functions better than the SmartBoard sometimes…you’re not plugged into a SmartBoard.” However, he continued to reflect on Open Board’s use stating, “I don't know if there's a real time function with it as I have not fully explored it yet.” Fred indicated, in many cases, he did not believe he had the opportunity to explore the full potential of the intended technology, so he shelved the idea for the time being. These instances continue to point to the first research question in which the conversations were helping Mr. Beasley, shape his instructional practice.
Technology to Transform the Learning Experience. After the first two conversations, Mr. Beasley was beginning to implement ideas discussed in the PD initiative, thus shaping his teaching practice. He reported that students began using their mobile technology to research, create, explore, and utilize other functions of Google’s application, SketchUp. The technology allowed him to act as a facilitator as he was “giving very little direct instruction” while only slightly prompting his students. This provided opportunities for students to research mathematical topics and ideas, owning them, something he struggled to make happen before.

Technology implementation allowed for more opportunities for students to research topics in class to complete their assignments. Mr. Beasley reported in our third conversation that his students had a “chance to research a little bit and look into things.” This was confirmed in the third observation as I noted he was “encouraging his students to be creative” and “to think carefully about what was presented in front of them and how to make what they had work.” Learners were given opportunities for self-guided research that were not available before.

During the second observation, I noted Mr. Beasley running around helping students, though he was not able to reach everyone as they were spread out due to COVID-19 social distancing protocols. Communicative technologies were again discussed to increase efficiency, enabling him to better assist students in need. Though he did not employ blog features, he noted how beneficial it would be, stating, “if we do an assignment, there's a question-answer session segment part that’s automatically generated which could be used for something like this [the project developed through this PD].” A
blog feature would allow an open forum for his students to discuss and share ideas in real-time in addition to backchanneling, if needed.

The final conversation took place after the third observation. I asked Mr. Beasley how he thought his teaching practice had been shaped throughout the project to confirm my own observations. He reported “I spoke to them [students] individually or to a small group; very little coming up here [pointing to the board in the front of the room]. In the first day or two I was up here.” Mr. Beasley was able to take a step back to answer questions while walking around the room as students explored their Sketchup creations, acting as a facilitator without the need to prompt them. Even more, the scores in the TRU Math rubric from the third observation for technology usage (see Appendix D) improved from an E [Enhancement] to a T [Transformation] as Fred’s practices changed.

I also noted that there was still no chat feature implemented into observed lessons, so in the final reflection, I asked how Fred had implemented a chat feature, which we had previously discussed. However, this was not implemented at this time, as he felt it would feel forced. He stated:

Chat in the future. The way things are just happening, kind of organically, I wanted to let that keep fostering. I didn’t want to do anything that would, uh, almost feel forced if I changed things up…but for future ones [projects], I’m going to incorporate that at the beginning.

Mr. Beasley continued to reflect on how to better his practice. He also noted his plan to have students use the AR in the SketchUp application on their smart devices once they were finished to further promote AOI.
Trends emerged from these conversations. As the goal of the PD was to shape technology implementation in a transformative way to promote AOI, Mr. Beasley’s emphasis on implementation and reflection rather than intention made changes in teaching and learning possible throughout the PD initiative. This informs Research Question 1.

**Technology Use Before and After the PD.** The second research question describes how the teacher used mobile technology in the classroom before and after the PD initiative. As many of the conversations aimed to change mobile technology through researcher intervention, Mr. Beasley also reflected on how he was going to use the technology in the future. Based on our conversations, there was a change in mobile technology use in the classroom.

Throughout our conversations, Mr. Beasley disclosed the school had access to the Google Suite because they “wanted to go beyond the Google Classroom…they [Google] are rolling out with more and more stuff.” Given this, I wanted to know specifically how he had been using the technologies that were already available to him. Fred reported he used Google Classroom for “some instruction, secondarily for a little assessment.” The first observation confirmed that Mr. Beasley was using his Google Classroom as more of a portal where he could share documents with students. So, though he had access to the entire Google Suite, he was mostly using it to share files and hold lectures via video conference. These technologies replaced traditional materials and activities, serving as a form of enhancing the learning experience (Puenteruda, 2006; Terada, 2020).

The school provided 1:1 Chromebooks for students. Mr. Beasley expressed he did not use the Chromebooks in his mathematics course often once he and his students
returned to in-person instruction. However, when he did utilize Chromebooks in his class, he reported in the initial conversations that they were being used mostly as an online graphing tool, “but other than that, not too much yet.” Based on the conversation, it was evident how this was his primary use of technology to transform the learning experience prior to the PD initiative.

One of my goals in each of the conversations was to discuss how Fred could provide transformational learning opportunities for his students using attainable technologies. He concluded in the final conversation that his students were using their Chromebooks and other mobile devices such as smartphones and iPads for more than the Sketchup application by stating, “they are now researching on their own.” Students were using their devices to explore additional information on their own, which they had not before.

It was evident Google Classroom was being used to promote more opportunities for students to share resources. Mr. Beasley indicated his students were using Google Classroom to share information to help one another with the project. He stated, “It was there to incorporate, so it kind of worked that way organically, which I like. They could work well organically and let it flow.” Fred was open to students using the technology available and believed it helped create the social atmosphere he preferred. My observations and TRU Math scores confirmed this. Discussions and reflections were helping the teacher find ways to provide opportunities for students to apply technology to mathematics lessons. These uses of technology indicate how Fred used mobile technology before and after the PD initiative answering Research Question 2.
**Theme 3: Opportunities for Learner Control**

The final theme that emerged from the data was the opportunity for learner control. This theme, Theme 3, concerns Mr. Beasley’s experience with teach digital natives, his interpretation of students building understanding of mathematics with mobile technology, and how he provides opportunities for Agency, Ownership, and Identity (AOI) with mobile technology. This corresponds to two research questions posed in this study. These questions were answered through reflective conversations, my observations, observation rubric scores, and artifacts.

The first research question addressed teacher participation in a PD initiative and how it influenced a teacher’s implementation of mobile technology in teaching and learning. As Mr. Beasley was instructing 21st century learners, many of our conversations focused on how to adjust his approach to reach his digital natives (Prensky, 2001).

**Teaching Digital Natives.** The PD initiative was constructed around conversations that aided in teacher reflection and discussion with the researcher. As Mr. Beasley described his students, it was clear they had qualities of 21st century learners as they were “natural collaborators” and were “creative.” Prior to our discussions, he felt he needed to stick to direct instructional methods as it was the easiest way for him to catch up after falling so far behind due to the COVID-19 pandemic. Our conversations provided time to bounce ideas around and think about how to better reach his students. These conversations led to a project with open-ended expectations to promote his students’ creativity. Directions for the project can be found in Appendix C. Additionally, Fred explained the expectations he relayed to his students:
I want you to do the space dimensions. I want you to put in three things. I want to see a green house space, and I want to see some seating and a multipurpose type area. That can mean what you want it to mean. You can add additional things and be as creative as you want to be.

What was once explicit and highly teacher-driven became more ambiguous and student-driven. Fred provided opportunities for students to learn beyond direct instruction as he expressed in our final conversation that he “gave them [students] no real big examples.” He simply demonstrated how the application used for the project, SketchUp, functioned and encouraged his students to “look online to find some things.” This practice allowed for student-led learning.

Providing opportunities for the students not only helped them learn and explore new concepts and ideas, but it also allowed Mr. Beasley more time to spend with them, helping as needed. In other words, he provided students with the minimum assistance they needed to learn on their own (Jackson, 2009). Fred appeared to be relieved that his students were doing much of the work. He reflected on how less time spent lecturing allowed him to let students work on their projects both in and out of class. He stated in the third conversation, “Hey, it takes class time. I didn’t have that and I’m not gonna need to hold a kid’s hand if they can already get up and walk, so why follow them? They are technical.” Because Fred’s students were technical, they were also excited to share their experiences with classmates outside of geometry as Fred reported in our final conversation: “my 8th grader is demonstrating Sketchup with her friends who are not in this class.” This embraced the goal of the PD initiative which gave the teacher ideas for
how to implement technology (Research Question 1), enabling opportunities for learners to take control.

**Building Understanding with Mobile Technology.** The third research question emphasized the teacher’s interpretation of his integration of mobile technology in building students understanding of mathematics. Throughout our discussions, Mr. Beasley expressed how his students responded to a less structured classroom as it gave them “a chance to respond quickly, in a more casual way, and also for a chance to express their thoughts.” According to Fred, this is when his students were the most responsive. Given this, there were many instances in our conversations in which Fred and I discussed how he could use the available technology to aid in building student understanding of geometry.

With a classroom full of 21st century learners, Mr. Beasley was not only interested in using technology available to his students, but also wanted to use technology in a meaningful way (Collins & Halverson, 2018; Darling-Hammond et al., 2017, Jackson, 2009). From his perspective, using the technology in a meaningful way encouraged the students to explore unfamiliar mathematics topics. Though students were not using mathematics jargon, Fred reported in the final conversation that “they are getting better over time, but the ideas are still there.” Even though students were not using the actual language, they were still learning mathematical ideas in the process.

Field notes from the final observation, which included student presentations of their final projects, showed how Mr. Beasley would prod his students only slightly and further explain the mathematics they encountered when presenting. During our final conversation after the final observed lesson, Fred expressed that the technology allowed
to “move them [students] towards the thought of thinking” about the math concepts. He also reported that the project allowed for his students to think in a more abstract manner. This was a shift from our initial conversations as Fred did not previously believe his students viewed themselves as powerful mathematical thinkers and problem-solvers complementing Research Question 3.

**Promoting Agency, Ownership, and Identity with Mobile Technology.** In both conversations and researcher observations, it was evident that students were more engaged and excited to learn the technology as “class was more active.” Fred provided opportunities for students to share their ideas and creations with student presentations. I noted from the final observation that the teacher “extracted answers from the students as they were presenting, providing opportunities for the students to own their ideas, share them [presentations] with their classmates, and encourage them [one another].” He also had his students explain reasoning behind their decisions while presenting, pushing a sense of agency, expressing their creativity. Further, Fred noted in our final conversation that his students achieve better when they can look at their final projects and see how they “used math to accomplish this [the project]” which he believes could be a link to success.

My observations revealed that Mr. Beasley was providing more time for students to actively engage in class, rather than passively watching him lecture. When asked if he thought students were doing most of the work, he reported in our fourth conversation, “I gave them no real big examples. I showed them how the program works, how it functions…You can look online to find some things. Go! Play! Have fun!” showing how he shaped his practice from a direct approach to a facilitating approach. Additionally, Mr.
Beasley’s project plan (see Appendix C) was not full of detail. When asked, he reported these directions were meant to be open to students’ interpretation as “You can add additional things, be as creative as you want to be.” Mr. Beasley was promoting more opportunities for creativity through mobile technology reaching higher levels of Bloom’s taxonomy (Bloom, 1956).

Mobile technology allowed opportunities for students to help one another and share their creations with classmates outside of Geometry class. Mr. Beasley reported in our final conversation “It’s giving a chance to go out, explore, be creative with their minds, and play around, which is fun.” What is more, his interpretation of students building an understanding of mathematics concepts was shaped through them becoming more inquisitive, promoting a change in how they viewed themselves as thinkers and problem-solvers. He acknowledged his learners were taking control of their own learning as there was very little from him and “it was all of them doing the stuff.” This continues to show how mobile technology allowed Mr. Beasley to provide opportunities for AOI resulting in his interpretation of students taking control of their own learning, building an understanding of mathematics (Research Question 3).

**Summary of Results**

A thematic analysis was used to find three major themes: *teacher workload*, *shaping teacher technology implementation*, and *opportunities for learner control*. Excerpts related to these major themes can be found in Appendix F. Correspondingly, these themes were organized to describe causes of the teacher’s lack of technology implementation, the shaping of a teacher’s practice, and what happened as a result from the Professional Development (PD) initiative. The PD sessions were structured using the
Teaching for Robust Understanding (TRU) Conversation Guides developed by Baldinger and team (2016). Our conversations helped the participant reflect upon the best approaches to reach his 21st century, social learners. These conversations were coded using ATLAS.ti.

The participant faced obstacles on his own. The PD initiative made time available for the teacher to reflect upon his practice and provide opportunities for Agency, Ownership, and Identity (AOI), which answered Research Questions 2 and 3. Additionally, the PD initiative helped shape the teacher’s practice by finding ways to effectively implement mobile technology into mathematics topics, which informed Research Questions 1 and 2 as the analysis showed the change in practice. Finally, transforming the learning experience with mobile technology opened opportunities for learners to take control of their experience, which answered Research Questions 1 and 3. Though the participant encountered obstacles (teacher workload), the thematic analysis confirmed that the PD empowered the teacher to shape his practice (shaping teacher technology implementation). The resulting transformational application use resulted in opportunities for learner control.
Chapter 5

Discussion, Implications, and Recommendations

There is need for studies to investigate how mobile learning can be used to promote higher levels of thinking, as the barriers teachers encounter make pedagogy difficult to change (Collins & Halverson, 2018; Crompton et al., 2018; Ertmer, 1999). Professional Development (PD) can alleviate some of these pressures. However, the present PD initiatives have not been adequate to support teachers when integrating technology in teaching and learning (Lang et al., 2017; Patterson & Han, 2019). This study investigated how mobile learning was utilized to engage students’ higher-level thinking.

The specific purpose of this study was to analyze how teacher participation in a PD initiative impacted mobile technology implementation in teaching and learning. In this chapter, I describe the influence the PD initiative had on a teacher’s instructional practice with mobile technology. Using Puentedura’s (2006) Substitution, Augmentation, Modification, Redefinition (SAMR) model and Schoenfeld and colleagues’ (2016a) Teaching for Robust Understanding (TRU) Math framework, this illustrative, single-case study builds on these theories and the importance of effective PD. I conclude with implications and recommendations for theory, research, and practice followed by connections to my scholarly practice.

Synopsis of Major Findings

The data analysis process was framed by the following questions: (a) How does teacher participation in a Professional Development (PD) initiative influence (or shape) teacher implementation of mobile technology in teaching and learning? (b) How does a
mathematics classroom teacher use mobile technology in the classroom before and after the PD initiative? (c) What is the teacher’s interpretation of their integration of mobile technology in building students understanding of mathematics?

Teachers often struggle with time constraints, preventing them from using technology effectively. Respectively, the COVID-19 pandemic added additional pressures to the teacher-participant’s practice. For example, students were disengaged, and the teacher’s schedule would change daily, making it difficult for him to plan lessons rich with technology, encouraging higher-order thinking. Prior to the PD initiative, the teacher tried to implement technology, but did not have time to research transformational ways it could be incorporated.

The teacher participating in this study showed an overall positive change in shaping his implementation of mobile technology. A major finding to address Research Question 1 is that technology was typically used to enhance the learning experience by merely substituting for traditional practices such as taking notes. However, through a PD initiative, the participant was able to set aside time to reflect upon his current practice and plan ways to transform the learning experience, making mathematics more relatable to his students. He learned how to provide opportunities for Agency, Ownership, and Identity (AOI) by letting the students do the work while he acted as a facilitator, resulting in opportunities for students to take control. This process of shaping the teacher’s mobile technology practice through a PD initiative informs Research Question 1.

Another major finding is that the PD initiative provided time for the teacher to reflect upon his practice which aided him in finding ways to shape his mobile technology implementation however, he had to be flexible. This study demonstrates the importance
of flexibility. The school could not afford to update their iPads, so the participant and I had to reconsider our initial plan. Mobile phones and Chromebooks made this project and the provided opportunities possible as learning could be taken outside the classroom and students could use the technology that was personal to them. The teacher-participant reported mobile technology was being used in transformative ways that were providing opportunities for learners to think creatively. In the project developed through this PD initiative, learners were given the opportunity to use their mobile technology tools to make abstract concepts visible in a hands-on, responsive way. This occurred through Google Sketchup and other multimedia technologies to better understand dilations and transformations informing. These examples of technology use after researcher intervention through the PD initiative complements Research Question 2.

A major finding to address Research Question 3 was that though students were not using mathematics language, the teacher reported the students were, in fact, learning the concepts and applying the ideas to their projects. Students were exploring ideas that the teacher would have lacked time to discuss in class. With the teacher now acting as a facilitator (Research Question 1), he had more time to expand on topics the students investigated. According to the teacher-participant, students became more active and masters of their own knowledge. What was once a classroom full of teacher reported insecure, passive robots became a classroom with students beginning to view themselves as thinkers and problem-solvers, excited to share their knowledge with others once again, satisfying Research Question 3.
Findings Related to the Literature

In this study, I observed how a teacher’s technology implementation was developed, and how it contributed to building a robust understanding of mathematics amongst the students. The findings suggest that intervention and collaboration shape a teacher’s mobile technology implementation even through difficult times informing Research Questions 1. This aligns with the literature as effective schools who support emerging technologies provide time and opportunities for collaboration (Collins & Halverson, 2018; Darling-Hammond et al., 2017).

This study serves as an example of how a PD initiative supported by Puentedura’s (2006) SAMR model and Schoenfeld’s et al. (2016a) Agency, Ownership, and Identity (AOI) dimension of the Teaching for Robust Understanding (TRU) Math framework can influence change in instructional practices. Given findings related to the literature, data suggests that using guides centered on the AOI dimension of the TRU Math framework did accentuate the teacher’s past experiences, knowledge, beliefs, and routines, which engaged students higher level thinking through mobile learning at the secondary level (Callaghan et al., 2017; Crompton et al., 2018; Nikou & Economides, 2018; Shernoff et al., 2017; Taylor, 2018). This expands on the available literature as mobile technology was being used in ways to improve instructional practices and learning outcomes in which a PD initiative took part in redesigning the curriculum to make it more technology focused and promote higher-order thinking. These opportunities to reach students higher level thinking complement Research Question 3.

Conclusively, reflective conversations actively connected the teacher to his practice. Though adding to the teacher’s workload, researcher intervention gave the
teacher a chance to share ideas, and rather than become discouraged, discuss ways to 
make the project work. Darling-Hammond and colleagues’ (2017) views on collaboration 
where educators work in teams, taking advantage of one another’s knowledge and skills, 
to collectively change practices aligning with the finding. Further, as most PD has shown 
to be ineffective in implementing best practices with current technologies, this study 
closes the gap by connecting the SAMR model and the AOI dimension of the TRU Math 
framework, fostering change in teacher practice answering Research Question 1 (Dias & 
Victor, 2017; Patterson & Han, 2019; Watson et al., 2020). As a result of participating in 
this PD, the teacher changed his practice by increasing transformative uses of mobile 
technology creating opportunities for agency, ownership, and identity as discussed in the 
PD (Research Questions 1 and 2). As reported by the teacher, this resulted in better 
thinkers and problem solvers, building understanding in mathematics (Research Question 
3).

Conclusions

Overall, the outcomes of this study show that a PD initiative shaped a teacher’s 
implementation of mobile technology. Additionally, mobile technology can create 
opportunities for students to build understanding of mathematics. Reflection and 
professional learning conversations centered around using mobile technology to 
transform the learning experience, opening opportunities for student AOI, resulted in 
opportunities for students taking control of their own learning. Figure 3 shows the T-AOI 
model implemented throughout this study demonstrating an emphasis on transformative 
environments on cognitive processes, providing a concrete example of an effective PD 
initiative, as it meets the characteristics described in Chapter 1.
Implications for Theory, Research, and Practice

The data suggests that by setting aside time for discussion and reflection on practice and removing barriers, teachers can focus on becoming better leaders and facilitators. Strong preparation leads to high-performing systems, that Darling-Hammond and colleagues (2017) proclaimed are learning organizations themselves. When colleagues take risks together, they share an open community of learning. As leaders continue to evaluate and change their own systems, they can determine what is working and what needs improvement.

In this study, mobile technology in the classroom not only helped shape the teacher’s implementation of it, but also increased teacher provided opportunities for student AOI. The PD and reflective conversations illustrated the possibilities of shaping a teacher’s mobile technology practice answering Research Question 1. Given this, data suggests that leaders should provide educators with professional learning opportunities that empower them to reflect and build upon available technology resources. By
providing educators with embedded professional learning opportunities, transformative uses of mobile technology are made possible.

In addition, implementing transformative uses of mobile technology through a PD initiative allowed the teacher to provide opportunities for AOI. This suggests leaders should provide educators with opportunities for embedded PD during the workday as it reduces teacher workload in the long run. In this study, providing a teacher with a reflective PD resulted in mobile technology use that afforded learners the opportunity to take learning outside the classroom. Transformative uses of mobile technology through this PD initiative resulted in supporting opportunities for students to take control and build their competencies in mathematics complementing Research Question 3. This suggests that leaders can provide teachers with similar embedded professional learning opportunities.

The PD had to be sensitive to time and teacher needs as the class schedule would frequently change. With an inconsistent agenda, the teacher-participant needed a personalized PD to make the most of the time he was investing. Given this, the PD provider should know their audience, the school’s context in this study, to personalize PD to the teacher-participants in which they are working. Further, the PD provider should act as a catalyst by helping the teacher-participant remove roadblock and lowering the barriers that keep the teacher(s) from implementing particular practices. In this study, I did not just tell the teacher what to do; we worked together with available technology tools and his class needs. Giving the teacher choices through a reflective conversation is one way I worked as a catalyst.
The findings also suggest that technology helped the teacher-participant operate more efficiently by reducing his workload during a lesson. This support allowed the student and teacher to switch roles (Research Question 1), where, as the teacher reported, students became the thinkers. More so, participating in this PD demonstrated a way for a teacher to introduce similar professional learning opportunities with colleagues. Though educators could accomplish this without technology, given that modern learners are digital natives, they want to learn and play with technology before attacking the given task. Therefore, educators can learn how to change their mobile technology practices, to improve students’ learning experiences.

The findings also suggest that PD research should include elements of information gathered pre, during, and post PD sessions to show growth overtime and support the teacher modify teaching practices in real time. It also allows for strengthened relationships and collaboration resulting in a shared vision. My model (T-AOI) demonstrated the impact of this approach, encouraging other forms of PD to follow. In conclusion, when we use mobile technology in transformative ways (T), the door of opportunity for AOI is opened, resulting in learners taking control as mobile technology allows them to go wherever their interests take them.

In addition, the data indicated that the learners became more engaged and hands-on as they relate to the technology. This is the vital piece that drives TRU Math to work as students engage with a given medium, encouraging a powerful environment that brings a richness to the learning (Schoenfeld et al., 2016a). In this study, the findings suggest that the researcher intervention aided the teacher in finding ways to best utilize mobile technology in which he believed would promote better understanding of the mathematics
concepts introduced (Research Question 3). The findings also suggest that teacher participation in a technology-focused PD aids in a more efficient operation by reducing workload, providing opportunities for AOI, resulting in learner control. The concepts in the PD are constantly evolving. Now that the teacher has participated in this initiative, he can introduce similar professional learning opportunities at his school. These ideas can be applied to other disciplines.

**Recommendations for Theory and Future Research**

Implementing transformational opportunities from the SAMR model for mobile technology use to promote AOI from the TRU Math framework made learner control possible. It is recommended that researchers build on my extended concept of mobile technology usage and AOI to reflect and investigate if their initiatives also promote learner control. This reflection would support in students to take ownership and direct learning wherever their interests took them.

The participant in this single-case study was a volunteer. If additional secondary mathematics teachers in this school had volunteered, the findings could have been impacted. A recommendation for future research is to replicate this study with all secondary mathematics teachers in the institution. Additional participants would better show how teacher practices of mobile technology implementation were shaped as comparing different practices would be possible. Further, a relationship between technology acceptance and change in mobile technology use could be conducted to determine how effective the PD initiative was in shaping mobile technology implementation.
A second recommendation for future research is to replicate this study in other secondary mathematics programs with various demographics. This could allow for further studies on the contextual differences and implications of working with diverse students. For example, a researcher could determine if different socioeconomic groups had different experiences by possibly having access to different technology resources. Replicating this study in other schools would allow comparisons to be drawn through cross-case analyses, revealing generalizations which could then be applied to other programs (Yin, 2014). Moreover, discrepancies in pedagogical approaches could be analyzed to compare the opportunities provided to students and discern if learner control occurred.

A final recommendation for future research would be to collect student data as I relied on the teacher’s interpretation of students’ understanding of mathematics. This would expand the findings and inform the study as to whether the PD initiative was effective in building student understanding of mathematics. It would also reveal the student’s perception of change in the teachers practice and how they may have reacted differently to what the teacher interpreted. However, for the purposes of this study, the focus was on the teacher, rather than the students.

**Recommendations for Practice**

Technology integration in classrooms is consistently under-used as teachers lack preparedness for effective usage to promote higher-order thinking (Blackwell et al., 2013; Bryans-Bongey & Rosen, 2019). Given this, it is essential for teachers to collaborate and take advantage of each other’s knowledge and skills resulting in a higher-performing systems (Darling-Hammond et al., 2017). This teaching study has provided an example
of collaborative experiences to improve a tangible solution, demonstrating how other schools could adapt and create approaches suited to their institution. Through a shared vision and peer-led groups, they could continue to create and build professional learning opportunities.

Most people’s daily routines heavily rely on technology. Today, mobile technology is commonly used for shopping, ordering food, finding directions, or help with do-it-yourself projects. As students are accustomed to turning to technology for informational purposes such as using social media as news sources and connecting with people with similar interests around the world or to accomplish a task, providing opportunities to gain knowledge with their technology brings the learning experience to life. Instructional leaders could have students use their technology to spend more time on basic learning tasks outside of the classroom, resulting in opportunities for more in-depth learning in the classroom. Through collaboration, leaders can learn to plan more creatively with the technology available to students. In conclusion, this study promoted opportunities for professional learning and utilizing technologies already available to the institution.

As a scholarly practitioner, a focus of my work is instructional design in supporting instructors with educational technologies. In my previous experience, I have noted areas in need of improvement, and I incorporate those ideas in instructional design and support. Many of my daily activities center on improving current practices and finding creative ways to utilize the resources available to us.

As it can be difficult to bring change with technology to a new environment due to first- and second-order barriers (Ertmer, 1999), this study demonstrates an approach
teams can take through peer-learning. By providing some options and helping the participant in this study reflect on his current practice in addition to his quality of being a life-long learner, we were able to promote opportunities for students to become better thinkers and problem-solvers through mobile technology use. In my current practice, this type of teacher-led learning to help my audience see why change is necessary is essential. It is also important that my audience feels they are a part of the decision-making process, so by providing time for discussion and options to improve our process in which they are a part, obstacles can be overcome (Berger, 2020). Even more, this study demonstrates an approach to how I can help educators learn through peer-led small groups, which research has shown to be effective in improving strong organizations (Darling-Hammond et al., 2017).

**Concluding Remarks**

This chapter provided a final discussion of the research analysis conducted to understand what it takes to shape a teacher’s implementation of mobile technology through a PD initiative. The results identified factors that tied transformational learning opportunities with mobile technology to student Agency, Ownership, and Identity (AOI), and increased opportunities for scholars to take control of their own learning. As a result of this PD initiative, the teacher reported a change in his instructional technology practice. Yet, challenges remain to successfully shaping the teacher’s practices as he continues to navigate barriers on his own.

This study focused on reducing teacher workload by using readily available technology, as many teachers leave this field due to the pressures and obstacles they face (Holme et al., 2017). Considering this illustrative case study, this research demonstrated
how a PD initiative can change instructional practices to create opportunities for a transformative classroom. While traditional methods of teaching and learning are still relevant (Taylor, 2018), the world around us is impacted by advances in technology and present skills will change. If institutions for learning embrace the means to make necessary changes to instructional practice, there will be less educator burnout and more opportunities to create transformational learning experiences for 21st century learners.
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Appendix A

TRU Observation Guide

<table>
<thead>
<tr>
<th>AGENCY, OWNERSHIP, AND IDENTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>The extent to which every student has opportunities to explore, conjecture, reason, explain, and build on emerging ideas, contributing to the development of agency (the willingness to engage academically) and ownership over the content, resulting in positive mathematical identities.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Each student...</th>
<th>Teachers...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Takes ownership of the learning process in planning, monitoring, and reflecting on individual and/or collective work.</td>
<td>Provide time for students to develop and express mathematical ideas and reasoning.</td>
</tr>
<tr>
<td>Asks questions and makes suggestions that support analyzing, evaluating, applying and synthesizing mathematical ideas.</td>
<td>Work to make sure all students have opportunities to have their voices heard.</td>
</tr>
<tr>
<td>Builds on the contributions of others and help others see or make connections.</td>
<td>Encourage student-to-student discussions and promote productive exchanges.</td>
</tr>
<tr>
<td>Holds classmates and themselves accountable for justifying their positions, through the use of evidence and/or elaborating on their reasoning.</td>
<td>Assign tasks and pose questions that call for mathematical justification, and for students to explain their reasoning.</td>
</tr>
<tr>
<td></td>
<td>Employ a range of techniques that attribute ideas to students, to build student ownership and identity.</td>
</tr>
</tbody>
</table>

Other focal points for observation:

What opportunities do all students have to see themselves and others as proficient mathematical thinkers, to grapple with challenges and construct new understandings, to build on others’ ideas, and demonstrate their understandings? How can more of these opportunities be created?

Goal: All students build productive mathematical identities through taking advantage of opportunities to engage meaningfully with the discipline and share and refine their developing ideas.

Appendix B

TRU Math Conversation Guide

Agency, Ownership, and Identity

Core Questions: What opportunities do students have to see themselves and each other as powerful doers of mathematics? How can we create more of these opportunities?

Many students have negative beliefs about themselves and mathematics, for example, that they are “bad at math,” or that math is just a bunch of facts and formulas that they’re supposed to memorize. Our goal is to support all students—especially those who have not been successful with mathematics in the past—to develop a sense of mathematical agency and ownership over their own learning. We want students to come to see themselves as mathematically capable and competent—not by giving them easy successes, but by engaging them as sense-makers, problem solvers, and creators of mathematical ideas.

Planning
What opportunities might exist for students to generate and explain their own ideas? To respond to each other’s ideas? How can we create more opportunities?

Reflecting
How have we seen students explain their own and respond to each other’s ideas? What has that looked and sounded like in specific cases?

Things to think about

- Who generates the ideas that get discussed?
- What kinds of ideas do students have opportunities to generate and share (strategies, connections, partial understandings, prior knowledge, representations)?
- Who evaluates and/or responds to others’ ideas?
- How deeply do students get to explain their ideas?
- How does (or how could) the teacher respond to student ideas (evaluating, questioning, probing, soliciting responses from other students, etc.)?
- How are norms about students’ and teachers’ roles in generating ideas developing?
- How are norms about what counts as mathematical activity (justifying, experimenting, connecting, practicing, memorizing, etc.) developing?
- Which students get to explain their own ideas? To respond to others’ ideas in meaningful ways?
- Which students seem to see themselves as powerful mathematical thinkers right now?
- How might we create more opportunities for more students to see themselves and each other as powerful mathematical thinkers?

Appendix C

Project Plan

2020 – 2021 Geometry Courtyard Envisioning Project

Class: 3rd Period Geometry

Deadline: End of the 4th Quarter (May 21st, 2021)

Value: 250 Points

Project: Students will redesign the school’s courtyard area to include a greenhouse, some seating, and a multipurpose space. They will also be told to be as creative as they want in adding various things as well as in how they define the space.

To accomplish this, students will begin by being introduced to SketchUp for Schools for a couple of days. First, they will be shown a tutorial video from YouTube. Thereafter, they will be shown by the teacher how to access, save, and create. The students first assignment will be to simply play around and see what they can do.

After becoming acquainted, the students will be shown the courtyard area and be given their instructions for this project verbally. Then, the teacher will provide the students with measuring tapes (such as those used for track and field events) and instruct the students to measure the courtyard space. They will be instructed that they may have to scale their creations using dilation and other various transformations.

The teacher will remain, mostly, out of the discussion and give very little guidance. Rather, the teacher will facilitate and encourage learning and creativity with some suggestive inquiry. Additionally, the teacher will allow the students to collaborate and communicate naturally without fixing a strict media therefor.

Purpose: The students will gain an understanding of the tool. Additionally, the students will use this tool to creatively explore and envision a space of the school using and learning various Geometry skills and topics by putting them into practice.
Appendix E

Steps for Data Analysis Process

1. Upon IRB approval, the researcher collected data in physical formats such as printouts and electronic formats such as video recordings and virtual artifacts.

2. The researcher organized the data based on date. The data was collected over a six-and-a-half-week period which included four conversations and three teacher observations. The sources of data included conversation guides, a TRU Math rubric, field notes, video recordings, and physical and virtual artifacts.

3. ATLAS.ti was used to code the different forms of data collected beginning with the Conversation Guides. A lumping approach was first used to gain a better understanding of the data after each meeting with the teacher to inform next practices for the PD sessions.

4. After a brief tutorial on using the TRU Math Rubric, an additional scorer watched the recordings and scored the provided opportunities for AOI and technology use.

5. Once all data was collected, the researcher used a splitting approach, or line-by-line approach.

6. The researcher used an irritative process with the splitting approach as the data was first coded, then placed into categories until three major themes were developed. This provided the researcher with a deeper understanding of the data, allowing her to map concepts and split the data into categories.

7. The researcher compared the results coded from the Conversation Guides to the other forms of data to confirm the results.

8. The themes were then aligned to the research questions.

9. A narrative was written for each theme to answer the research questions (Chapter 4).

10. Conclusions, implications, and recommendations for theory, research, and practice were provided based on the thematic analysis described in Chapter 4 (Chapter 5).
Appendix F

Excerpts Related to the Three Major Themes

Theme 1: Teacher Workload

*Key codes*: time constraints, constant change, COVID-19, fallen behind, lack of responsiveness, unresponsiveness, math phobic

Research Question 1

“…we’re a new school to some degree…so we’re just learning the vibe and trying to figure things out here.”

“That’s the plan, but I can't be the IT guy and do that, so I am trying to find the grounds to not be the IT guy anymore.”

“schedules would change in less than a minute’s notice.”

“I can’t fully devote on what needs oversight.”

“Project-based learning is good fun; I’ve done very little of that this year, though I wish I could have done more.”

“It wasn’t hitting up as far as their abilities, their skills.”

“tried some hybrid things”

“sometimes they [students] tend to be a little bit less responsive.”

“most of them [students] just didn’t really respond. If forced, they would reluctantly show up.”

“free, so the price is right.”

Research Question 3

“I’m trying to assess a little bit. I haven’t really had enough time to really assess individual learning…this year is kind of a downer, it’s the nature of the year but just trying to see where things are.”

“see, get, repeat, done.”

“it’s a big step for some of those kids…with word problems, they can’t conceptually analyze, they can’t put words into numbers and proceed.”

“doing all the learning.”
Researcher field notes

“aid in building students’ knowledge in application and analyzation,”

“pay explicit attention to accuracy, catch mistakes…and correct errors resulting in the highest levels of Blooms (1956) hierarchy of learning”.

“prompt his students to explain their ideas and reasoning further”

“encouraged students to help one another.”

Theme 2: Shaping Teacher Technology Implementation

Key codes: envisioning future adjustments, research, sharing ideas with one another, less teacher interference

Research Question 1

“more of the social type”

“I just don't like the way Jamboard works in real time. I find it immensely frustrating…”

“…but in sharing information, thoughts, ideas, it’d be very useful; people doing things at the same time.”

“I liked the functions better than the SmartBoard sometimes…you’re not plugged into a SmartBoard.”

“I don't know if there's a real time function with it as I have not fully explored it yet.”

“giving very little direct instruction”

“chance to research a little bit and look into things.”

“encouraging his students to be creative”

“to think carefully about what was presented in front of them and how to make what they had work.”

“if we do an assignment, there's a question-answer session segment part that’s automatically generated which could be used for something like this [the project developed through this PD].”
reported “I spoke to them [students] individually or to a small group; very little coming up here [pointing to the board in the front of the room]. In the first day or two I was up here.”

**Research Question 2**

“wanted to go beyond the Google Classroom…they [Google] are rolling out with more and more stuff.”

for “some instruction, secondarily for a little assessment.”

“but other than that, not too much yet.”

“they are now researching on their own.”

“It was there to incorporate, so it kind of worked that way organically, which I like. They could work well organically and let it flow.”

**Theme 3: Opportunities for Learner Control**

*Key codes*: exploration, ownership, thinking critically, creativity, collaboration, inquiry-based learning, digital natives

**Research Question 1**

“natural collaborators”

were “creative.”

“gave them [students] no real big examples.”

“look online to find some things.”

“Hey, it takes class time. I didn’t have that and I’m not gonna need to hold a kid’s hand if they can already get up and walk, so why follow them? They are technical.”

“my 8th grader is demonstrating Sketchup with her friends who is not in this class.”

**Research Question 3**

“a chance to respond quickly, in a more casual way, and also for a chance to express their thoughts.”
“they [students] are getting better over time, but the ideas are still there.”

“move them [students] towards the thought of thinking”

“class was more active.”

“extracted answers from the students as they were presenting, providing opportunities for the students to own their ideas, share them with their classmates, and encourage them.”

they “used math to accomplish this [the project]”

“I gave them [students] no real big examples. I showed them how the program works, how if functions…You can look online to find some things. Go! Play! Have fun!”

“You [students] can add additional things, be as creative as you want to be.”

“It’s giving a chance to go out, explore, be creative with their minds, and play around, which is fun.”

“very little from me, it was all of them doing the stuff.”