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A Case Study on Targeted Support Using TPACK Model for Newly Hired Secondary Mathematics Teachers

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A CASE STUDY ON TARGETED SUPPORT USING TPACK MODEL FOR NEWLY HIRED SECONDARY MATHEMATICS TEACHERS

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ABSTRACT

A CASE STUDY ON TARGETED SUPPORT USING TPACK MODEL FOR NEWLY HIRED SECONDARY MATHEMATICS TEACHERS

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Old Dominion University, 2022
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As teachers plan for instruction, technology integration is an important factor in the planning and implementation process. This is become imperative in a virtual learning environment for instructors to be competent (Gregory & Lodge, 2015). Problems exist with integrating technology that aligns with teaching and learning in content areas. Among the many possible factors that contribute to these problems is lack of understanding of technology, lack of support for teachers with technology, everchanging technology tools, inadequate training alignment to instruction, technology training that is not content-specific, lack of support with the integration of technology, pedagogy, and content (Koehler et al., 2013).

This case study with an intervention focused on investigating the essential characteristics of planning and implementing lessons with newly hired secondary mathematics teachers. A mixed methods design was employed to provide triangulation of multiple data points to validate key findings. The TPACK (Technological, Pedagogical, and Content Knowledge) framework by Mishra and Koehler (2006) provided a guide for planning and implementing lessons as well as to build teachers' confidence in the integration of technology during instruction. Through planning interviews, survey data, class observations, teacher reflections, field notes, and teacher artifacts of lessons, the researcher examined the essential characteristics of planning and implementing a lesson using the TPACK model. Findings indicated that use of the TPACK model provided

support for newly hired mathematics teachers in their incorporation of technology into instruction.

Eight implications emerged from the findings in the study: using the TPACK survey to customize training for teachers by identifying areas of support, using the TPACK model for virtual planning, contextual knowledge in virtual classrooms, comprehending technology, implications of software-focused and use of sample lessons, virtual professional development with TPACK model, level of support with TPACK Planning, and TPACK survey interviews. This research informs practitioners and researchers to understand the complexity of teaching and the importance of providing differentiated support and training based on the needs of new teachers.

This dissertation is dedicated to all the teachers who make a positive difference in students' lives and are always learning and reflecting to improve their practice. Teachers truly make a difference in the lives of their students. We provide the foundation for every career and future of each student that enters our classroom. My desire has always been to make a positive impact in every life that I encounter. Reflecting on my many years of teaching, I realized that the most challenging times occur with uncertainty and unfamiliarity with the environment. As a new teacher many years ago, I started mid-year without a mentor and no support. Within the first week, I questioned whether I made the right choice in my career. I knew that I had to figure it out quickly, or I would not last until the end of the year. With ongoing reflection and adjustments to my teaching, I learned how to positively impact student learning and create a welcoming environment where all students could thrive to their fullest potential. One of my former students wrote to me at the end of the school year, “You made a good choice in your career, I have no doubt.” This is my “WHY” for my dissertation to support “New Teachers.”

To my family, thank you for your encouragement and for believing in me to complete my doctorate. To my father, Col. Rodney Dean McKitrick II, who taught me that hard work will always pay off, you were right. To my heavenly mother, Pamela Carney McKitrick, your prayers have led me through tough times. Reflecting on my favorite poem by Langston Hughes. *Mother to Son*, “Life for me ain’t been no crystal stair.” I realize that life is no crystal stair, and not to give up. To my daughters, Courtney, Elaina, and Christina, remember never to give up even when things are tough! Finally, to Geraldo, thank you for your understanding during this time.

Thank you again to all who are making a difference in the lives of others!

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CHAPTER 1

INTRODUCTION

Teacher preparation and training is a central component of creating successful learning environments for students especially in the use of instructional technology. One of the core components required in teaching includes technological competence (Beaudoin, 2015). Since the early 2000's, educators realized there was a need for a conceptual framework to guide research on the integration of technology (Herring et al., 2016). Information technology literacy is one of the inevitable skills needed for the 21st century. In our globalized society, jobs require skills that are sometimes not obtained through school. Often there is a disconnect between the workplace and how students are being taught and prepared for the future. Instructional technology is an avenue to spark students' interest, build connections, and make learning more relevant (Morgan, 2015; Robinson, 2006, Tucker, 2012; Tucker 2017). According to the Elementary and Secondary Education Act of 2001, all K-12 schools are mandated to integrate technology within the content areas (U.S. Department of Education, 2002). In 2005 Bill Gates stated, before leaders in business, education, and governors, "American high schools are obsolete preparing students using the wrong tool for the times" (Association for Career and Technical Education [ACTE], 2006b, p.6). In 2010, the National Education Technology Plan was implemented to reinforce the integration of technology (U.S. Department of Education, 2010). Two goals of these federal education acts are to improve student achievement and for students to become technologically literate (U.S. Department of Education, 2010).

The National Education Association NEA (2012) collaborated with leaders in education, businesses and policy makers to develop a Framework for "21st Century Skills" (p.2). These skills included the "Four Cs": critical thinking, communication, collaboration, and creativity (p.2). Partnership for the 21st Century Skills (P21) dates back two decades, are not new, but still are important skills for the current times (Boss, 2019; Rotherham & Willingham, 2010). The 4C's are connected to the use of technology within a classroom by providing opportunity for students to use technology for critical thinking, collaborative opportunities, creativity, and communication (Zimmerman, 2018). Students need opportunities to be creative, communicate, think critically, solve problems, find creative solutions, work collaboratively, leverage technology, and demonstrate the ability to be innovative (Niess et al., 2019; Tucker, 2012; Virginia Department of Education [VDOE], 2020). Educators need to provide learning opportunities to optimize learning and prepare students for tomorrow's workforce.

According to the U.S. Department of Education's 2010 National Educational Technology Plan, the majority of teachers are not well prepared to use technology during instruction (Matherson et al., 2014; US department, 2010). Matherson et al. (2010) noted teachers need proper training that is authentic and sustainable. Teacher preparation programs must evolve as instructional technology tools have changed (U.S. Department of Education, 2015). Understanding technologies are evolving along with the constraints in teaching technology stimulated the need "to rethink teacher education and professional development" (Koehler et al., 2013, p. 14). Many teachers "often have inadequate experiences with using digital technology for teaching and learning" (Koehler et al., 2013, p. 14). Often teachers have experienced inadequate training since instructional technology training is often provided as a "one-size-fits-all approach" (Koehler et al., 2013). Using Gynther's (2016) suggestions that teachers have a range of needs for training, the training needs to be personalized to meet the needs of the learner.

Overview of Teacher Preparation Programs

Teacher preparation, often referred to as pre-service training, occurs prior to employment (Jordan, et al, 2018). Most teachers' pre-service preparation requires them to earn a minimum of a bachelor's degree in teaching or the subject area that they will be teaching. The requirements for initial teaching certification or licensure are dependent on state criteria and could include the following: subject area bachelor's, pedagogy courses, other coursework, credit hour requirement, minimum grade point average, recency of requirement, practicum or student teaching, and assessment (U.S. Department of Education, 2003). Since this study was conducted in Virginia, the researcher examined the requirements that teachers needed for employment which included certification in the area that they will teach – in this case mathematics – or be eligible for certification with a given amount of time under a provisional license (VDOE, 2020bc).

Professional Development

As noted in Lawless and Pellegrino's (2007) literature review for technology focused professional development, the federal government has invested in schools to have the following (Lawless & Pellegrino, 2007 p. 576):

a. improving the capacity of schools to use technology
b. training the next generation of teachers to use technology
c. retraining the current teaching workforce in the use of technology in their classrooms
d. minimizing inequitable access to technology

Since the beginning of the 21st century, the digital divide and inequity in K-12 schools, impacted "maintaining a teaching force equipped to use technology in support of student learning" (Lawless & Pellegrino, 2007 p. 578). The quality of the professional development depends on the impact of student learning. Kennedy (1998) found that 10 of 93 professional developments was linked to student learning. Three phases of professional development were discussed by Lawless and Pellegrino. The first phase, consisted of the type of professional development, content, support with technology, and duration. The second phase, consisted of knowledge, attitudes, and instructional behaviors. The third phase, consist of student outcomes (Lawless & Pellegrino, 2007). These phases impact the type of professional development with regards to technology and instructions influences teachers; implementation and student learning (Lawless & Pellegrino, 2007).

Across the United States, teachers are required to maintain certification by completing professional development to stay current in teaching methods and to renew their certification. In Virginia, there are six Standards for Professional Teachers that include (1) knowledge of students, (2) knowledge of content, (3) planning, delivering, and assessment of instruction effectively, (4) safe, effective learning environment, (5) communication and collaboration, and (6) professionalism (VDOE, 2020f). When designing and implementing professional development for teachers, training should be aligned with these standards.

At the school district level in this study, there are several different types of support and training provided for newly hired and continuing teachers. This training and support system includes internal professional development at the school level, school district level, mentoring program, new teacher orientation, collaborative learning teams, and external professional development. In the 2020-2021 school year, the types of training that were offered within the school district were distance learning which includes both synchronous and asynchronous learning, how-to videos, Just-in-Time Training, train the trainer model, quarterly, monthly, or weekly training, or intensive training over a period. Teachers also learn from each other through collaboration and self-reflection (PWCPS, 2020).

The new teacher mentor program used in the district for this study provides a different level of support based on prior teaching experiences. All newly hired employees attended a district-wide new teacher orientation that included a school-specific day orientation and district-wide virtual event. The school-specific day occurred on August 12, 2020, which consisted of meeting with the principal and assigned mentor, superintendent welcome, mental health and wellness pre-recorded sessions, pre-recorded “Just-in-time Teachers’ Video Tips” from experienced teachers in the school district, and several human resource topics. On the division-wide virtual day, newly hired employees attended a synchronous live session on content (internal training) and conscious classroom management (external training). All secondary teachers attended Secondary Day for Content Sessions on Canvas Curriculum (internal training) and Desmos session (external training). Mentors are expected to provide zero experienced teachers with weekly check-in support and monthly meetings for Just-in-Time training. For example, Just-in-Time training could be how to submit grades or what to expect for back-to-school night. A novice teacher is expected to attend district-wide content-based induction training throughout the school year. This training included learning outcomes to reflect on current teaching, identify classroom management strategies that help engage students in learning mathematics, and reflect on questioning techniques and how they relate to mathematical literacy. In addition, teachers reflected on strategies that support students’ thinking, reasoning, and understanding of mathematics. Table 1 lists the district and new mathematics teacher training participants in this study received.

Table 1

Training and Support Timeline

Time Frame	Support and Training
August 12 and 14, 2020	Newly Hired Instructional Connect Conference.
August 17, 2020, TPACK survey	TPACK Survey emailed out to all newly hired secondary mathematics teachers.
August 19, 2020	Secondary Day for ALL teachers Content, Pedagogy, and Technology.
August 2020 to March 2021	Support and Training: TPACK model for Secondary Mathematics Teachers.
October 2020; December 2020; February 2021	Novice Newly Hired Secondary Mathematics Teachers: Pedagogy Training
January 25, 2021, TPACK survey	First Semester Post Survey emailed out through a Microsoft secure network

Theoretical Framework

In 2006, Mishra and colleagues extended Shulman's (1986) work on Pedagogical Content Knowledge (PCK) to develop the TPACK (Technological, Pedagogical, Content Knowledge) framework (Mishra et al., 2015). TPACK is defined as:

> A framework for teacher knowledge for technology integration. This framework describes the kinds of knowledge that teachers must have about technology, pedagogy, and content -- as well as the complex interactions and intersections of these knowledge types. The interaction of these bodies of knowledge, both theoretically and in practice, produces flexible knowledge needed to successfully integrate technology use into teaching (Mishra et al., 2015, p. 721).

This study used the TPACK survey to guide resources and support for newly hired secondary mathematics teachers with the integration of technology during planning with the TPACK framework. Approval for this study was granted by the Old Dominion University Human Subject Review Board and a Northern Virginia Public School from the program evaluation office (Appendix A). Approval was granted to use the TPACK survey (Appendix B) by Dr. Schmit-Crawford from Iowa State University. All participants were required to complete a participant consent form prior to taking part in this study (Appendix C).

Rationale for TPACK Targeted Support

The U.S. Department of Education, National Center for Education Statistics (NCES), Beginning Teacher Longitudinal Study (BTLS) conducted a study of beginning teachers over a five-year period. The results indicated "Among all beginning teachers in 2007–08, 10 percent did not teach in 2008–09, 12 percent did not teach in 2009–10, 15 percent did not teach in 2010–11, and 17 percent did not teach in 2011–12" (NCES, 2011, p. 3). Research conducted by DeAngelis (2012), indicated "Thirty percent of elementary and secondary school teachers leave the teaching profession after three years and up to half take off after five years" (p.66). Findings indicated that teachers often feel isolated and lonely when they begin teaching. Practical resources and the knowledge needed to run a successful classroom are often missing for new teachers (DeAngelis, 2012). One solution is to partner universities with schools to provide a support network that includes professional development and mentoring for novice teachers. Based on results from DeAngelis (2012), there was only one out of 600 novice teachers who left the teaching profession when a partnership occurred with a university and schools to support novice teachers.

It is well documented that teacher preparation programs produce graduates who are professionally qualified but within a few years leave the profession (Carver-Thomas & Darling-

Hammond, 2017; Podolsky et al., 2016). There is a gap between teachers' perceptions and teaching effectively (Darling-Hammond, 2006). Teacher preparation bridges a gap between reality in teaching and coursework theory which varies with pre-service fieldwork and in-service teaching experiences (Feiman-Nemser, 2003). The findings of a study focused on how graduates performed as new teachers generated five themes. These themes included "challenges with transitioning from student to teacher, reality, work conditions, socializing new teachers, and teacher perceptions of readiness to teach" (Jordan, et al., 2018, p. 20). Such findings highlight the importance of overall teacher support and working conditions (Darling-Hammond, 2013).

Due to COVID-19, schools were confronted with moving learning from traditional settings within school buildings to virtual learning (U.S. Department of Education, 2019). Because of the pandemic, new teachers' experiences in physical classrooms were cut short. Therefore, these new teachers needed extra support during the 2020-2021 school year. Reasons for using the TPACK framework were to support newly hired secondary mathematics teachers with the complexity of the integration of technology, pedagogy, and content. New teachers, in this setting, referred to both novice educators with no previous experience and experienced teachers who were new to the school district. Because of the unique pandemic teaching environment and the school district remaining virtual for at least the first semester of the school year for secondary students, this study was designed to support teachers working in asynchronous and synchronous learning environments.

For this study, the purpose of the TPACK survey was to identify strengths and areas of growth. The pre-survey results were used by each teacher to select topics for the support sessions. The intervention was tiered depending on the level of support needed for each teacher as noted in Table 2. The individualized support consisted of approximately 45 minutes per session. The responses during the planning and interview were recorded. Teachers were informed that the planning and interviewing were recorded and only first names were used to maintain confidentiality during the recording. Additionally, all participants were given a pseudonym to protect the individual's identity during the transcription. The TPACK survey was designed from the TPACK framework (Koehler et al., 2013)

Table 2

Participants' Tier Levels of Support

Tier I Support	Tier II Support	Tier III Support
Pre-Assessment TPACK Survey	Pre-Assessment TPACK Survey	Pre-Assessment TPACK Survey
Professional Development for Newly Hired Teachers	Professional Development for Newly Hired Teachers	Professional Development for Newly Hired Teachers
Post-Assessment TPACK Survey	Intervention Support with TPACK Framework	Intervention Support with TPACK Framework
	Reflections on Implementation	Observations
	Post-Assessment TPACK Survey	Reflections on Implementation
		Post-Assessment TPACK survey

Virtual Learning

Traditional schools have been known as "brick and mortar" schools which refers to teachers and students meeting face to face for learning opportunities in a physical space (Taylor & McNair, 2018). A synchronous learning environment is where the teacher and students meet through an online platform for content-related instructions (Amiti, 2020) and have the advantage of teachers being able to address student questions on the spot (Skylar, 2009). Another benefit of this type of instruction is that lessons can be recorded for students to watch again later (Perveen, 2016). Asynchronous learning environments provide learning resources and assignments for students to access at anytime and anywhere (Perveen, 2016). Teachers need to have the learning material ready for students to access anytime which could include videos, handouts, assignments, and other resources within learning management platforms (Perveen, 2016). The school system in this study chose to adopt two methods of delivery during the first semester which included synchronous and asynchronous learning environments.

Technological Knowledge

Technological knowledge is often used as a broad term to refer to many different technology components (Table 3). Throughout this research, the focus will be on teacher's educational and instructional technology knowledge which is represented in the TPACK model as TK. The Committee of Information Technology Literacy of the National Research Council (NRC, 1999) concluded that TK is aligned closely to "Fluency of Information Technology," or FITness (Koehler et al., 2013, p.4). Researchers in educational technology such as Mishra and Koehler (2006) and Niess (2005) proclaim that effective integration of technology in the classrooms requires that teachers have knowledge of TPACK and the interactions of the domains (Polly, 2010). Likewise, teachers need to know how to apply TPACK when planning and implementing a lesson using technology (Polly, 2010). Even though student achievement has been linked to technology use in mathematics, the effective use of technology in mathematics classrooms to impact student learning are not widespread (Polly, 2010; Polly 2008a; Wenglinsky 1998).

Table 3

Technology Terminology

Terminology	Definition
Educational/Instructional Technology	"The field of educational technology is concerned with the use of various types of equipment as teaching and learning aids" (National Assessment Educational Progress, 2018, p.10).
Information and Communication Technology (ICT)	"Knowledge and skills can be applied in the context of developing and using any of the technologies" (National Assessment Educational Progress, 2018, p.94).
Technology Knowledge (TK)	"Knowledge of operating digital technologies" is aligned to information technology (Herring, et al., 2016, p.16).
Technological Literacy	"The capacity to use, understand, and evaluate technology (National Assessment Educational Progress, 2018, p. 133).

Secondary mathematics teachers within this case study with an intervention are expected to use a variety of educational/instructional technologies including Canvas, which is a Learning Management System (LMS) for asynchronous learning and Zoom for synchronous learning. Likewise, mathematics teachers are encouraged to use Desmos and virtual manipulatives to help students build conceptual understandings of mathematics concepts. Also, teachers have access to Microsoft apps and software which include but are not limited to FlipGrid, OneNote, Clever, Office 365, and other Microsoft products. Desmos is a free, dynamic, and easy-to-use mathematics software that provides online calculators, geometry tools, activities, and much more (Desmos, 2020; McKitrick-Rojas, 2020). In the spring of 2019, the state of Virginia embedded the Desmos Calculators into the toolbar of the state Standards of Learning exams.

Content Knowledge

According to Koehler et al. (2013), content knowledge (CK) is knowing the subject area and understanding the structure of the domains, the teacher needs to know why he/she is addressing the domains. Their definition is “teachers’ knowledge about the subject matter to be learned or taught” (p.3). The teacher should have a deep understanding of the subject matter which allows him/her to understand possible student misconceptions.

Pedagogical Knowledge

Pedagogical knowledge (PK) refers to the knowledge of the content and how one might transfer that knowledge in ways that students can develop an understanding of the concepts and apply the recently acquired knowledge to new situations. According to Shulman (1987), knowledge of pedagogy includes components of classroom management, organization, structure, assessment, and adaptivity. Other important factors include knowledge of the learning process and knowledge of the individual student (Guerriero, 2016).

Contextual Knowledge

According to Mishra (2019), the TPACK framework added contextual knowledge to encompass all seven domains. The framework includes Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical and Content Knowledge (TPACK) (Table 4). The contextual information is the teacher’s ability to synthesize then adjust during teaching and learning (Herring et al., 2016).

Table 4

Contextual Knowledge Embodies the Seven Domains of TPACK

TPACK Knowledge	Descriptions of knowledge
Technological Knowledge (TK) (Information Technology)	Knowledge of operating digital technologies
Pedagogical Knowledge (PK)	Process and practices or strategies of teaching and learning
Content Knowledge (CK)	Knowledge of Subject Matter
Pedagogical Content Knowledge (PCK)	The interaction of PK and CK
Technological Content Knowledge (TCK)	The interaction of TK and CK
Technological Pedagogical Knowledge (TPK)	The interaction of TK and PK
Technological Pedagogical and Content Knowledge (TPACK)	The interaction of TK, PK, and CK

Note: (Herring et al., 2016, p.16).

Background and Significance

According to Koehler et al. (2013), information technology is evolving, and teacher support and training are needed. Teaching is a complex profession that involves many bodies of knowledge. The complexity of knowledge structure occurs across different methodologies and contexts. Effective teaching is being able to transfer knowledge to a diverse group of learners. The domains of knowledge include knowing how students think and learn, knowing the subject matter, and knowing technology. Often technology training lacks follow-up support (Koehler et al., 2013).

Instructional technology in mathematics continues to advance. In 1986, the first graphing calculator appeared in classrooms which sparked changes in the way teachers taught mathematics (Abu-Naja, 2008; Nelson et. al, 2009). Laumakis and Herman (2008) found that when teachers are trained with ways to use graphing calculators, student achievement increased.

Now, students and teachers can use online calculators and technology to enhance learning and teaching. One of these online resources is Desmos, an online technology tool that consists of calculators and support activities and geometry tools (Desmos, 2020). The Desmos calculators are free online calculators which are available globally and are used in several state assessment exams as well as on the digital Scholastic Aptitude Test (SAT) and National Merit Scholarship Qualifying Test PSAT/ NMSQT (College Boards, 2021; Desmos, 2020; VDOE, 2019). This tool has become well accepted in the area of mathematics instruction.

Kolb (2019) discussed that "learning with technology is not about the tools, it is about the methods the teachers use with those tools" (p.26) (Ball & Kay, 2010; Kay & Lauricella, 2011). Teachers need background knowledge of information technology on how to access it as well as how to use it during instruction. In addition, teachers needed content knowledge of mathematics and pedagogical knowledge of strategies of how to teach to maximize student learning and achievement when using technology to build an understanding of mathematical concepts, develop reasoning, and thinking skills of students.

Statement of the Problem

There are challenges with integrating information technologies that align with teaching and learning in content areas (Koehler et al., 2013). Among the many possible factors that contribute to these problems is a lack of understanding of technology, lack of support for teachers with technology, ever-changing technology tools, inadequate training alignment to instruction, technology training that is not content-specific, and lack of support with the integration of technology, pedagogy, and content (Koehler et al., 2013). One way to support newly hired teachers is to provide individualized support in the integration of information technology by using the TPACK Framework.

Purpose Statement

The purpose of this study was to examine the targeted support provided to newly hired secondary mathematics teachers using the TPACK framework and the integration of educational /instructional technology. This mixed-methods case study with an intervention provided a deeper understanding of individualized support and the impact the TPACK framework had on the planning and implementation of instruction.

Research Goals

The goals of this study were to be proactive in identifying areas of support for newly hired secondary mathematics teachers and to develop the essential characteristics of planning and implementation using information technology, pedagogy, and content knowledge. The two key domains for this research using the TPACK framework consisted of: (a) teachers' thought processes and knowledge, and (b) teachers' actions and their observable effects (Koehler et al., 2013).

Research Questions

The research questions for this study were derived from the TPACK Technological Pedagogical Content Knowledge framework from Mishra and Koehler (2006, 2009) for teaching and learning.

1) How does targeted individualized support and professional development impact newly hired secondary mathematics teachers' knowledge of technology, pedagogy, and content integration during instruction?
2) What are the essential instructional characteristics of integrating technology, pedagogy, and content knowledge that are developed during planning and implementation?

3) What strategies support teacher integration of technology during instruction?

Research questions were designed for a mixed-methods case study involving an intervention. According to Yin (2018), "Case study research has its place in doing evaluations…to describe an intervention and the real-world context in which it occurred" (p.18). The first research question justified the quantitative data that was collected and analyzed. The second and third research questions justified the qualitative data that was collected and analyzed. Appendix D contains interview questions that were used to collect data and to support the central research questions. The interview questions aligned with the research and related research questions are found in Appendix E.

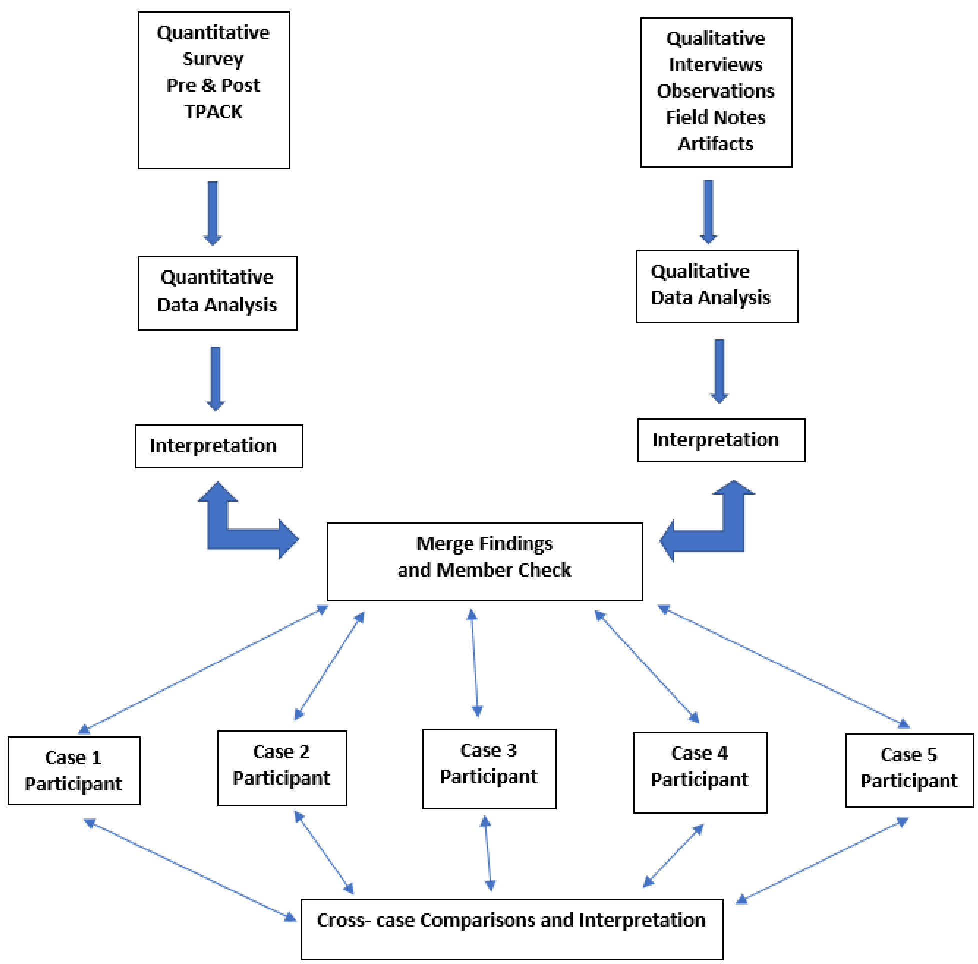
Research Design

At the beginning of the school year, this research started with a survey to quantify the level of TPACK knowledge of newly hired secondary mathematics teachers. According to Creswell and Creswell (2018), the approach defines the design and the "first phase of quantitative data collection" (p.42) occurs in mixed-methods studies. Using a deductive approach, the researcher established the cases through the qualitative and quantitative data collected that moved from general to specific premises (Creswell & Creswell, 2018). Within this research design of a mixed-methods case study with an intervention, "both types of data are gathered concurrently in a convergent core design and the results are merged together" (Creswell & Creswell, 2018, p.230) (Figure 1).

The findings were merged, and a member check was conducted on both quantitative and qualitative data collected then cross-case comparisons and interpretations occurred to converge on key findings. Yin (2018) discussed three rationales for mixed-methods case studies: converging evidence, survey data, and to define the frequency of the process. This mixed methods case study incorporated all three of the rationales as discussed by Yin in this study. In chapter three methodology, chapter five findings, and chapter six discussion, the converging of evidence and mixed methods design was reported then discussed further to justify design and confirm the findings of the study.

Figure 1

Mixed Methods Case Study Design



Note: (Creswell & Creswell, 2018). Designed for this Mixed Methods Case Study

Limitations

Mishra et al. (2015) identified two known limitations of the TPACK framework. One limitation is that when utilizing the framework, teachers need to think about their teaching and learning which varies based on educational and work experiences. To address this challenge, questions were asked during the planning and training process to stimulate thinking. The second limitation is how technology is being integrated. To address this challenge, questions were asked about the technological tools' affordance and constraints (Mishra et al., 2015) (Appendices D & E).

This study used purposeful sampling of newly hired secondary mathematics teachers in one school division. In this mixed-methods case study with an intervention, the focus was on mathematics teachers hired for the 2020-2021 school year. The individuals who participated in the study were teachers who desired individualized support with the integration of digital technology. An additional limitation for this study is that all teachers did not have the same level of teaching experience, which ranged from novice to experienced teachers, nor did they have the same level of education, which ranged from bachelor's to postgraduate degrees. To maintain consistency among the various levels of experience and education, the researcher used an observation data collection form, semi-structured interviews, observations, and reflection protocols (Appendices F & G)

Assumptions

In this study, there were three assumptions. One assumption was that all teachers were qualified to teach their subject area. Another assumption was that all newly hired teachers had some experience using information technology. The study also assumes that teacher responses were true reflections of their thinking of technology, pedagogy, and content knowledge to the Pre- and Post-TPACK survey.

Definitions of Key Terms

Technology terminology can be found in Table 3, and TPACK Domains can be found in Table 4.

- Contextual knowledge: "Would be everything from a teacher's awareness of available technologies to the teacher's knowledge of the school, district, state, or national policies they operate within" (Mishra, 2019, p.1).
- Creativity: "A process or way of thinking by which things are novel, effective, and produced. In addition to these elements of newly created originality, and effectiveness or value, creative ideas or products also frequently have an aesthetic sense that is tied to context. In effect, this makes them novel, effective, and whole" (Mishra et al., 2015, p.721).
- Desmos Technology: Desmos is a free, dynamic, and easy-to-use mathematics software program that provides online calculators, geometry tools, and Desmos Activity (Desmos, 2020).
- Trans-Disciplinary Thinking: "A schema for thinking that involves thinking across disciplines and/or making connections between disciplines. This includes connecting between ideas or disciplinary content in different areas often thought of separate, but with connections and links that allow each different area to better explain the other" (Mishra et al., 2015, p.721).
- Theoretical Framework: "This is the structure that supports the theory of a research study or line of research endeavor. The framework describes the theory that connects to the line of research and explains why a given research problem is

of interest for study. It organizes the use of theory to allow research to uncover the meaning, nature, and challenges of a phenomenon. This allows a line of research to provide knowledge and understanding to act in more informed and effective ways" (Mishra et al., 2015 p.721).

To communicate with stakeholders and for this study, the following terms need to be defined: (PWCS, 2020, p.37).

- Asynchronous learning: "Online or distance learning where the learner accesses curriculum content but does not interact with the teacher or others in real-time. It allows students to learn at different times and in different places" (PWCS, 2020, p.37).
- Canvas: "A platform as service provided by Instructure, Inc., one of the nation's leading providers of LMSs, used to deliver online content for use by students PreK – University" (PWCS, 2020, p.37).
- Modules: "These are used to organize course/class content by weeks or units" (PWCS, 2020, p.37).
- Formative assessment: "An assessment that allows teachers to determine which concepts, skills, standards a student is having success or difficulty with while the teaching is taking place. It allows teachers to make real-time modifications to the instruction" (PWCS, 2020, p.37).
- Summative assessment: "An assessment given to evaluate learning at the end of a curriculum unit or units" (PWCS, 2020, p.37).
- Synchronous learning: **"**Online or distance learning where the student can ask questions, dialogue, gain feedback, and/or interact with the teacher(s) in real-time. Some examples

include virtual classrooms, live webinars, streaming in real-time, or video conferencing" (PWCS, 2020, p.37).

Chapter One: Summary and Overview

This chapter introduced the research study, presented the theoretical framework of the TPACK model adopted for this study and provided a rationale for TPACK targeted support with newly hired secondary mathematics teachers. This mixed-methods case study provided the essential characteristics of planning and implementation of instruction using the TPACK model and questions aligned to the framework to stimulate technological knowledge, pedagogical knowledge, and content knowledge while teaching. The problem statement and research questions were presented and support the purpose and goals of the study. The goals of this study were to be proactive in identifying areas of support for newly hired secondary mathematics teachers and to develop the essential characteristics of planning and implementation of technological, pedagogical, and content knowledge. Lastly, the chapter identified limitations and potential weaknesses of this study.

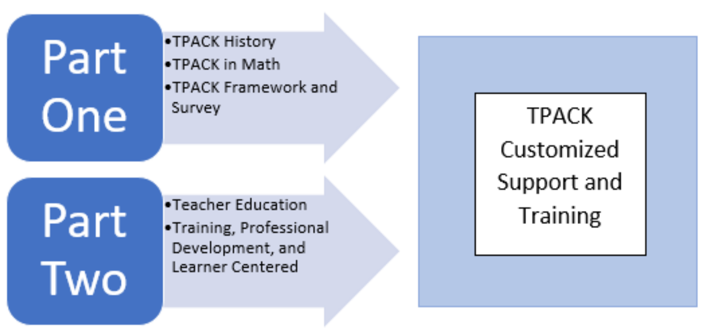
CHAPTER 2

REVIEW OF LITERATURE

This mixed-methods case study with an intervention used the TPACK framework from Mishra et al. (2015) to identify areas of support for newly hired secondary mathematics teachers and to identify essential characteristics of planning and implementation of instruction. This research study concentrated on customizing training to meet the needs of mathematics teachers through the content area in which they teach, as well as the strategies of knowing how to teach the content including the integration of technology. The literature review consists of two sections: (1) TPACK and its history and connection to mathematics teaching and (2) teacher education as it relates to preparation and professional development (see Figure 2).

Figure 2

Literature Review to Support Research Study

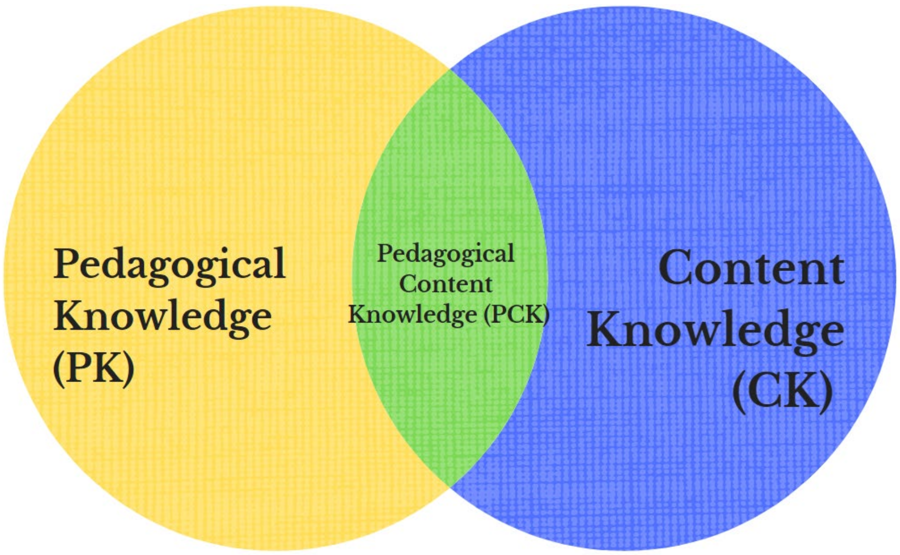


TPACK History and Mathematics Education

In the early 2000s, education needed a conceptual framework to guide research and teacher preparation programs in ways to integrate technology into instruction. The use of Shulman's (1986) Pedagogical Content Knowledge model was the foundation of the TPACK (Technological, Pedagogical, and Content Knowledge) framework (Herring et al., 2016). The Pedagogical Content Knowledge (PCK) model in Figure 3 illustrates the knowledge needed in content and pedagogy for effective teaching to occur at the intersection of pedagogy and content knowledge (Koehler & Mishra, 2009).

Figure 3

Pedagogical Content Knowledge (PCK)



*Note:*Modified Image of Shulman's (1986) Pedagogical Content Knowledge Model

TPACK in Mathematics

Mathematics teachers' knowledge of instructional strategies to use digital technology has been limited in the literature with most teachers believing that mastery of skills is demonstrated with paper and pencil (Kastberg & Leatham, 2005; Niess et al., 2009; Walen et al., 2003; Yoder, 2000). Often professional development focused on technology has been taught in isolation and not related to the curriculum content (Niess et al., 2009). Therefore, teachers often do not utilize the technology within the classroom (Ferrini-Mundy & Breaux, 2008; Niess et al., 2009). To address the lack of technology use, there was a push from the Association for Mathematics Teacher Educators (AMTE) for improving teacher preparation programs and training for mathematics teachers with technology (Niess et al., 2009).

The strategies to use technology effectively during instruction did not evolve at the same rate as technology evolved (Niess et al., 2009). The International Society for Technology in Education (ISTE) (2018) catalyzed teachers to consider the technology skills and knowledge that students will need for the 21st century. The release of the National Education Technology Standards for Students (NETS-S) (ISTE, 2000) focused on how technology was used within a school setting (Niess et al., 2009). The focus of NETS-S and the National Council of Teachers of Mathematics (NCTM) shifted from knowledge of how to use technology to effectively use technology to support student learning of mathematics. Teachers should plan for instruction incorporating technology, reflect on the implementation of the technology and how it supported student learning, and address any misconceptions (Earle, 2002, Niess et al., 2009).

The Association of Mathematics Teacher Educators (AMTE) formed a Technology committee to investigate how teachers used technology in their classrooms which resulted in the development of mathematics standards for TPACK in this process. Initial themes included:

- An overarching conception about the purpose for incorporating technology in teaching mathematics.
- Knowledge of students' understandings, thinking, and learning of mathematics with technology.
- Knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics.
- Knowledge of instructional strategies and representations for teaching and learning mathematics with technology (Niess et al., 2009, p.8).

These initial themes were evident in this study by identifying which digital tools enhanced student learning and thinking of a particular mathematical concept. Likewise, the instructional strategies used with the digital tools to represent mathematical concepts during teaching and learning was discussed during the planning process using the TPACK framework.

Bos (2011) conducted a study on professional development for elementary teachers using TPACK. The purpose of the study was to examine graduate in-service teachers as they developed instructional units along with the TPACK framework for mathematics. The technological content knowledge consisted of the use of technology to develop conceptual understanding and representation of mathematical concepts. The areas of pedagogical and technological knowledge requires seeking the appropriate technology to maximize student learning (Bos, 2011). The interaction of technology, pedagogy, and content consist of a lesson design for learning mathematics with technologies. (Niess, 2008; Thompson & Mishra, 2007). This study examined both qualitative and quantitative data of thirty elementary teachers. The participants were asked to design instructional units using Web 2.0 tools with mathematics. The findings of the study indicated that experienced teachers acknowledged the importance of pedagogical and mathematical content with interactions of technology. Likewise, experienced teachers recognize the importance of problem-solving and creativity with technology. The participants chose websites that enhanced learning mathematical content, for example, the National Library of Virtual Manipulatives which allowed for observation of patterns and multiple representations (Bos, 2011). Bos's study supported the purpose and overarching themes of knowledge learning mathematics with technology and developing curriculum material that integrate technology with learning and teaching mathematics. Likewise, the study supported the instructional strategies and representation for teaching mathematics with technology.

Whereas Niess et al. (2009) documented an interview with a prior undergraduate mathematics education student, to follow up on the teacher after three years on implementing technology during instruction. The teacher indicated only using technology once during the three years of teaching to have students investigate systems of equations to discover the number of solutions within a given system. In this case, the overarching theme of seeing the purpose for incorporating technology in teaching mathematics was not transferred from undergraduate studies to teaching practice.

TPACK Framework and Survey

The TPACK framework was initially designed to be a conceptual framework to assist educators when integrating technology into instruction. There have been studies that have used TPACK as a quantitative measure (Cavangh & Koehler, 2013). As well as numerous studies that used the TPACK framework within a qualitative design to develop a deep understanding of the integration of technology and TPACK domains (Cox & Graham, 2009). A recommendation from Abbitt (2011) was to create norms for TPACK levels when using it as a measurement tool. The following studies provide evidence for the use of the TPACK framework as well as the reliability of the TPACK survey.

Koh (2019) conducted a study on scaffolding TPACK design for supporting teachers' pedagogical change in a graduate course within an educational technology program. The impact of scaffolding TPACK design through a learning rubric, lesson design, and TPACK activity type increased the confidence of forty-seven teachers on a pre and post course survey. The use of Mishra and Koehler (2006) TPACK framework was used to better understand how pedagogical innovation in information and communication technologies (ICT) in lessons influenced a change from teacher-centered to student centered (Koh, 2019). TPACK framework with ICT integrated lesson were developed with specific content and pedagogical strategies and provided an opportunity for teachers to synthesize the knowledge interactions within domains. TPACK is a theoretical explanation of the why teachers need to integrate technology when considering the content and pedagogical knowledge and not just technology skills (Koh, 2019). Change can be difficult when considering professional expertise. Teachers need opportunities to collaborate on design, problem solve, and reflect using the TPACK model in order to stimulate change in pedagogical practices (Koh, 2019).

Providing scaffolding support using TPACK lesson design allows for teachers to grapple on their pedagogical practices, contextual challenges, and TPACK lesson design. The scaffold TPACK lesson design supported the change in pedagogical practice. The learning rubrics in the study consisted of the dimensions: active, constructive, authentic, and intentional. The findings from the scaffolding TPACK lesson design included a “change in teachers’ confidence”, “change in teachers’ lesson design”, and “feedback about the design scaffold” which strengthen the student-centered pedagogical change in practice (Koh, 2019, pp.587-588).

Graham et al. (2012) conducted a study using the TPACK Framework for teacher candidates. The researchers found that pre-service teachers’ TPACK knowledge effectively impacts the integration of Information and Communication Technology (ICT) with pedagogical and content knowledge. The study took place at Brigham Young University and was carried out to identify how and why teacher candidates integrated technology when given three design content tasks. All 137 elementary teacher candidates were required to take pre and post assessments, and 133 agreed to participate in the study. Participants were taking introductory educational technology, methods, and introduction to TPACK courses during the time of the research. The study consisted of a qualitative and quantitative component.

The first section included the qualitative component of design task examples with rationale that was coded into categories the levels of technology integration. There were two researchers, who were independent of each other, that coded 200 responses from the design task. For each design task, participants were given two prompts. The first prompt item code was digital technology. “Describe briefly an instructional strategy or activity (that uses digital technology) that you might use to help students gain knowledge and skills in this objective (Graham’s et al. 2012, p. 536).” The second prompt item was rationale. “Why did you choose to use the technology in the way you described above (Graham’s et al. 2012, p. 536)?”

The second section included the comparison of qualitative to quantitative component by patterns of change in students’ rationale between pre and post course assessment. The pre and post assessment was analyzed using a paired sample t-test to determine if the “pre and post course difference for the participants were statistically significant” (Graham et al., 2012, p.536). As referenced from Koehler and Mishra (2008) used technology in broad perspective without distinguishing between the different types of technology. However, majority of researchers who are using the TPACK refer to the integration of technologies as digital (Graham et al., 2012). The researchers within this study focused on ICTs and the decision making of teacher candidates using the TPACK framework for instructional decisions.

The findings from Graham’s et al. (2012) study using the TPACK framework for teacher candidates provided a “clearer understanding of how to differentiate between PCK and TPACK constructs and better understanding of the types of rationales teacher candidates give for integrating technology into their lesson design” (Graham et al. 2012, p. 542). Harris and Hofer (2009, 2011) found that social studies teachers focused more on content, then the activities and learning outcomes. Likewise, Harris et al. (2009) found that teachers would first focus on the curriculum, second on activities that would assist in student learning, and third the technology that would support the activities. In Harris and Hofer’s studies, the findings indicated that when teachers focused on planning, the lessons became more student-centered rather than teacher-centered.

Niess (2009), in her work with in-service teachers using TPACK, found that when teachers recognized that technology can improves students understanding, teachers integrated the technology within their lessons. Kersaint (2007) also found that pre-service teachers viewed technology as a way to engage, create a positive attitude, and build confidence in mathematics. In addition, the use of technology helps students visualize the mathematics. Likewise, Cavin (2008) found that teacher candidates who use technology within a lesson did so because the technology improved students' conceptual understanding, speed, and organization of computation.

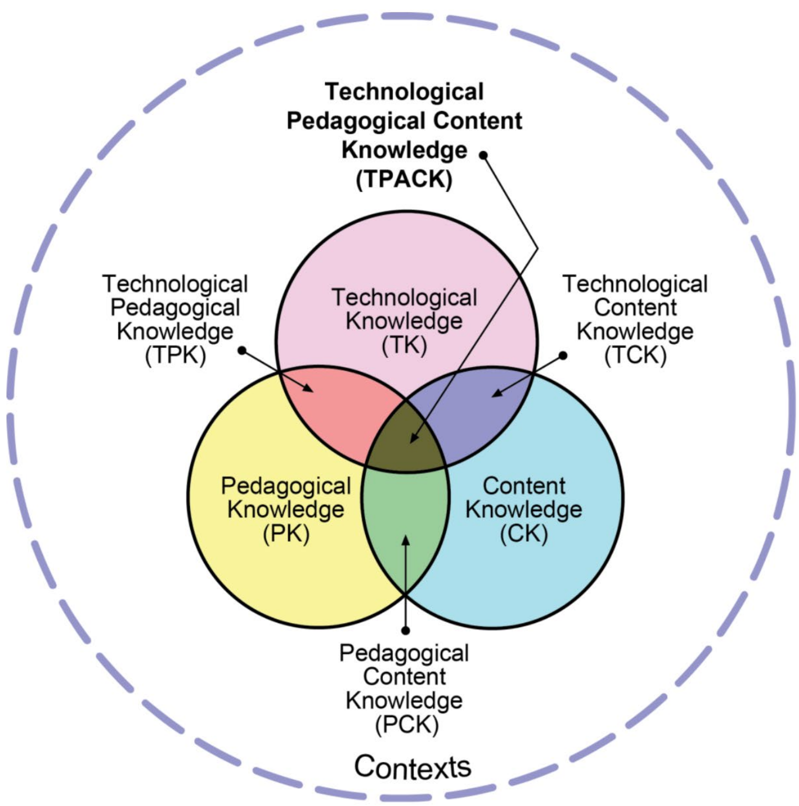
The TPACK Framework is a well-known and established framework (Koehler et al., 2013) within the professional research community and is a good fit for the research study presented here. The TPACK survey was created and implemented in a pilot study of 124 pre-service teachers as an aid to implementation of the TPACK framework (Schmidt et al., 2009). There were initially 54 Likert scale items within seven domains of the TPACK Survey and there have been numerous studies carried out with pre-service and in-service teachers.

A study by Johnston and Moyer-Packenham (2012) consisted of 144 pre-service elementary teachers' evaluations of technology for future mathematics teaching. The methods included both quantitative and qualitative analysis of the criteria pre-service teachers used to rank technology tools for mathematics classroom instruction. The results indicated that pre-service teachers first identified the technology tool they planned to use, then planned "a lesson around that technology tool, rather than selecting an objective first and finding appropriate technology to support the mathematical learning" (Ronau et al., 2012, p. 221).

The use of Universal Design for Learning infused TPACK and teachers' efficacy study that consisted of, "fifty-four pre-service teachers enrolled in the secondary general methods course from 2011-2014" (Herring et al., 2016, p.147). TPACK questions for the study were designed using the TPACK domains of Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological, Pedagogical, and content knowledge (TPACK) (Figure 4). A survey conducted at the beginning and end of the semester indicated students scored higher on the post TPACK assessment with a Cohen's $d = 1.04$ (Herring et al., 2016; Schmidt et al., 2009).

Figure 4

Technological Pedagogical Content Knowledge (TPACK)



Note. Technological Pedagogical Content Knowledge (TPACK) model. Permission to reprint for dissertations granted from http://tpack.org/

In 2006, Mishra and Koehler added contextual knowledge (Figure 4, outer circle) as an essential part of the integration of technology. This requires teachers to understand the complex relationships surrounding the content, pedagogy, and technology for successful integration. The context knowledge includes knowing about "the students, the school, the school social networks, parental concerns, and the available infrastructure" (Koehler et al., 2013, p.17). Qualitative data indicated that "student teachers who participated in the one-to-one interviews were confident in their understanding of Universal Design for Learning (UDL) infused TPACK and the impact on student teaching sense of efficacy and successful completion of the teacher performance assessment" (Herring et al., 2016, p.158).

In 2009, there were two existing TPACK surveys which included one for undergraduate students (Schmidt et al., 2009) and another survey for teaching online (Archambault & Crippen, 2005). Archambault and Barnett (2010) conducted a study on the nature of technological pedagogical content knowledge (TPACK) with online teaching. Using the TPACK teaching for online, the factor analysis indicated it was difficult to distinguish between the interactions of the domains. However, technology use was clearly distinguishable and content and pedagogical knowledge was noteworthy.

Technological Knowledge

Technology can include a pencil that is used for writing, a microscope that is used for viewing small objects, and a calculator used for computation (Koehler et al., 2013). The functions of a pencil become transparent compared to more advanced technology (Bruce & Hogan, 1998; Koehler et al., 2013; Simon,1969). Digital technology is rapidly changing, unstable, protean, and opaque which includes computers, handheld devices like smartphones, and software applications (Koehler et al., 2013; Papert, 1980; Turkle, 1995). Understanding that technologies have their propensities, potentials, affordance, and constraints impacts the effectiveness of certain technologies on a task (Bromley, 1998; Bruce, 1993; Koehler & Mishra, 2008; Koehler et al., 2013).

For example, in a study that compared the effectiveness of virtual and concrete manipulatives to teach Algebra to secondary students with learning disabilities, Satsangi et al. (2016) examined such uses and found that the results of intervention with three students indicated a 90% average of correctly solving problems using both virtual and concrete manipulatives. Although this was a very small sample, the use of virtual and concrete manipulatives had a positive impact on student learning and achievement for the three secondary students with learning disabilities. The study consisted of a pre-assessment, lessons using virtual and concrete manipulatives, and post-assessment (Satsangi et al., 2016). The authors explained how virtual and concrete manipulatives impacted their students with learning disabilities when teaching secondary mathematics. Although concrete, hand-held manipulatives have been researched and proven to be beneficial, there is little research on the impact of virtual manipulatives.

Montijo (2017) examined how teachers planned the use of Desmos and TI-83 Plus Graphing Calculators with 146 students. The study was to determine if student used Desmos Calculator, they would experience a statistically significant difference in problem-solving confidence levels (Montijo, 2017). The results indicated that "the ANCOVA had a significant difference between the problem-solving confidence of students who received instructions using either the Desmos or TI-83 plus graphing calculator" (Montijo, 2017, p.74). The researcher found that graphing calculators improved students' confidence in problem-solving in math.

Pedagogical Knowledge

Pedagogical knowledge (PK) consists of teachers' depth of knowledge about the "process and practices of teaching and learning and would apply to knowing how students learn, general classroom management skills, lesson planning, and student assessment" (Koehler et al., 2013, p. 4). A teacher with profound knowledge of pedagogy knows how students obtain and construct knowledge as well as keeping a positive learning environment and curiosity of learning the content (Koehler & Mishra, 2009). In addition, teachers need to understand the developmental theories of learning, social-emotional needs of students, and cognitive development to apply within the interactions that occur in a classroom. Marzano et al. (2001) identified Nine High Yield Instructional Strategies to enhance student achievement within all subject areas:

- Identifying similarities and differences,
- Summarizing and note-taking,
- Reinforcing effort and providing recognition,
- Homework and practice,
- Nonlinguistic representation,
- Cooperative Learning,
- Setting and providing feedback,
- Generating and testing hypotheses,
- Cues, questions, and advance organizers.

Additionally, the National Council of Teachers of Mathematics, (2015) developed eight effective mathematics teaching practices to improve student learning. One of the strategies included purposeful questions, a topic researched by the United States Department of Education's Institute of Education Sciences (IES) through the What Works Clearinghouse (WWC). The overarching themes that were suggested to improve the teaching and learning of algebra and included developing a deeper understanding of algebra, promoting process-oriented thinking, and encouraging precise communication to allow students to talk about mathematics using precise language. A few of the suggested purposeful questions to facilitate discussions include:

- What were the steps involved in solving the problem?
- Why do they work in this order?
- Would they work in a different order?
- Could the problem have been solved with fewer steps?
- Can anyone think of a different way to solve this problem?
- Will this strategy always work? Why?
- What are other problems for which this strategy will work?
- How can you change the given problem so that this strategy does not work?
- How can you modify the solution to make it clearer to others?
- What other mathematical ideas connect to this solution? (What Works Clearinghouse, 2019, p.5)

Another effective practice is promoting productive struggle. Warshauer (2014) was interested in finding out what productive struggle looks like in a middle school mathematics classroom. In a study of video recordings of 6th and 7th grade math classes, conversations between teachers and characteristics in which teachers support struggles productively were noted. The three frameworks emerged: how the students were affected by the task's cognitive demand, how struggles were handled, and how thinking was supported.

Selecting the right mathematical tasks that promote transfer learning is essential to providing the students opportunities to transfer their knowledge to new and different situations, (Hattie et al., 2017). Boaler (2016) researched rich mathematical tasks and the impact they had on a growth mindset for the learners. The study concluded learning is based on experiences and whether teachers or facilitators provide opportunities to solve authentic problems can impact students' ability to make connections and transfer their knowledge to new and different situations.

Smith and Stein (2018) explain how teachers can orchestrate mathematics discussions in their classrooms through five practices: anticipating student response, monitoring student work, selecting student solutions, sequencing student solutions, and connecting student solutions These five practices are a set of instructional routines for planning and implementing during a lesson to support mathematical content and building student thinking. This instructional strategy requires teachers to unpack the practice of setting goals and selecting a task, anticipating student responses, monitoring student work, selecting and sequencing student solutions, and connecting student solutions during a lesson (Smith & Stein, 2018).

Content Knowledge

Teachers need to possess a deep understanding of the fundamentals within the content that they teach (Koehler et al., 2013). To address content knowledge, the current study's content focused on the Virginia Standards of Learning for Mathematics and district curriculum unit plans which are based on the Understanding by Design (UbD) process (Wiggins & McTighe, 2012; VDOE, 2020d). The three stages of UbD include:

Stage 1 -Desired Results: What will students need to know and understand as a result of this unit and lessons?

Stage 2 – Assessment Evidence: How will students and the teacher know when the students are successful?

Stage 3- Learning Plan: What learning experiences will best facilitate the desired outcomes of the unit? (PWCS Unit Documents, 2020)

The UbD model uses ongoing reflection to help teachers refine and redirect learning experiences for individuals and the class. Teachers are encouraged to look for evidence that the lesson design and teaching were effective for all learners as well as ways to improve student learning and extend their thinking (Wiggins & McTighe, 2012).

Researchers identify two types of knowledge within mathematics: mathematical content knowledge (MCK) and mathematical content knowledge of teaching (MCKT) (Ball, 1991a, 1991b, Ball, & et al, 2008; Hill et al, 2005; Ronau et al., 2012). The mathematical content knowledge includes knowing how to do mathematics and a deep conceptual understanding of mathematics and its processes. Whereas the mathematical content knowledge of teaching is the “how-to” of teaching mathematics. For example, “Knowing algebra is one set of skills; knowing how to teach algebra effectively requires a different kind of knowledge” (Ronau et al., 2012, p.179).

Within the TPACK model, there are intersections with pedagogical and content (PCK), technological and content (TCK), technological and pedagogical (TPK), and an intersection of technological, pedagogical, and content knowledge (TPACK). The Pedagogical Content Knowledge (PCK) aligns with Shulman’s work on transformation of the subject area for teaching students. PCK incorporates the curriculum, art of teaching, learning, assessing, and providing feedback to promote learning (Koehler & Mishra, 2009). Technological Content knowledge interactions have a profound relationship in that the knowledge gains through the technology impacts the content and similarly the content knowledge influence the type of technologies used (Koehler & Mishra, 2009). For example, a calculator is used to perform mathematical calculations, so individuals need to understand mathematics to know what operations need to be performed and how to use the calculator to carry out the calculations.

Technological Pedagogical knowledge is important to know how technology can impact teaching and learning (Koehler & Mishra, 2009). When considering which technology tool to use, teachers must plan how the tool will impact student learning and understanding. TPACK intersection of all three core components is the foundation of effective teaching with technology. Knowing how technology can be used to build on prior knowledge to develop new epistemologies or enhance existing knowledge is critical in the interactions with content and pedagogical techniques (Koehler & Mishra, 2009). Each teacher has a different learning environment within the interactions of TPACK components and must consider contextual knowledge when planning and implementing the use of technology within a classroom.

Contextual Knowledge

Contextual knowledge can be acted on or changed based on the context of the classroom environment. This type of knowledge, represented by the outer circle in Figure 4, has become more critical for teachers to meet the needs of all learners. The understanding of contextual knowledge impacts the effectiveness of using the TPACK framework (Mishra, 2019).

Pape et al. (2012) found that classroom connectivity technology (CCT) can create opportunities for students to engage in dialogue which leads to mathematical and science thinking. The study consisted of four years of randomized trials on classroom connectivity in promoting mathematics and science achievement (CCMS). Four principles that emerged from the data gathered included:

- Principle 1: Effective CCT implementation is dependent upon the mathematical task that supports the examination of patterns leading to generalized and conceptual development.
- Principle 2: Effective CCT implementation is dependent upon classroom interactions that focus mathematical and science thinking within students and collective class.
- Principle 3: Effective CCT implementation is dependent upon formative assessment instructional practices that lead teachers' and students' increased knowledge of students' present understanding.
- Principle 4: Effective CCT implementation is dependent upon sustained engagement in mathematical and science thinking (Ronau et al., 2012, pp.177-178).

Pape et al. (2012) illustrated the complexity of teaching mathematics with this sample and the importance of knowing the context of the classroom environment.

Contextual knowledge is also important for culturally responsive instruction. Berry and Thomas (2017) conducted a qualitative metasynthesis of 12 published research papers focusing on Culturally Relevant Pedagogy (CRP) and Culturally Responsive Teaching (CRT) published between 1994 - 2016. Results identified six areas that impacted student learning: (a) caring; (b) knowledge of contexts and teaching practices using contexts; (c) knowledge of cultural competency and teaching practices using cultural competency; (d) critical consciousness; (e) high expectations; and (f) mathematics instruction/teacher efficacy and beliefs.

Teacher Education and Training

Teacher education programs should bridge the gap between theory and practice by providing opportunities to integrate technology with teaching content supported through the

TPACK Framework. Merriam and Bierema (2014) described the connection between adult learning and life experiences as critical in learning. Schon (1983) described how learning occurs through two key reflective practices, “reflection-on-action” and “reflection-in-action” (p.49). An example of a reflection-on-action would be if a teacher decides to use a new digital tool during a lesson. The teacher would reflect on how the lesson went with the use of the new digital technology and how it improved student understanding of a concept. Reflection-in-action is like thinking on your feet. Based on the contextual information occurring within the experience, the teacher would need to adjust using the new digital technology with students either by providing additional clarification or changing direction. The reflection-in-action often occurs with a more experienced teacher compared to a novice teacher (Schon, 1983). Effective teaching occurs when educators are provided opportunities to reflect on their experiences integrating technology, pedagogy, and content knowledge (Journell & Tolbert, 2016).

Typically, in universities across the United States, pre-service teachers learn their content from content experts such as mathematicians, scientists, and other subject area professionals separate from educational pedagogy experts (Journell & Tolbert, 2016). This creates a disconnect between the content and pedagogy for these future teachers. Furthermore, Berson and Berson (2014) explain that when educators are trained in using technology and become confident, the implementation of technology in classrooms will be successful. Additionally, Diacopoulos (2018) found that pre-service teachers’ beliefs and dispositions could influence their development of content, technological, and pedagogical knowledge. Teachers’ beliefs on their abilities to implement a task impact the effectiveness of teaching mathematics (Niess et al., 2019). Similarly, Ayieko et al. (2019) conducted a study on building knowledge of technology for pre-service secondary mathematics teachers within an integrated technology mathematics methods course. Findings indicated that pre-service teachers demonstrated an improvement in their TPACK knowledge, leading to the conclusion that “teachers’ knowledge for teaching mathematics in secondary mathematics is incomplete without the inclusion of knowledge of technology” (p.26).

A study on pre-service teachers’ training by Ketsman (2019) explored pre-service teachers’ perspectives towards using a blended learning approach with classes. Findings indicated that pre-service teachers who experienced integration of technology within their courses adopted a blended approach when teaching compared to those who had the traditional format exclusively. This provided critical information on teacher education programs in preparation for teaching.

In preparing future STEM teachers, “developing knowledge of technology integration across multiple course experiences in one’s program of study” is important for new teachers to experience when promoting use of digital tools (Enderson & Watson, 2019, p.415). The study used simulation applications and digital tools for modeling STEM ideas to promote a dynamic environment, which helped learners develop a deeper conceptual understanding. Without such experiences, future teachers are at a disadvantage in thinking of ways to incorporate technology into instruction that will engage learners in their own development of concepts.

There have been numerous ways to address incorporating technology into instruction, but the challenge is that technology is always changing, and teachers need support in this area. There are three ways TPACK development could be used with pre-service teachers: (1) use the TPACK framework in an educational technology course; (2) include instructional strategies within educational technology or methods courses; and (3) weave TPACK throughout various educational programs so that students see it across their coursework (Herring et al., 2016).

Teachers' Training and Professional Development

Teaching is a field that continues to grow through the interaction between individuals, content, technological, and pedagogical practices. To maintain teaching credentials, teachers are often required to obtain training and education on current practices and to continuously grow in their knowledge of content, pedagogy, and technology. The emerging trend in education and training is to meet the demands and needs for preparing teachers who are not fully licensed or career switchers. Based on Gynther's (2016) premises, teachers have a range of needs to be met in their training.

Research on technology integration in schools, Davies & West, (2018) indicated that students have used technology "to gather, organize, analyze, and report information" which has had little impact on students' standardized tests (p.31). They suggested that future research needs to focus on "providing students and teachers with increased access to technology along with training in pedagogically sound best practices, including advanced approaches for technology-based assessment and adaptive instructions" (p.31). They suggest the effectiveness of technology integration is determined by the success of the learning outcomes. The three ways to evaluate the use of technology being used by teachers and students are: access to technology, use of technology to instruct, and implementation of technology to accomplish learning outcomes.

Shapley et al. (2010) indicated teachers often use the computer for administrative purposes, communicating through email, and instructional resources. This differs from student use where they primarily use technology for gathering information or completing tasks (Davies & West, 2018). Efforts to improve the use of technology in the classroom have turned the focus towards professional development for teachers. Harris et al. (2009) identified five models of professional development with technology: software-focused, use of sample lessons, technology-based educational reform efforts, standardized professional development workshops, or technology-focused teacher education courses. However, Harris et al. (2009) noted that there is not enough evidence to conclude these models improve learning outcomes.

Professional development methods for integrating technology include enhancing one's skills with technology, using collaborative learning environments, and mentoring the integration of technology (Davies & West, 2018). Other ways to access skill-based technology include video-based self-assessment (Calandra et al., 2009; West et al., 2009), electronic portfolios (Derham & Diperna, 2007; Chuang, 2010), and individual response systems (Cheesman, et al., 2010; Davies & West, 2018). Prior studies investigated how collaborative environments can improve professional development outcomes with the integration of technology. MacDonald (2008) found that teachers needed the "authentic teacher contexts" (p.431). Another increasing collaborative environment is social networking with online discussions. According to Vavasseur and MacGregor (2008), teachers benefit from the online communities of sharing content-based knowledge and technology.

Mooney (2018) used the technological, pedagogical, and content knowledge (TPACK) framework along with Polya's (1945) four-step problem–solving approach in an online social environment to stimulate learning for all students in his study. The author's goal was to create an environment where students could feel more comfortable expressing their thoughts in mathematical language. Mooney (2018) used Google Docs for classroom discussion and geogebratube.org. The result of using a different platform was that it allowed students to discuss mathematics online. One student, who usually observed and rarely talked in class, participated the most within this platform. This student was an artist and visual thinker. This platform allowed her to interact with abstract concepts tangibly through GeoGebra. She was then able to articulate her thoughts with her written language. This technology tool allowed students to become thinkers and doers of mathematics. The author provided background information on implementation and examples of how technology could be used to reach all students. This is relevant to emerging trends in education and training for teachers and professional development by creating learning intentions with technology to meet the needs of students. Finally, the use of mentoring in using technology to increase the integration of technology by shifting professional development to mentoring at different stages of adopting technology benefits new teachers (Kopcha, 2010).

Technology professional development often focuses on improving teachers' attitudes towards technology and increasing their self-efficacy with little emphasis on pedagogical practice. Inan and Lowther (2010) found some scholars recommend a change in professional development to focus on the understanding of pedagogical technology practices. Ertmer and Ottenbreit-Leftwich (2010) stated that teachers need to know how technology can be used to develop knowledge, which is one reason the TPACK framework was proposed as a framework to guide training with the integration of technology (Harris, Mishra, & Koehler, 2009).

Niess et al. (2009) conducted a study on in-service teachers to determine the impact of four weeks of professional development on teachers' TPACK knowledge. Qualitative methods were employed to determine the stage of teachers' TPACK which included: recognizing, accepting, adapting, exploring, or advancing. Archambault and Crippen (2009) conducted a study that examined the TPACK knowledge among K-12 online distance educators in the United States. They examined a national sample of 596 K-12 online teachers and measured their knowledge with the TPACK framework. The results indicated that technology and pedagogy as well as technology and content had a small correlation while the relationships between pedagogy and content had a large correlation.

Lyublinskaya and Tournaki (2012) conducted a study on the effects of the use of handheld devices on student achievement in algebra. The study consisted of a year-long professional development program that included four Algebra teachers implementing the TI-NSpire within the curriculum. A rubric was used to determine the TPACK levels that were created and designed by the researchers. The results from the study found that teachers' TPACK scores for written artifacts were consistent with the professional development presentations. The implementation of artifacts with the classroom was at a level equal to or lower than the written artifacts and there was not a consistent level of improvement through the schools. Lastly, of teachers who had higher TPACK levels, their students performed higher on the Regents exam (Lyublinskaya & Tournaki, 2012).

To provide high-quality professional development with digital technology, it is important to develop an understanding of the user and the benefits for the learners on the implementation of the new technology (West, 2018). Research has shown that the most effective professional learning is job-embedded (Herring, 2016). Strategies and approaches for TPACK development are listed in Table 5 (Herring et al., 2016, pp.198-199).

Table 5

Adapted TPACK development Approaches and Strategies.

TPACK approach	Description
Instructional planning approach	Utilize curriculum units of study during planning with TPACK Framework.
Reflective approach	Individualized support and training that includes all desired TPACK levels.
Problem-based approach	Use authentic problems and/or problem-solving strategies with the TPACK framework and technology such as Desmos.
Computer-adaptive approach	Interactive, online software assess teachers' TPACK formatively, as learning progress.

Three reasons to evaluate training programs include: (1) To improve the program, (2) to maximize the transfer of learning to behavior and subsequent organizational results, and (3) to demonstrate the value of training to the organization (Kirkpatrick & Kirkpatrick, 2016, p.6). Teacher training impacts the implementation of technology, and how it is used to build students' understanding of concepts. The importance of collaborating to support effective mathematics teaching practices is critical. Building teachers' capacity by "a key aspect of the 'Professional Principle' is recognizing that their learning is never finished and that they must build a culture of professional collaboration that is driven by a sense of interdependence and collective responsibility" (NCTM, 2018, p.35).

Hawley and Valli (1999), identified eight effective professional development practices impacting outcomes: (1) the goals of the teacher for students' achievement, (2) what teachers think they need to learn, (3) the contextual environment within the school, (4) ability to problem solve, (5) ongoing support, (6) relevant information, (7) opportunities to develop understanding, and (8) training that has a comprehensive process for improvement. Joyce and Showers (1980) suggested that professional development should include developing a deep understanding of concepts, modeling from experts, opportunity to practice and receive low-risk feedback, and authentic contextual environments. While Garet et al. (2001) found that long-term professional development is more effective than short-term training. Teachers also indicated that hands-on and content-focused training in the workplace was beneficial.

Learner-Centered

Learner-centered professional development (LCPD) that incorporates both developing TPACK knowledge and providing support with the integration of technology provides effective teachers learning opportunities (Polly, 2011; Polly and Hannafin 2010; National Partnership for Education and Accountability on Teaching NPEAT, 2000; and Orrill, 2001). According to Polly and Hannifin's (2010) synthesis of the American Psychological Association's Learner-Centered Principles and research found that professional development training should include the following (Polly, 2011, p. 84).

- Focus on student learning outcomes,
- Provide teachers with ownership of their professional development activities,
- Promote collaboration,
- Address knowledge of both content and pedagogy,
- Support reflection on teacher's daily work,
- Ongoing activities.

Polly (2011) conducted a year-long case study of elementary teachers who participated in a professional development where teachers developed TPACK through technology-rich tasks then implemented these tasks with the integration of technology in their mathematics lessons. The study was funded by a statewide teacher quality grant at a southeastern United States university. In the Technology Integration in Mathematics (TIM), teachers received 48 hours of training focused on technology standards-based pedagogies, which included rich mathematical tasks and questioning strategies. This training occurred during the summer months for four days then four six-hour follow-up trainings throughout the year (Polly, 2011). The professional development consisted of "posing a task, modeling the use of any technologies, and then supporting students' work through questioning" instead of procedure-based instructions (Polly, 2011, p.85). Throughout the school year, project staff would co-plan two lessons with each participant. The research questions of the study consisted of the following:

1. To what extent do teachers integrate technology into their mathematics classroom?
2. How do teachers' enactments of technology rich mathematical task reflect their TPACK?
3. What types of support offered during the professional development are most closely associated with teachers' enactment of TPACK? (Polly, 2011, p.86)

The two teachers reported in the study were chosen purposefully in that they taught in the same high poverty Title 1 elementary school (Polly, 2010). The data sources consisted of observations of classrooms and during professional development. Coding was noted from 0 to 3 where 0 was no use of technology and 3 was where technology was used as a tool for learning.

The level of technology use was recorded as planning support and related to professional development content, planning support included no planning support, co-planned, and directly adopted. The findings in this study indicate that teachers who co-planned with a project staff used higher levels of technology during observations than the lessons that were not co-planned. The implications of the study suggested that the need for LCPD support outside of training workshops is needed (Polly, 2010). Likewise, some teachers have a depth of content knowledge but may need intense support with pedagogical and technological knowledge development (Polly, 2010). In order to bridge the gap between teachers' knowledge, the use of the TPACK framework and LCPD with support influences transferable and sustainable implementation of the integration of technology to enhance student learning.

For teachers to integrate technology successfully within their classrooms, there needs to be professional development opportunities that are embedded instructionally and implemented over a period of time and include opportunities for teachers to reflect on implementation (Matherson et al., 2014). Based on education research, Matherson et al. (2014), identified ten recommendations for professional development:

1. Allow teaching to drive training and use common language for effective classroom learning (Loucks-Horsley et al. 2001).
2. Teachers have opportunities to develop their knowledge and skills (Loucks-Horsley et al. 2001).
3. Leadership opportunities for teachers participate in their learning experience (Loucks-Horsley et al. 2001).
4. Establish a collaborative learning community with participants (Loucks-Horsley et al, 2001).
5. Demonstrate the strategies that teachers would use with their students Loucks-Horsley et al. 2001).
6. Provide opportunities for teachers to assess their effectiveness and make improvements (Loucks-Horsley et al. 2001).
7. Align standards of learning to methods of teaching and activities (Garet et al. 2001).

8. Involve collaborative learning teams in training (Garet et al. 2001).
9. Be purposeful in integrating training align to the needs of the school (Garet et al. 2001).
10. Provide a sustainable learning opportunity for teachers instead of short term.

The use of the TPACK framework is an example of providing sustainable training when developing a lesson. Matherson et al. (2014) provided an example of making decisions with the TPACK framework to develop a lesson the includes (p. 49):

1. Learning goals are based on content standards.
2. Pedagogical strategies are aligned with the learning experience and outcome.
3. Activities engage students through scaffolding and enhanced learning experiences.
4. Digital tools and resources will assist in the students achieving the goals.

Job-embedded professional development for teachers should be relevant and sustainable using the TPACK model to integrate technology within the content areas (Matherson, et al., 2014).

Mentoring Novice Teachers

Strong and Baron (2004) studied the relationships between the mentor and mentee and found that when mentors avoid acting in an expert manner, there was more dialogue between both parties. There has been a shift in mentoring programs to be more learner-centered rather than product-oriented. The foundation of the learner-centered mentor program is based on adult learning by Knowles (Zachary & Parks, 2011). According to Knowles (1984), adult learning theory is optimal when the individual is involved in the learning process which includes diagnosing, planning, implementing, and evaluating their understanding. Facilitators need to promote a supportive climate and allow the learning to be self-directed. There is an increase in readiness to learn when there is a specific need for the learning. When the adult learner can apply their life experiences, learning is enriched. Adult learners desire immediate application of new learning and adults are internally motivated (Knowles, 1980).

Just-In-Time

Just-in-time has several different methods and strategies for implementation that correspond to the needs of the learner within the contextual environment (Beckett, 2000). The essential component for adult learning is the information needed to improve performance or complete a task (Bersin & O'Leonard, 2005). For example, Dabbagh and Fake (2016) researched Tech Select Decision Aide: A mobile Application to facilitate Just-in-Time Decision Support for Instructional Designers. The Just-in-Time mobile app supported instructional designers and facilities in the creation of instructional training resources for technology. To measure the effectiveness of the mobile app, the researchers used the Usefulness, Satisfaction, and Ease of Use (USE) survey. The findings indicated that the mobile app has the potential to be a tool for Just-in-Time resources for instructional designers with technology. Just-in-time education has been used in many occupations. Beckett et al. (2002) define Just-in-Time Training (JiT) as "the negotiated provision in managerial workplaces, of learner-generated immediate skill formation" (Beckett et al., 2002, p. 332).

According to the U.S. Department of Education (1994), two-thirds of teachers in the United States reported that they do not decide on what type of professional development that they received within their school system (Bransford et al., 2004). A study by Trivette et al. (2009) analyzed the effectiveness of adult learning models which included just-in-time training, accelerated learning, and guided design. The Just-In-Time training involved individualized, tailored training to meet specific requests or concerns (Redding & Kamm, 1999). The outcome of Just-In-Time learning is an increase in knowledge and performance. Accelerated learning occurs in the relaxed emotional state where the learner is actively engaged. The environment is a positive learning atmosphere, and it is a holistic adult learning method to promote creativity (Meiser, 2000). The research synthesis found that effective training will have the components of planning, application, and deep understanding which includes the learner experiences.

Professional development training is most effective when the learner is an active participant. This adds value to the training. Providing multiple learning experiences gives the learner opportunity to practice and reflect on the learning experiences which develops mastery of new knowledge. Ineffective training includes passive learning and instructional videos in which the learner is not actively engaged in the learning.

Trust et al. (2020) examined the many ways that teachers obtained just-in-time resources for teaching during the coronavirus pandemic. They found many educators used social media for resources to share information that would aid the shift to remote teaching. According to Hall and Hord (2006), a person's beliefs and practices remain a complex process to change. The acceptance of new knowledge impacts the belief and attitudes to change instructional practices (Zwart et al., 2007). Guskey (2002) argues that beliefs and attitudes change when new knowledge of instructional practices are implemented and has an impact on the students' outcomes. Students improvement within the contextual environment impacts the change in instructional practices and impacts teachers' beliefs and attitudes.

Contextual knowledge of teaching is multifaceted, and a dynamic learning environment is critical in the integration of technology and the interaction of the components within the TPACK framework. Prior education research has focused on teachers' knowledge and actions of observable activities (Koehler & Mishra, 2009). Developing new knowledge and skills can be challenging during times with busy schedules. Teachers are less likely to acquire new knowledge unless it is relevant to them (Ertmer et al, 2010; Koehler et al., 2013). Often teachers have experienced inadequate training since technology training is usually implemented as a "one-size-fits-all approach" (Koehler et al., 2013). "What is needed is an approach that treats teaching as an interaction between what teachers know and how they apply this knowledge in the unique circumstances or contexts within their classrooms" (Koehler et al., 2013, p. 3).

Chapter Two Summary

In summary, the literature review in part one examined the TPACK history, TPACK in Mathematics, TPACK framework and survey. In part two of the literature review, the researcher examined teacher education, teacher training, professional development and learner centered approach to training. These two parts of the literature review defined the rationale for this study which focused on using the TPACK framework to customized support and training. The attributes of adult learners revealed in the literature review was the need for training to be relevant to specific needs and learner-centered.

CHAPTER 3

METHODOLOGY

This chapter includes an overview of the research design, rationale for the methods that were used to conduct this study, procedures, the framework for the study design, and a timeline. In addition, the specific methodology that was used to conduct the study is described which includes: setting, instrumentation, description of the sample, participants, data collection, and data analysis. Finally, this chapter discusses the theoretical proposition, limitations, and issue of trustworthiness.

Overview of Research Design

The goals of this mixed-methods case study with an intervention were to be proactive in identifying areas of support for newly hired secondary mathematics teachers and to develop the essential characteristics of planning and implementation of information technology, pedagogy, and content knowledge in the classroom. This study examined the relationship between targeted support using the TPACK model and the integration of information technology with newly hired secondary mathematics teachers. The intervention of the individualized support and training was evaluated by the growth in Pre- and Post-TPACK knowledge surveys and the findings from qualitative data.

Data collection included both open and closed-ended questions from surveys, interviews, observations, and unobtrusive data such as written reflections and lesson designs. Since the measure of the intervention occurred with the same participant, a paired (dependent) t-test was used to analyze the data in SPSS. Semi-structured individual interviews were recorded before, during, and after the planning using the questions aligned with the TPACK survey as a guide to support newly hired secondary mathematics teachers. The interview process adhered to protocols to maintain consistency with subjects (Appendix G). To maintain consistency during observations, the researcher used an observation data collection form based on Merriam's (2009) recommended checklist during observations. The elements that were considered during an observation included: physical setting, participants, activities and interaction, conversations, subtle factors, and own behavior (Merriam, 2009, pp. 120-121) (Appendix F).

In addition, the researcher used field notes and written reflections after observations. Qualitative data consisted of a case study to develop a general understanding of how to support new teachers using the TPACK framework. The researcher used a hybrid coding model to analyze the qualitative data using a priori codes based on the TPACK framework as a method of coding data for the qualitative research. (Creswell, 2009) (Appendix H).

This study was designed to find common themes that support teachers' planning and implementation using the TPACK Framework along with the relationship between the types of training that will occur for each participant. The qualitative analysis was used in corroboration with the quantitative data to gain a deeper understanding of the factors influencing a teacher's self-efficacy with TPACK during this professional development cycle of assessing, training, supporting the planning and implementation of instruction, then reflecting. Using qualitative research by coding data with the TPACK framework in corroboration with the quantitative data helped gain a deeper understanding of the factors influencing a teacher's self-efficacy with TPACK during this professional development cycle.

Research Rationale

The design that was most appropriate for this research was an individual case study with an intervention. According to Yin (2018), case studies investigate contemporary events within some real-life context which can be descriptive or exploratory case studies. There are three conditions that a researcher must examine when deciding on the design of the study which includes: (a) type of research questions, (b) control the investigator has over the behavioral events, and (c) focus on contemporary as opposed to historical phenomena. Case studies often use the questions “how” and “why” which allow the focus to be on contemporary events (Yin, 2009, 2018). Within this study, the questions that were used during planning and to individualize support are aligned with Yin’s perspectives of “how” and “why” questions (Appendix D).

According to Yin (2018), a rationale for a mixed-methods case study is “converging evidence (triangulation) might be obtained when different methods are used” (p. 235). This study was based on a survey, interviews, and observations. There was no control group and there were no variables within the study. Data collection included both open and closed-ended questions from surveys, interviews, observations, and unobtrusive data to draw on possibilities, statistical analysis, and text analysis (Creswell & Creswell, 2018) (Figure 1). The quantitative data was used to obtain information prior to training and individualized teacher support. In determining the type of qualitative data gathered, the researcher examined the research questions to consider the case study design (Creswell & Creswell, 2018). Case studies are inquiry-based research that explores programs, events, activities, processes, or individuals (Creswell, 2009). In addition, case studies are “bounded by time and activity, and the research collects detailed information using a variety of data collection procedures over a sustained period of time” (Creswell, 2009, p.13).

As a participatory investigator, whose role was non-evaluative as a professional development specialist for secondary mathematics, it was the participant’s decision on how to implement the integration of instructional technology, content, and pedagogy within a secondary mathematics classroom. According to Yin (2014) case studies are either epistemological relativist or realist depending on the circumstances. If an observer is independent of the study, then it is epistemologically realist. If the study has multiple realities and perspectives that are observer-dependent, then the case study is from a relativist epistemological orientation. Since the researcher provides that intervention within this study, the research fit a mixed-methods case study design which was observer-dependent.

Procedures of the Research

Data were collected using both quantitative and qualitative methods. The researcher adapted a survey comprised of twenty-nine items from the original TPACK survey (Schmidt et al., 2009). The adapted survey aligned to mathematics only for this study and demographic information was collected at both the beginning and the end of the study (Appendix B). Qualitative data collection was through interviews and observations. Individualized support sessions used the TPACK framework for six months in online Zoom meetings (Table 6).

Timeline

On August 17, 2020, the TPACK survey was emailed to newly hired secondary mathematics teachers (Appendix I). Newly hired secondary mathematics teachers participated in a Connect Conference on August 14, 2020, and Secondary Day on August 19, 2020. Based on results from the TPACK survey additional training and support were recommended in the domain areas of technology, pedagogy, and content during the first semester for approximately six months. Individualized support was provided to participants with a three or below in any of the domain areas and for those who requested and needed support. Novice secondary mathematics teachers received professional development induction sessions in October, December, and February to support learning in the areas of pedagogy.

Table 6

Research Procedures

Group	Pre-Assess	Implementation	Post-Assess
Newly Hired Secondary Mathematics Teachers Novice to Experienced	TPACK Survey	New Teacher Connect Conference Just-in-Time Training Content, Pedagogy Technology	TPACK survey
		Desmos Technology Canvas Courses Secondary Day	
	Pre-conference Interviews and Observations	Individualized support using TPACK Model for Desmos and other support as needed.	Post-conference Interviews and Observations

Teachers received an invite in November to participate in Desmos Canvas Courses which were designed to build capacity in the integration of technology within secondary mathematics classrooms. The training was customized to meet the needs of the teachers and allowed for teachers to collaborate through synchronous meetings and to individualize learning through asynchronous modules. At the end of January, TPACK surveys were emailed again to the teachers, who had completed them in August. Research started in August 2020 and ended in March 2021 (Table 1).

Setting

This mixed-methods case study was conducted at several middle and high schools within a large school district located in the mid-Atlantic region of the U.S. This school system is the second largest in the state and serves 91,524 total students, with approximately 21,357 students in middle school and approximately 28,058 students in high school. The student demographics indicate a diverse population consisting of Hispanic/ Latino of any race (35.5%), Black or African American (20.07%), Asian (9.15%), two or more races (5.74%), other (0.41%), and white (29.17%). Approximately 16% of students within the population receive special education services and approximately 26% of students are identified as English Learners. There are approximately 11,783 employees within the school system of which there are approximately 6,362 teachers. The school system has 63 elementary schools, 16 middles schools, 13 high schools, three traditional K-8 schools, two nontraditional K-12 schools, and one Governor's School (VDOE, 2020).

Research Questions

The research questions for this study were designed with the Technological Pedagogical Content Knowledge Framework as a reference for developing teachers' knowledge through support using the TPACK model (Mishra & Koehler, 2006; 2009) (Table 7):

1) How does targeted individualized support and professional development impact newly hired secondary mathematics teachers' knowledge of technology, pedagogy, and content integration during instruction?
2) What are the essential instructional characteristics of integrating technology, pedagogy, and content knowledge that are developed during planning for the implementation of instruction?
3) What strategies support teacher integration of technology during instruction?

Table 7

Breakdown of Research Questions

Research Question	Dependent Measure	Data Collection	Analysis
How does targeted individualized support and professional development impact newly hired secondary mathematics teachers' knowledge of technology, pedagogy, and content integration during instruction?	Tier 1 Initial Learning	Pre and Post TPACK Survey All newly hired secondary mathematics teachers will have an opportunity to complete the TPACK survey.	Paired t-test Excel Spreadsheet and SPSS (secured and password network)
What are the essential instructional characteristics of integration of technology, pedagogy, and content knowledge that is formed during planning and implementation?	Tiers 2 and 3 Individualized Training and Support Initial Learning and Individualized Support (Teachers score 3 or below any TPACK Domain) or (Teacher request for support and need)	Interviews, observations, reflections, artifacts (activity design), and field notes.	Coding, categories, and themes from transcriptions of records and other written documents.
What strategies support the teachers' integration of technology during instruction?	Tiers 2 and 3 Individualized Training and Support	Interviews, observations, reflections, artifacts (activity design), and field notes.	Coding, categories, and themes from transcriptions of records and other written documents

Instrumentation

The instrument used was a survey of pre-service teachers' knowledge of teaching and technology (Schmidt et al., 2009) known as the TPACK survey (Appendix B) and was created by educators at Iowa State University and Michigan State University. The initial TPACK survey was a pilot study of 124 pre-service teachers and the reliability of the TPACK scores had an internal consistency alpha reported for each domain (Appendix B) (Schmidt et al., 2009). This self-assessment was developed so teachers could evaluate their proficiencies on technological knowledge, pedagogical knowledge, and content knowledge, as well as integration of pedagogical content knowledge, technological pedagogical knowledge, technological content knowledge, and technological pedagogical content knowledge. "Each item response is scored with a value of one assigned to strongly disagree, all the way to five for strongly agree. For each construct, the participant's responses were averaged. For example, the six questions under TK (Technology Knowledge) are averaged to produce one TK (Technology Knowledge) Score" (Schmidt et al., 2009, p.2).

Participants

The criteria to participate in the study was one had to be a newly hired secondary mathematics teachers which included experienced teachers to teachers having zero years teaching full-time in a classroom. A request to participate was sent on a secure email network to newly hired secondary mathematics teachers within the participating school system (Appendix I). According to Merriam and Tisdell (2016), purposeful sampling highlights a targeted group, and the criteria for the group selection defines the purpose of the study.

The research consisted of five case studies of newly hired secondary mathematics teachers at the high school and the middle school levels. Emails were sent prior to training sessions for participants to choose the topics to discuss. Table 2 details the levels of support provided to participants. All participants were given a pseudonym to protect the individual's identity. The participants could opt out of the additional support or opt-out of the study at any time. The timeframe for the participants included early support in September and October 2020, mid support in November and December 2020, and later support in January, February, and March 2021.

Data Collection I -Quantitative: Survey and Amount of Support

Initial data collection consisted of a TPACK survey prior to professional development at the beginning of the school year. A Post-TPACK survey was given again within six months of the Pre-TPACK survey. The survey was created as a Microsoft form and only accessible to the recipients through the individual's secure password. Only the researcher can access the data through a secure password network. The data from the Pre- and Post-TPACK survey and member check survey are kept in a secure password-protected network in a spreadsheet. A professional learning management system was used to register and mark the completion of training. The number of hours of training sessions completed was recorded and a report generated on the district's survey evaluations was used to determine the overall effectiveness of the training sessions. Training that received an average of three or higher was considered overall effective based on the participants' evaluation of the training. The researcher facilitated or co-facilitated training for teachers, but some training was provided from outside presenters or other professional trainers. For example, Desmos professional development was conducted through

Desmos to provide a trained Desmos facilitator for the workshops. The learning management system training was provided by instructional technology coaches within the school division. Content training was co-facilitated by the curriculum coordinator and professional development specialist (researcher). The researcher provided training for Desmos Geometry and introduction training to Desmos. Instructional support staff from the Office of Professional Learning and Student Learning are required to keep a record of the support and type of support that was provided to educators. The researcher's service log report was analyzed in March to determine the number of hours each participant received support and the type of support (Table 8).

Table 8

Data Collection Procedures

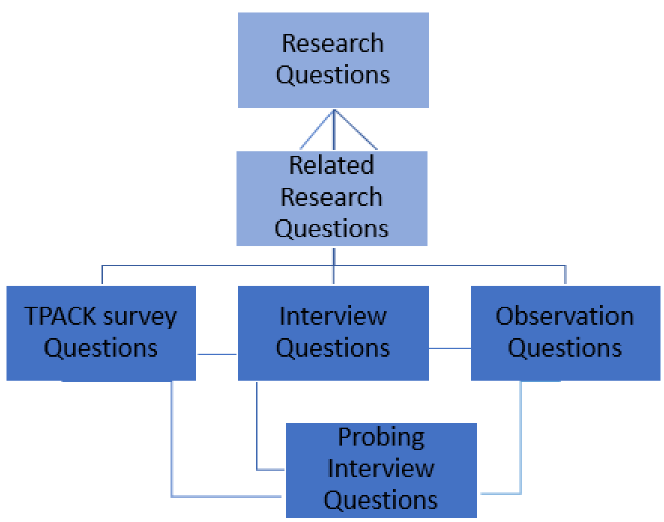
Instrument	Pre-Assessment	Post-Assessment
Survey	Pre-assessment on TPACK	Post-assessment on TPACK
Interview Questions	Pre-interview prior to support	Post-interview after support
Observations Notes	Pre-Conference Observation form	Post-Conference Observation form
Field Notes	Field Note Collections Before support	Field Notes Collections After Support
Transcripts	Zoom Sessions	Transcribed recordings
Professional Learning Management	Enrollment in Training	Completion of Training
Researcher's Support Log	After support- documentation of service support provided.	

Data Collection II -Qualitative Interviews and Field Notes

Qualitative data were collected through Zoom recordings and transcriptions. The qualitative research design consisted of research questions, related research questions, alignment with TPACK survey questions, interview questions with probing questions, and observation questions (Figure 5). Although the initial interview questions were sufficient to stimulate responses, probing questions were used to follow up or provide clarity (Merriam, 2009) (Appendices D & E**).** The TPACK survey questions are embedded within the interview and observation questions.

Figure 5

Qualitative Research Design



Semi-structured individual interviews were recorded before, during, and after the planning using the questions aligned with the research questions as a guide for teacher support (Table 9). Each interview consisted of approximately seven-minute pre-conference, thirty-minute planning session, and eight-minute post-conference. Consent forms were emailed prior to planning interview sessions. The forms were completed with electronic signatures and emailed back to the researcher. The researcher read the interview protocol to the participants prior to any interviews. (Appendix G). School administration was notified, and the researcher requested permission to work with the teachers. A detailed rationale and purpose of the study were provided to each participant.

Table 9

Alignment of Research Questions with Interview Questions and Reflection

Research Questions	Interview Questions
R1. How does targeted individualized support and professional development impact newly hired secondary mathematics teachers' knowledge of technology, pedagogy, and content integration during instruction?	How can I support you with technology, pedagogy, and content? (pre-intervention question) What instructional technology would you like to use with your classes? (pre-intervention question) What are the next steps to implement the technology and instructional task? (post-intervention question)
R2. What are the essential instructional characteristics of integration of technology, pedagogy, and content knowledge that is formed during planning and implementation?	How are students using technology during instruction? (during planning intervention) How are the learning standards being used within your lesson? (during planning intervention) How will you implement the instructional task? (during planning intervention) Why have you decided to use these instructional strategies within your lesson? (during planning intervention) Describe some significant moments within your lesson and how technology was used for student learning. (follow-up after implementation)
R3. What strategies support the teachers' integration of technology during instruction?	How has the planning session been helpful? (post-intervention question) How would you change the lesson to improve student learning using pedagogy, technology, and/or content?

The researcher collected all the data and maintained the data in a secure password network and locked file cabinet. Types of collected qualitative data included: pre- and post-planning interview notes and Zoom recordings transcribed, virtual class observation notes, field notes taken prior to and after planning interviews and observations, documentation of types of support provided in a spreadsheet and work calendar, and examples of lessons created by teachers using technology.

Data Collection III -Qualitative Observations and Field Notes

To maintain consistency during observations, the researcher created an observation data collection form using Merriam's (2009) checklist (Appendix G). The elements to consider during an observation included: physical setting, participants, activities and interaction, conversations, subtle factors, and own behavior (Merriam, 2009, pp. 120-121). In addition, the researcher used field notes to describe the thoughts about what was going on during the observations and reflections to model for the study. Physical setting observation notes described the physical environment and what resources, and technology was being used. Participants were described by their role in schools and grade level as well as other characteristics. The activities and interactions described the sequence of the activities, duration of the activities, norms, structures, and interactions. The interactions included observations between the activities and students, activities and teacher, and students and teacher along with the content and pedagogy being implemented. Other data collected were the conversations and nonverbal communications as well as the researcher's behavior as an observer. There were three levels of support depending on each teacher's need for support with technology, pedagogy, and content knowledge. Related research questions were used to unpack the types of technology tools used during instruction. Likewise, the related research questions revealed how the digital tools were used to develop student understanding of mathematical concepts. Finally, the related research questions revealed how preparation and formative assessments with technology can be used to identify student understanding of mathematical concepts. The related research questions were aligned with the observation form in Table 10.

Table 10

Alignment of Related Research Questions with Observation Form

Research Questions	Observation Form
RRQ 1 How are teachers using graphing utilities and/ or calculators during instruction?	What resources and technology are in the setting?
RRQ 2 How are teachers using instructional technology activities during instruction?	What norms or rules structure the activities and interactions?
RRQ 3 How does the preparation and planning of instructional technology, content, and pedagogy impact implementation of a lesson?	What is going on? Is there a definable sequence of activities?
RRQ 4. How does the use of formative assessment within instructional technology impact the teacher's perception of students' conceptual understanding of mathematics?	How are people and the activity connected?

Data Collection IV Qualitative Artifacts

There were twenty-two recorded sessions for training and planning through a secured password school district Zoom account. Observations of virtual synchronous classrooms were not recorded by the researcher. The researcher used an observation protocol form (see Appendices F & G) to observe 15 synchronous learning environments in secondary mathematics virtual classes. There was a total of 422 pages of qualitative data collected which included transcribed recordings, observations, field notes, teacher reflections, and artifacts which were approximately 136,400 words. The data was collected through secure password-protected recorded Zoom meetings, observation notes by the researcher, Canvas Platform, Desmos and Nearpod shared activities, and secured password-protected surveys through Microsoft form and emails.

Data Analysis

There were four parts of data analysis that occurred within this study. The first part was the Pre- and Post-TPACK survey. The second part of the analysis was qualitative data with multiple data points which included a quantitative member check. The third part was a qualitative member check on the quantitative data from the Pre- and Post-TPACK survey. The fourth part was analyzing the amount of time of support and training with the amount TPACK growth that occurred.

To analyze data from the pre- and post-TPACK survey and to address research question one, the researcher conducted a paired t-test. According to Green and Salkind (2008), a paired t-test should be run under the following conditions (p.169):

- Repeated-measure designs with an intervention.
- Repeated-measure designs with no interventions.
- Matched-subjects design with an intervention.
- Matched-subjects design with no intervention.

This study had two volunteer groups which consisted of a participant group with an intervention and a non-participant group without intervention.

The hybrid coding schemes were used to analyze the qualitative data which started with the initial coding (Saldana, 2016, 2021). Hybrid coding consisted of deductive and inductive methods. The deductive reasoning occurred with the existing research on TPACK and initial coding using technology, pedagogy content, and other categories. Inductive reasoning was used during the coding process which expanded the other based on the contextual and emotions (Appendix H). As noted in Figure 6, the coding process for this study involved ten steps. Appendix J provides a sample of initial coding. Common words were collapsed into categories and used to create a Wordle (Appendix K). Initial data point coding was organized in a table to align all the components within planning and implementation (Table 11).

Figure 6

Hybrid Coding with TPACK

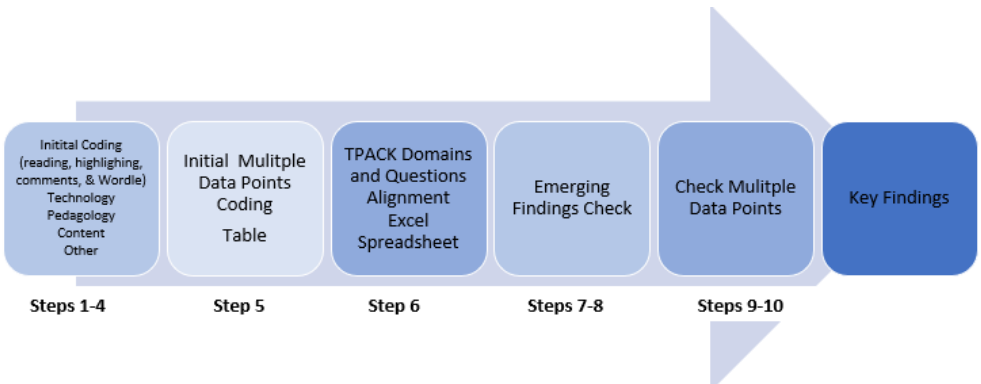


Table 11

Initial Data Point Coding

Data Point	Description	Initial Code
Participant 1 Planning Interview	"Identify slope and y-intercept and graphing a line from the slope Intercept form".	Content Topics
Participant 1 Teacher created Desmos Activity	Use the draw feature to find the slope of each line then type in your answer for each line.	Students use draw Feature in Desmos to identify the slope of the line.
Field Notes	Provided support by modeling how to create a table…	Modeling Strategies in Desmos Activities
Participant 1 Observation notes 3rd period	"let me give you a little direction…you're telling me if that's a correct answer or incorrect answer as if you're the teacher" ...	Teacher's Clarity in directions Error Analysis Problem

Steps seven and eight in Figure 6 involved identifying emerging key findings by reading through the spreadsheets and creating a list of the common emerging key findings (Appendix L). Next, a member check on the emerging key findings was conducted (Appendix L). The final step was checking the multiple data points by creating a table for each participant that supported emerging findings, then cross-referencing to identify the key findings (Appendices M & N). Notes were made as comments then an initial data point table was created for each subject within the study (Appendix J). Next, a focused coding process occurred for each subject that consisted of comments aligned with the interview questions and TPACK framework in a spreadsheet (Appendix L). Based on Saldana's (2016) recommendation, initial codes were collapsed, subsumed, rearranged, or reclassified, aligning with the TPACK framework predetermined codes. For each subject, the emerging themes were noted and placed into a list of characteristics for planning and implementation as well as a list of strategies that supported the integration of technology. The initial characteristics of planning and implementation and strategies that supported the integration of technology were emailed to each subject for them to confirm the initial findings. Finally, the multiple data points were checked and converged to the key findings (Appendix O).

Validation of Findings

To validate the findings in the Pre- and Post-TPACK survey, the researcher conducted final interviews for the participants to examine their survey answers. This provided additional qualitative data to confirm their answers to the closed questions by justifying their thinking and/or to identify any contributing factors that may have influenced their answer**.** According to Creswell and Creswell (2018), member checking serves as a check for interpretation of the data collected and ensures the truth value of the data.

Role of the Researcher

The role of the researcher is critical in research for understanding potential biases. The researcher's current position was as a professional development specialist for secondary mathematics who supported new teachers in a non-evaluative role. This role as a professional development specialist is to provide training, support district events, support curriculum, and support teachers with planning and instruction individually or during collaborative learning team meetings. For new teachers, the researcher co-facilitated new teacher training throughout the school year and conducted non-evaluative observations to provide growth-producing feedback.

Given the researcher's professional role in the school division, individualized support with informational technology was provided upon request. The role of the researcher with the individualized support was a participant as an observer or "active membership role" (Adler & Adler, 1998; Merriam, 2009). During planning and interviews, the researcher took field notes prior, during, and after the individualized support session. The role of the researcher during observations in the classroom was that of a nonparticipant observer (Merriam & Tisdell, 2016). Observations took place in the natural setting of a classroom rather than a different location. Observations represent firsthand accounts to ensure that the voice of the participants was being heard and to construct reliable meaning from the data being collected (Merriam & Tisdell, 2016).

Theoretical Proposition

The use of the TPACK framework and survey was used to identify areas of targeted support for newly hired secondary mathematics teachers. This mixed-methods case study provided a model design to guide the support for a diverse group of newly hired secondary mathematics teachers. Using the mixed-method approach within this study strengthened the findings by analyzing quantitative and qualitative data then comparing the result of the study, creating triangulation (Creswell & Creswell, 2018).

Limitations

The design of this study was a limitation. Since the researcher in this study was the only person responsible for data collection and analysis, there was potential for researcher bias. To address this challenge, the researcher used multiple strategies to avoid bias such as field notes and consulting with experts. This study consisted of quantitative data from the TPACK survey. By using multiple sources of data points such as the survey, interviews, observations, and artifacts, the triangulation of the data strengthened the validity and reduced biases. Another limitation is that this study took place during COVID-19, when teachers and students were forced to use technology, there were multiple restrictions in place, and participants were dealing with the social-emotional impacts of a pandemic.

Issues of Trustworthiness

The purpose of this research is to improve teacher support through identifiable targeted areas of technology, pedagogy, and content. The use of triangulation through multiple data sources meant comparing data collected from observations, interviews, and unobtrusive data at different times and places (Merriam, 2009). Analyzing quantitative and qualitative data and then comparing the results provided study validity. The recommendations to conduct a credible study include triangulation, peer review, researcher flexibility, member check, and data saturation (Merriam, 2009). The use of multiple data sources reached a point of saturation which confirmed the findings. To maintain internal validity, the study adopted the TPACK survey that has been used in multiple studies (Yin, 2009). This study also employed the use of member check and respondent validation of restating their thinking through solicitation of feedback using continuous reflection (Creswell & Creswell 2018). Lastly, the researcher consulted throughout the study with the participating school system's office of accountability and members of the dissertation board.

Chapter Three Summary

Chapter three described the research methods and rationale for the design used in this study. Central and related research questions were presented and addressed. The specific methodology adopted for the study consisted of an overview of the research design, research rationale, timeline, research design framework, setting, participants, instrumentation, procedures, data collection, and data analysis. Research data collection included both open and closed-ended questions, multiple forms of data drawing on all possibilities, statistical analysis, text analysis, and cross-case comparisons and interpretations to converge the qualitative and quantitative data (Creswell & Creswell 2018). There were multiple data sources at various times and places to collect the qualitative data which included interviews, observations, and unobtrusive data. The quantitative data collection used a well-known and reliable survey to increase the validity of the study. Finally, this chapter discussed the issue of trustworthiness and ethical procedures as well as strategies used to increase the credibility of the study.

CHAPTER 4

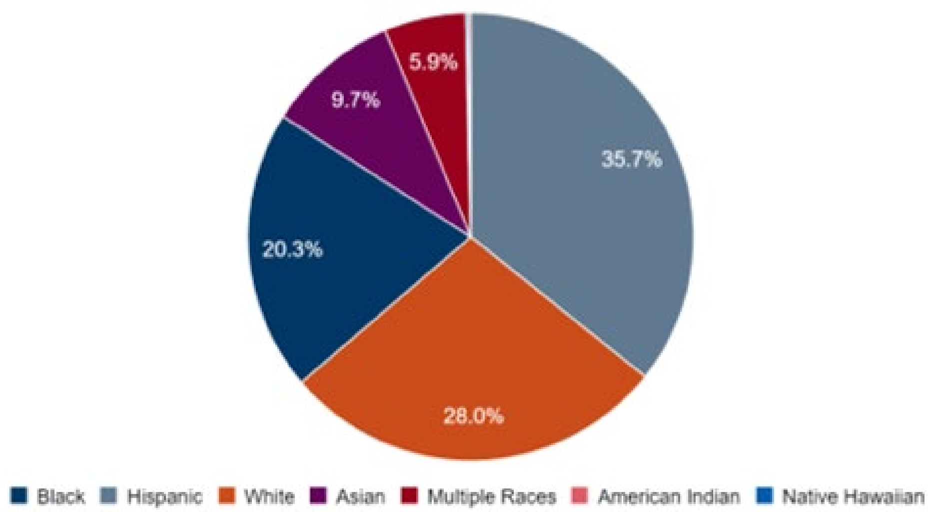
CONTEXTUAL INFORMATION

Demographic Information

This case study with an intervention was conducted in the Mid-Atlantic region of the U.S. at two middle and two high schools. The school district is the second-largest school system in the state with 11,795 full-time employees that include 6,375 teachers. In 2020-2021, there were 496 new educators hired which was a decrease of 43% from the prior school year. In the 2020-2021 school year, total student enrollment was 89,577. Figure 7 contains student demographic information for 2020-2021.

Figure 7

Mid Atlantic School District: Student Demographic 2020-2021



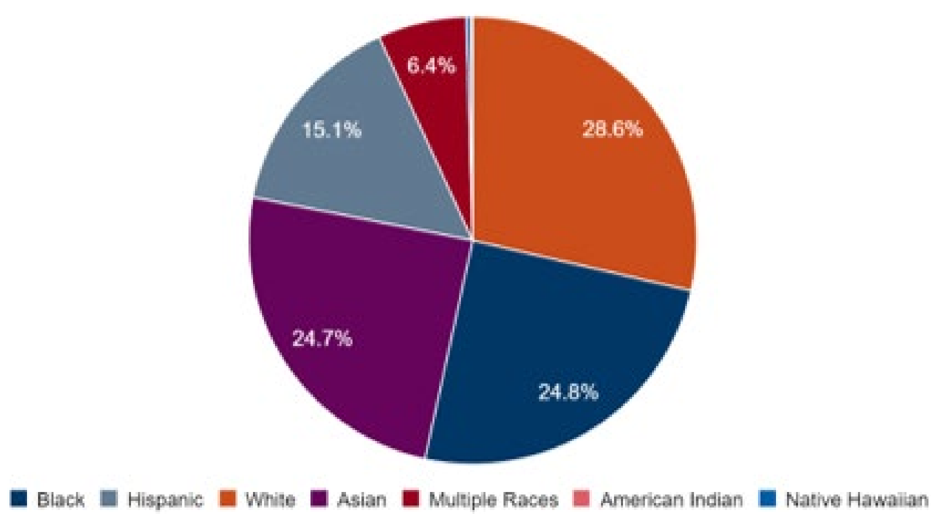
Note. Resource of Data –Virginia Department of Education (VDOE) (2020-2021). https://www.doe.virginia.gov/statistics_reports/school-quality-profile/index.shtml

The Mid-Atlantic Region School District has 39.7% of economically disadvantaged students, 27.7% are English Language Learners, and 12.8% are students with learning disabilities. The teacher quality report indicates the percentage of teachers who are not fully endorsed for the content area they are teaching or who have less than one year of classroom experience. The teacher quality report indicates that 2.6% are inexperienced teachers, 5.6% are out of field teachers, and 0.3% are both inexperienced teachers and out of field teachers (VDOE, 2020e).

Two middle schools had teachers participate in the study. The pseudonym for the first school is Western Middle School which is a first through eighth grade school with a population of 657 for the 2020-2021 school year. Figure 8 contains the student demographics for Western Middle School.

Figure 8

Western Middle School: Student Demographic 2020-2021



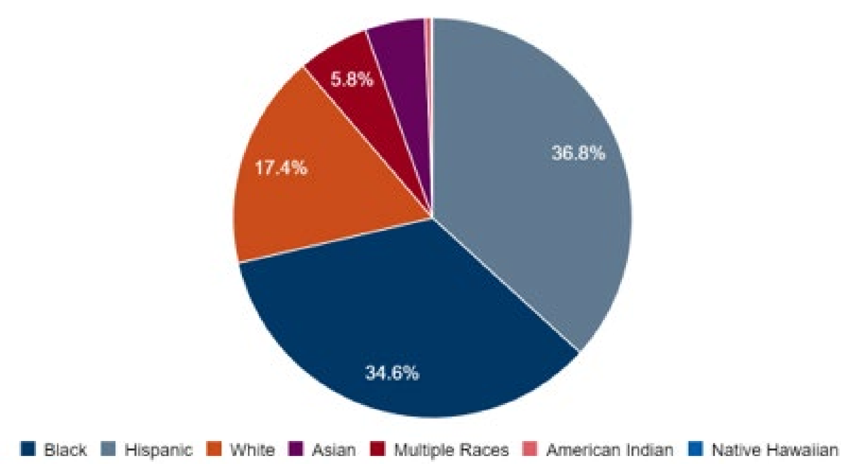
Note. Resource of Data – VDOE Virginia Department of Education (2020-2021).
https://www.doe.virginia.gov/statistics_reports/school-quality-profile/index.shtml

The Western Middle School has 21.3% students who are economically disadvantaged, 18.9% are English Language Learners, and 7.3% of students with learning disabilities. The teacher quality report indicates that 10.7% are inexperienced teachers and 4.2% are out of field teachers (VDOE, 2020e).

The pseudonym for the second school is Eastern Middle School which is sixth through eighth grade and has a total enrollment of 985 students. The student demographics for Eastern Middle School are provided in Figure 9.

Figure 9

Eastern Middle School: Student Demographic 2020-2021



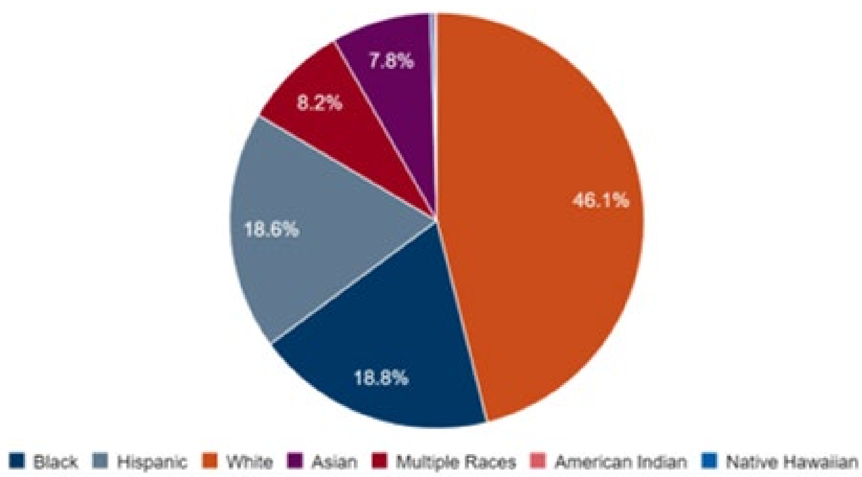
Note. Resource of Data – VDOE Virginia Department of Education (2020-2021). https://www.doe.virginia.gov/statistics_reports/school-quality-profile/index.shtml

The Eastern Middle School has 49.7% students who are economically disadvantaged, 32% are English Language Learners and 14.5% are students with learning disabilities. The teacher quality report indicates that 6% are inexperienced teachers and there are no out of field teachers (VDOE, 2020e).

Two high schools had teachers participate in the study. The pseudonym for the first school is Central High School which is a ninth through twelfth-grade school with a population of 2,953 for the 2020-201 school year. Figure 10 contains the student demographics for Central High School.

Figure 10

Central High School: Student Demographic 2020-2021



Note. Resource of Data – VDOE Virginia Department of Education (2020-2021). https://www.doe.virginia.gov/statistics_reports/school-quality-profile/index.shtml

Central High School has 16.5% economically disadvantaged students, 6% are English Language Learners and 10.4% are students with learning disabilities. The teacher quality report indicates that 6% are inexperienced teachers, 2.4% are out of field teachers, and 0.6% are both inexperienced teachers and out of field teachers (VDOE, 2020e).

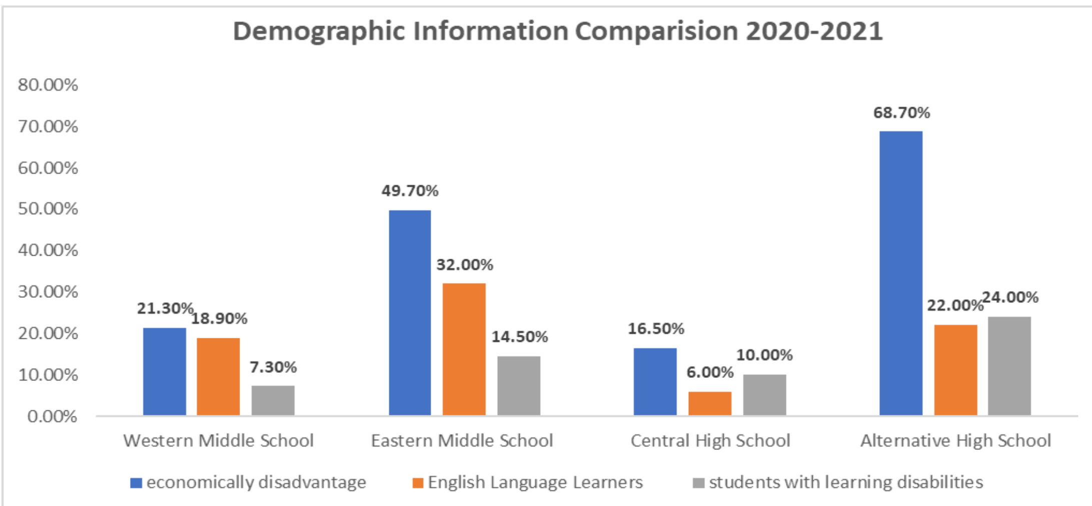
The pseudonym for the second high school is Alternative High School which is a ninth through twelfth-grade school with a population of 388 for the 2020-2021 school year. There was a decrease of 27% from the prior year. Student demographics for Alternative High School are 48.3% Hispanic of any race, 28.8% Black/African American, 13.1 % White, 0.7% American Indian/Alaskan, 3.0% Asian, 0.2% Hawaiian/Pacific Islander, and 5.8% two or more races. The students receiving special services as of June 2020 consisted of 68.7% economically disadvantaged, 22.8% English Learners, and 24% Special Education. For this school, it is important to note a chronic absenteeism rate of 68.9%. Chronic absenteeism includes excused and unexcused absences that are 10% or more of the school year (VDOE, 2020).

Based on the demographic information, this study consists of a range of schools from different parts of the county. As noted, two middle schools consisted of a first through eighth-grade school with 21.3% of the students who are economically disadvantaged compared to a middle school with grades sixth through eighth grade where 49.7% of the students are economically disadvantaged (Figure 11). Likewise, the two high schools consist of a range from a higher percentage of economically disadvantaged students to a lower percentage of economically disadvantaged students. One of the high schools was an alternative high school in which students who attend the school may have experienced multiple disciplinary referrals at their base high school. In addition, the schools that had a higher percentage of economically disadvantaged students also had a higher percentage of their population as English Language

Learners and more students receiving special education services. Both Eastern Middle School and Alternative High School had a higher percentage of their population as Hispanic and Black (Figure 12).

Figure 11

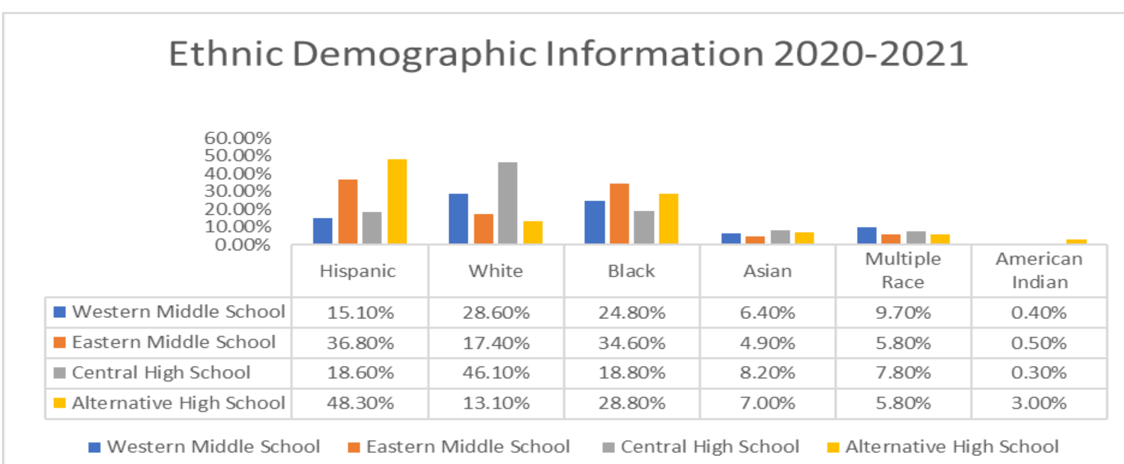
Demographic Information Comparison



Note. Resource of Data – VDOE Virginia Department of Education (2020-2021).

Figure 12

Ethnic Demographic Information



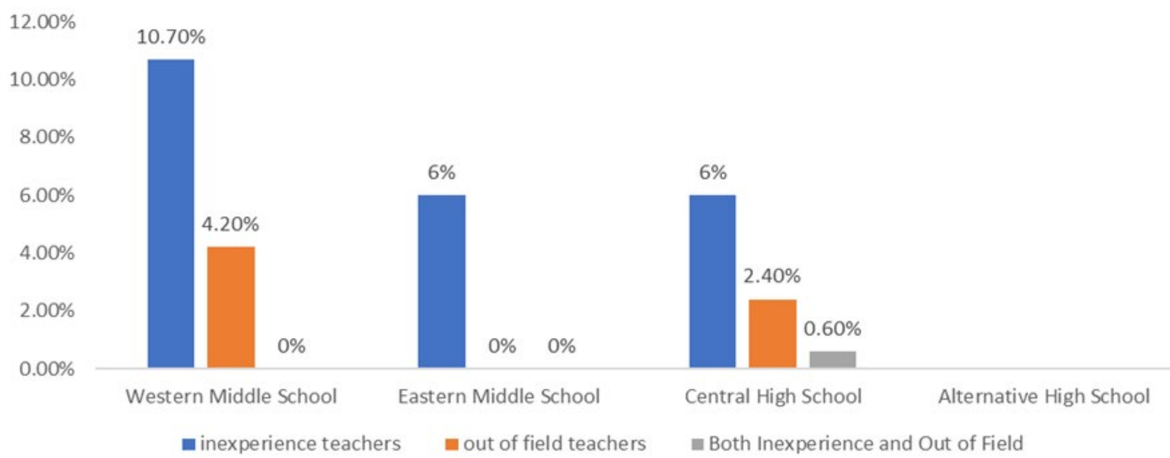
	Hispanic	White	Black	Asian	Multiple Race	American Indian
Western Middle School	15.10%	28.60%	24.80%	6.40%	9.70%	0.40%
Eastern Middle School	36.80%	17.40%	34.60%	4.90%	5.80%	0.50%
Central High School	18.60%	46.10%	18.80%	8.20%	7.80%	0.30%
Alternative High School	48.30%	13.10%	28.80%	7.00%	5.80%	3.00%

Note. Resource of Data – VDOE Virginia Department of Education (2020-2021).

The teacher quality report indicated that Western Middle had the highest percentage from this study of inexperienced teachers and out of field teachers (Figure 13). There was no public data found on the Alternative High School (VDOE, 2020e).

Figure 13

Teacher Quality Report



Note. Resource of Data – VDOE Virginia Department of Education (2020-2021).

Pandemic School Year 2020-2021

The World Health Organization (WHO) released a consolidated package March 7, 2020, to provide guidance on responding to the transmission of the COVID-19. The Centers for Disease Control (CDC) also released recommendations of social distancing to avoid transmission of COVID-19. The Governor of the state where this study was conducted declared a state of emergency and this action impacted the operations of schools throughout the state. The superintendent's goal for the school district used for this study was to continue to provide instruction safely and effectively.

On March 23, 2020, the Governor announced the closure of all schools for the remainder of the school year. The school district adjusted to student learning with a focus on review of previously taught material and no new learning. The fourth quarter was ungraded and remained a period of optional distance learning for students online and offline. During the spring, the school district purchased a learning management system and increased funding of one-to-one devices for students. In the summer months, content area focus groups made up of teachers created resources and templates for Canvas, the new learning management system. In July 2020, the school district purchased Zoom, an online, synchronous platform for all teachers to prepare for the fall of 2020.

On September 8, 2020, the school system announced a 100% distance learning model for the first quarter then a transition to a 50% capacity in-person and distance learning model by the second quarter. Students were given the option to remain virtual. Students receiving special education services and other vulnerable populations were eligible to receive service in person at the beginning of the school year. Based on information from several sources, including the Centers for Disease Control and Prevention and the American Academy for Pediatrics (AAP), there were limits placed on the number of times students could be on devices per age and grade level band as noted in Figure 14. These limits included instructional content, assignments, and screen-based homework.

Figure 14

Daily Screen Time Limits

Grade	Daily Screen Time Maximum
Pre-Kindergarten (PK)	60 minutes
Kindergarten – Grade 2	90 minutes
Grades 3 – 5	120 minutes
Grades 6 – 8	150 minutes
Grades 9 – 12	210 minutes

Note. Resource from School District Informational Website.

Due to the risk factor of COVID-19 within the region, the transition to the hybrid model for secondary students was postponed to after the first semester. The hybrid model consisted of students attending two days per week based on their assigned house (see Figure 15). Vulnerable students continued for four days in person, and everyone remained virtual on Mondays. Based on meetings with school board members, stakeholders, and superintendent staff, secondary students started the hybrid model on February 23, 2021 (Figure 16). Therefore, this study was conducted during significant shifts due to the pandemic and focused on planning and implementation of instruction primarily through asynchronous and synchronous learning environments. As a result of this pandemic, schools were forced to be flexible and to provide just-in-time training on areas of focus for all stakeholders.

Figure 15

50/50 Hybrid Model of House A/B

50/50 Hybrid Schedule For 2020-21 School Year

Monday	Tuesday	Wednesday	Thursday	Friday
Virtual Day - asynchronous at-home learning for students using Canvas **Planning and PD for Teachers** - Teachers office hours, additional individual/small group learning support, and counseling support available and/or provided as appropriate	Identified vulnerable attend school in-person	Identified vulnerable attend school in-person	Identified vulnerable attend school in-person	Identified vulnerable attend school in-person
	House A attends school in-person	**House B** attends school in-person	**House A** attends school in-person	**House B** attends school in-person
	House B learns synchronously with in-person student via-live streaming of instruction	**House A** learns synchronously with in-person student via-live streaming of instruction	**House B** learns synchronously with in-person student via-live streaming of instruction	**House A** learns synchronously with in-person student via-live streaming of instruction
	House C (all virtual) learns synchronously with and/or without in-person students as appropriate to the teacher/class assignment	**House C** (all virtual) learns synchronously with and/or without in-person students as appropriate to the teacher/class assignment	**House C** (all virtual) learns synchronously with and/or without in-person students as appropriate to the teacher/class assignment	**House C** (all virtual) learns synchronously with and/or without in-person students as appropriate to the teacher/class assignment

Note. Resource from School District Informational Website.

Figure 16

Transitional Timeline to Hybrid Model

Note. Resource from School District Informational Website.

Newly Hired Teachers' Training and Support

In the middle of August 2020, there was a two-day Connect Conference for all newly hired educators. August 12 was a school-specific day for new educators to visit their school and receive site-specific training adhering to social distancing or be provided with a virtual training option from the school. August 14 was the division-wide day for Conscious Classroom Management, content-specific general information on curriculum unit documents, mental health awareness, and pre-recorded virtual poster sessions from experienced teachers. All staff were expected to return to work on Monday, August 17 in a virtual environment and to pick up computers for distance learning teaching. On Wednesday, August 19, all secondary teachers were expected to attend a virtual Secondary Conference which consisted of Canvas content area resource sessions and for mathematics virtual training with Desmos. There was a delay in starting school due to the training that all teachers needed for Canvas (the learning management system) and Zoom. The first day of school was September 8, 2020. Teachers were informed to work with students on getting them familiar with Canvas and other technologies as well as getting to know the students and supporting their social and emotional well-being.

Normally, students would have started school on August 25 with approximately 300 minutes of instructional time per week of which approximately 250 minutes per week was content instruction. The instructional time was reduced by approximately 30% to 50% in secondary courses in the virtual and hybrid learning models. Teachers were required to teach the curriculum in less time using different learning environments.

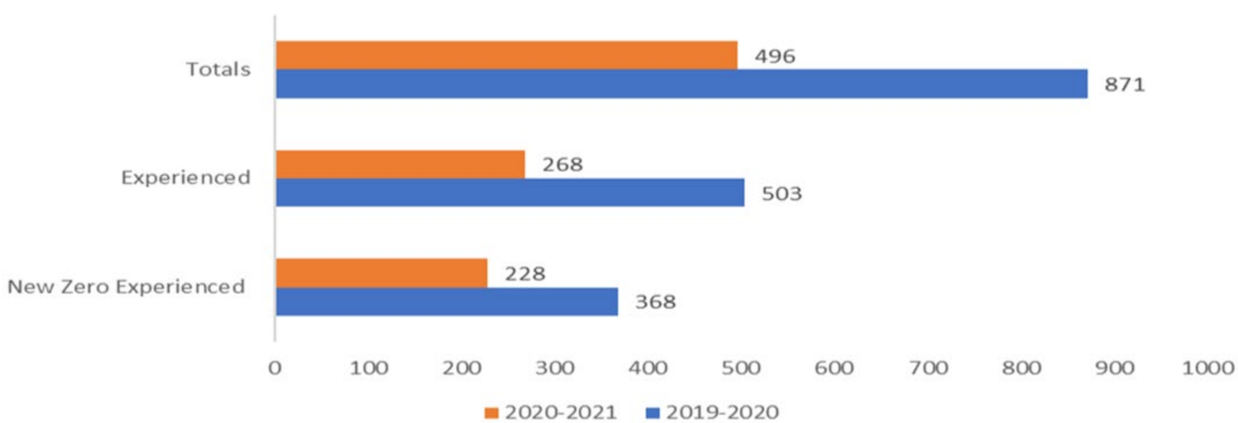
The mentoring program for newly hired teachers consisted of two types of support depending on the experience a teacher had. The first type of support was for educators teaching for their first full year. This support matched a school-based teacher mentor (formal mentor) with the newly hired educator (PWCS, 2021). The support for first-year teachers was also required by the state. The second type of support was for experienced educators new to the school district but not new to teaching. These teachers may have been matched with an informal mentor depending on their needs.

The Office of Professional Learning has two specialists and one supervisor who oversees the program and provides support throughout the ninety-seven schools within the school district. The types of support provided at the district level include establishing a collaborative mentoring framework by providing training for lead mentors, mentors, and educator support teams. The office also provides a OneNote notebook that includes topics and resources for monthly school-based meetings. Each school has an educator support team that coordinates the mentor program at the school level which determines the area of focus based on school and teacher needs. These meetings are available monthly for novice and experienced teachers. There also was individualized mentoring, which is a state requirement for zero experienced teachers to work collaboratively with a non-evaluative support mentor. Training for mentors took place in a hybrid model that combined face-to-face with online modules.

There was a 43% decrease in teachers hired during the 2020-2021 school year (Figure 17). The uncertainty during this pandemic impacted the hiring of both experienced and zero experienced teachers. There was a 46.7% decrease in newly hired experienced teachers and a 38% decrease in zero experienced newly hired teachers. Some of the contributing factors for a lower number of new teachers included a reduced number of students enrolled, the uncertainty of the number of students who would remain in the public school system, a lack of qualified teachers applying for teaching positions, and the uncertainty of the school year. In the 2020-2021 school year, the total student enrollment within the school district decreased by 2,693 from the 2019-2020 school year's total of 92,270 students. For secondary mathematics, there were 27 new teachers hired in 2020-2021 which was an 18% decrease from the prior school year. Out of the 27 new teachers in the 2020-2021 school year, two-thirds of the teachers had more than three years of experience and one-third had less than three years of experience.

Figure 17

Newly Hired Teachers Comparison in 2020-2021 to 2019-2020



Note. Resource from School District Office of Professional Learning.

Because of the pandemic, the mathematics coordinator and the researcher for this study decided to extend the support training session to teachers with less than three years of experience. This provided more opportunities for teachers to collaborate based on previous first experiences. In prior years, the mathematics staff focused on zero experienced teachers for extra support training sessions throughout the school year. Both the mathematics coordinator and the researcher have experience teaching mathematics at the middle and high school levels. The professional development specialist for secondary mathematics is the researcher and active (non-evaluative) participant within this case study.

The foci of the mathematics new teacher induction training sessions were to provide support and resources, build a positive collaborative team, and develop pedagogy strategies to increase student learning and engagement in mathematics. During the 2020-2021 school year, the new teaching induction training sessions occurred on October 27, December 10, and February 17. The learning outcomes for October 27 included reflecting on current teaching, identify classroom management strategies that would help engage students in learning mathematics, reflecting on questioning techniques, and how they relate to mathematical literacy. On December 10, the learning outcomes included reflecting on mathematics with stations using breakout rooms in Zoom. Teachers considered strategies that support students' thinking and address their misunderstandings during instruction to better meet the needs of students. On February 17, the learning outcomes included reflecting on feedback and what to do when the answer is wrong. Teachers considered strategies that support their students' thinking and reasoning and address their understanding. The mathematics coordinator created a shared group folder to provide resources for these novice teachers. Both the coordinator and researcher provided additional support throughout the school year as needed.

Based on an inquiry search on March 28, 2021, in the Professional Learning Catalog PowerSchool and opportunities emailed to Secondary Mathematics Teachers, the training listed in Table 12 was provided within each category and subcategory. The school district hired external professional development for educators during the transitional year as well as purchased resources such as *Distance Learning Playbook Grades K-12 Teaching for Engagement and Impact in Any Setting* (Fisher et al., 2020).

Table 12

Training Opportunities for Educators

Category of Training Opportunity	Number of Course
Teaching Method	
Simultaneous	35
Virtual Teaching Strategies	55
Content Area	
Mathematics	12
Focus Area	
Culturally Response Instructions	5
English Learners	20
Level	
High School	73
Middle School	72
Elementary School	61
Tools	
Canvas	21
Desmos	8
Nearpod	1
Other	8

Note. Resource from School District Office of Professional Learning.

On November 19, 2020, the mathematics office emailed all secondary mathematics teachers the opportunity to participate in Desmos Canvas Courses which included introductory and exploratory sessions for Desmos Scientific Calculator, Graphing Calculator, Geometry Tools, and Desmos Activities. These Canvas courses provided an opportunity to explore Desmos in an asynchronous and synchronous learning environment which was facilitated by the researcher. Likewise, there was a virtual Desmos training for Secondary mathematics teachers on August 19, 2020, which was facilitated by Desmos. On Secondary Day, there was Canvas Content area training led by focus group designers to provide teachers with information on the resources that were available within the Canvas courses.

Case Study Participants

The pseudonym for the first participant was Teresa who was an experienced educator. Teresa taught middle school mathematics for thirty-five years in grades six through eight which included Algebra 1. She has a bachelor’s degree in mathematics education. Teresa was retired for five years prior to the 2020-2021 school year and was called back into service as a new teacher. Several changes occurred since Teresa retired including new mathematics Standards of Learning objectives and assessments. On June 1, 2018, the state department of education announced that Desmos Calculators would be available for students to use on the Standards of Learning mathematics assessments. The Desmos calculator was embedded in the online assessments as a digital tool that students could use on the state exam. Teresa had experience with other graphing utilities but not with Desmos Calculators. Teresa had many years of teaching in a traditional school building, but she had zero experience teaching in a virtual setting. Therefore, the support that Teresa needed was with the new standards and curriculum changes, Desmos calculators, and teaching in a virtual environment. Teresa was assigned to Western Middle School in which she taught eighth grade Pre-Algebra 1 and Pre-AP Algebra 1.

The pseudonym for the second participant was Paulette who was an experienced educator who taught for fifteen years at the middle and high school levels. She has a bachelor’s degree in computer technology and a master's degree in education. She has an active state license in Elementary Grades Pre-K to sixth grade, Mathematics and Algebra 1, Middle Education 6-8

Science, and 6-8 Mathematics. Paulette transferred to the Mid-Atlantic School district from a neighboring school district and was assigned to teach at Alternative High School that had semester courses. Therefore, Paulette had to teach her courses from September 2020 to January 2021 with less time to prepare students for the state exams. Paulette taught first-semester Geometry and Algebra 1. In the second semester, she taught Geometry and Algebra, Functions, and Data Analysis. This was the first year Paulette taught high school Geometry.

The pseudonym for the third participant was Annie who was a novice educator with one year of experience in 2019-2020 teaching math and special education in an adjacent state. She has a bachelor’s degree in mathematics and a provisional license in mathematics. Currently, Annie has not taken any educational courses. Annie was assigned to teach seventh-grade mathematics and Pre-AP Algebra 1, and she was assigned a mentor who is the mathematics coach at Eastern Middle School. Annie was also invited to attend three additional training sessions for Secondary Mathematics which were facilitated by the mathematics coordinator and the researcher.

The pseudonym for the fourth participant was Catherine who was an experienced educator with 20 years of teaching experience at the secondary level. She also has administrative experience as a department head of mathematics and operating a private school. She has a bachelor’s degree in business and mathematics, and a master's degree in mathematics. Catherine has a doctorate in theology focusing on child development and psychology. She holds a postgraduate professional license in mathematics. Catherine has experience in other states and districts teaching mathematics and preferred teaching with the state-adopted mathematics textbook overusing the Canvas resources within the modules. Catherine was assigned to Eastern Middle School to teach eighth-grade mathematics. Both Catherine and Annie were in a collaborative learning team that met every Monday. In her professional capacity, the researcher supported the collaborative learning team and worked with the teachers individually on Wednesdays to support the integration of technology in the classroom using the TPACK framework for guiding the planning and implementation of lessons.

The pseudonym for the fifth participant was Karl who was an experienced educator with 10 years of teaching experience and several years of administration experience. He obtained a bachelor's degree in secondary education and a master's and a doctorate in administration. Karl was assigned to Central High School and taught Algebra II, Pre-AP Algebra II, and Trigonometry. Karl enrolled in the Canvas Desmos Graphing Calculator course in November 2020 and participated in the asynchronous assignments. Due to his schedule, he was unable to participate synchronously, therefore, we scheduled individualized support with Desmos to develop a Desmos Activity.

The case study consisted of three timeframes: early-year support from September to October 2020, mid-year support from November 2020 to January 2021, and late-year support from February to March 2021. The intensity of the individualized support within the case study consisted of three categories: high intense support greater than or equal to 30 hours, moderate support greater than or equal to10 but less than 30 hours, and low support less than 10 hours (Table 13). The timeframe of the individualized support was based on consent forms signed and initial interviewing using the TPACK framework. It is important to note that the relationship building and support between the researcher and participants did occur prior to the initial consent and planning and implementation interviews. The time prior to interviewing established the creditability of the researcher in developing trusting relationships.

Table 13

Individualized Timeframe and Intensity

Participant	Timeframe	Hours of Support
Teresa	Early Support: September 2020	High Intensity more than 30 hours of support
Paulette	Early Support: October 2020	Moderate between 10 to 30 hours of support
Annie	Early Support: October 2020	Moderate between 10 to 30 hours of support
Catherine	Mid-year Support: December 2020	High Intensity more than 30 hours of support
Karl	Mid-year Support: January 2021	Low Intensity less than 10 hours of support

Note. Resource from Support Log.

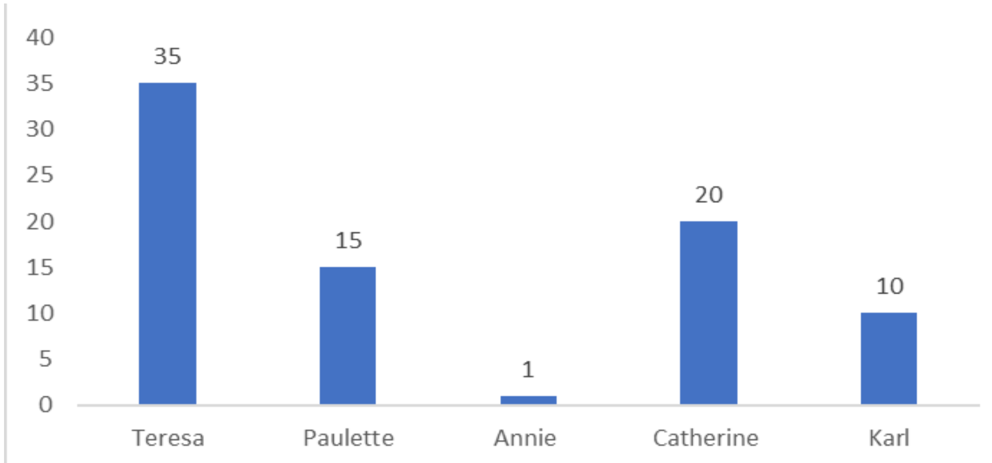
Demographic Information of Participants

There were four females and one male who agreed to participate in the case study. The ethnic grouping of participants within the case study was two Black and three White. The self-reported educational level of participants consisted of two bachelors' degrees, one master's degree, and two doctorate degrees. The years of teaching experience ranged from one year to thirty-five years of experience (Figure 18). The age range of participants is illustrated in Figure 19.

All individualized support was customized to meet the need of the teacher based on the content area which they teach, the strategies of knowing how to teach (i.e., pedagogy), along with the integration of technology using the TPACK framework to guide the planning and implementation of instruction.

Figure 18

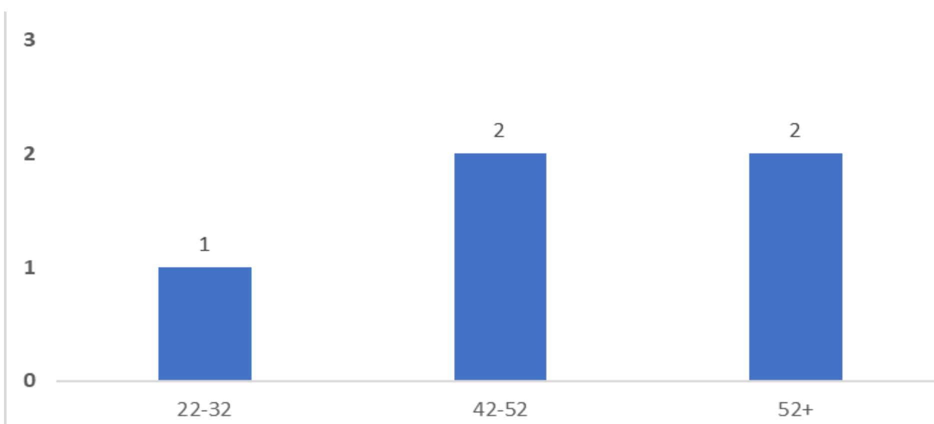
Participants Years of Teaching Experience



Note. Resource from Interviews.

Figure 19

Age Range of Participants



Note. Resource from Interviews.

On August 17, 2020, a TPACK survey was emailed out to all newly hired mathematics teachers. All five participants in the case study answered the open-ended question: Describe a specific episode where you effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson. Figure 20 provides the responses from the five participants in this study.

Figure 20

Pre-TPACK Survey Data

August 17th TPACK Survey

Subject	Teresa	Paulette	Annie	Catherine	Karl
Teaching Experience	35	15	1	20	10
Content Area	Pre-AP Algebra 1 and Pre-Algebra	Geometry and Algebra 1	Pre-AP Algebra 1 7th Grade Math	Pre-AP Algebra 1	Algebra II and Trig.
School	Traditional Middle School: Grades 1-8	Alternative High School 9-12	Middle School Grades 6-8	Middle School Grades 6-8	High School Grades 9-12
Describe a specific episode where you effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson	I have not taught in 5 years, so I do not have this experience.	This summer I taught Math 7 to a group of students through Google classroom. I had not used classroom before, so it was fun learning it as I taught the 8-week course. For one lesson on the Law of Large Numbers, students were given a link to a virtual number cube and a .pdf document they opened in Kami to track their rolls. We then combined the data on a group document and noted that experimental probability became closer and closer to matching theoretical for rolling 1-6.	I have taught/supported math special education for grades 5-8. I have used IXL, khan academy and Moby max. I have used IXL to target a specific topic I noticed the student struggled with and assigned problems for them to complete to help them practice those skills. I would explain the topic in a certain way and IXL would explain the topic, so the student would have different strategies to use.	In past years, I have used Kahoot, J-labs, and Google Classrooms as teaching strategies. By using Kahoot, it allowed the students to work collaboratively in groups to sharpen their skills. I used J-labs as a form of reinforcing skills and assessment. PowerPoint Presentations were uploaded via Google Classroom. I have used the document camera to display math warm-up exercises and various mathematical documents. I utilized the Smart Board as a teaching tool. I even have my YouTube account: Teaching Math still up and running which allowed students to view for extra teaching.	I taught a College Algebra lesson with 12th grade students with multiple skill backgrounds in math. For all students to succeed, I grouped students by level to give direct instruction to them based on their knowledge. Secondly, I then moved the students where groups were "mixed by ability". I challenged each group with a problem and asked them to help each other before coming to the front of the classroom to present and explain their solution. Students were using an app called Explain Everything which allowed them to use technology and "mirror" their work to my screen in the front of the class. This activity allowed students to teach other students while I assisted and monitored their progress. I noticed the struggling students listening to the other students and learning from them.

Note. Resource from TPACK Survey Data.

Researcher's Background

The researcher has four years experience as a Professional Development Specialist of Secondary Mathematics in the Office of Student Learning and Office of Professional Learning. The position duties include creating and implementing professional development, analyzing data to determine needs for training, support curriculum work, support secondary mathematics teachers and schools with instruction, support newly hired teachers, support training throughout the district, and other duties. This position is a nonevaluative support role. The researcher is a certified Math Specialist with training on Lesson Study and Content Coaching. The focus of lesson studies was to reflect on the implementation of lessons to improve practices (Kanellopoulou, 2018; Murata & Kim-Eng Lee, 2021). In addition to Content Coaching by West and Staub (2003), the researcher has received training in Cognitive Coaching by Costa and Garmston (2016), Student-Centered Coaching by Sweeny and Harris (2017), and Fierce Conversations by Scott (2017).

Prior to this study, the researcher participated in instructional walk-throughs in classrooms to collect qualitative data to identify trends and patterns within classrooms. During her qualitative coursework at Old Dominion University, the researcher conducted a qualitative study with Collaborative Learning Teams and individual teachers to determine how Desmos was being used within classrooms and the impact on student learning. Lastly, the researcher, observed a doctorate student conduct interviews on culturally responsive instructions and analyzed the disciplinary data for schools within the study.

Chapter Four Summary

This chapter provided background on the Mid-Atlantic U.S. School district and the four schools with participants in the case study. There is a range of diversity within each school and a range in the experience and education of study participants. This case study with an intervention represents a small sample of the newly hired secondary mathematics teachers. Information on the COVID-19 pandemic and the changes that occurred within the school were also provided. Finally, the chapter discussed the researcher's background, training, and experiences as they related to the study.

CHAPTER 5

FINDINGS

The purpose of this case study with an intervention was to identify the essential characteristics and strategies of planning and integrating technology with new teachers. Part one of the findings presents the data collected from the Pre-TPACK and Post-TPACK survey. The identified areas of support for each participant from the Pre-TPACK are presented along with the areas of growth after the intervention with the Post-TPACK survey. Part two presents the coding process and key findings from multiple data sources, including interviews, observations, field notes, and artifacts from each participant. In part three of the findings, post-interview data are provided to confirm the findings of the case study. Part four presents the amount of time provided for individualized support and the findings from the TPACK survey. In part five, the convergence of evidence from the data is presented to generate the triangulation (Yin, 2018). The researcher compared the findings with participants and non-participants to determine if the intervention had an impact. Finally, the researcher examined the triangulation of the key findings with the TPACK survey and interview questions.

Part 1: TPACK Survey (Quantitative Data)

The modified TPACK survey that was used for this study was designed to measure individual proficiencies on technological knowledge, pedagogical knowledge, and content knowledge as well as integration of pedagogical content knowledge, technological pedagogical knowledge, technological content knowledge, and technological pedagogical content knowledge. Seventeen newly hired teachers completed the survey out of twenty-seven new teachers. Based on the results from the survey, a follow-up email was sent to each teacher which included resources tailored to the results of their survey. At the end of each email, the researcher offered to provide support. From September 2020 to February 2021, five teachers requested individualized support with digital technology tools to help increase students' understanding of mathematics and agreed to participate in the case study. All the newly hired secondary mathematics teachers for 2020-2021, who completed the Pre-TPACK survey had the opportunity to complete an optional Post-TPACK survey. Nine out of the seventeen teachers completed the post-survey. Therefore, there were two groups of teachers who completed the survey. One group received individualized support using the TPACK model and the other group did not receive individualized support with TPACK. Research question one was addressed within this data analysis.

1. How does targeted individualized support and professional development impact newly hired secondary mathematics teachers' knowledge of technology, pedagogy, and content integration during instruction?

Figures 21 and 22 provide a sample of Pre- and Post-TPACK survey raw data collected prior to coding. Using a spreadsheet to assign a code was recommended by the TPACK questionnaire. The Find and Select (Replace) tools were used within the software to quantify the data collected (Figures 23 and 24).

Figure 21

Sample Pre-TPACK Survey Data

F	G	H	I	J	K	L
Please select	I know how to solve	I can learn technolo	I keep up with impc	I frequently play ar	I know about a lot o	I have the technical
Yes	Agree	Agree	Agree	Agree	Neither Agree or Disag	Agree
Yes	Disagree	Agree	Neither Agree or Disag	Agree	Disagree	Neither Agree or Disag
Yes	Disagree	Agree	Agree	Agree	Neither Agree or Disag	Agree
Yes	Agree	Agree	Neither Agree or Disag	Agree	Neither Agree or Disag	Agree
Yes	Neither Agree or Disag	Strongly Agree	Agree	Agree	Agree	Strongly Agree
Yes	Disagree	Agree	Agree	Agree	Neither Agree or Disag	Agree
Yes	Disagree	Agree	Disagree	Disagree	Strongly Disagree	Agree
Yes	Agree	Agree	Agree	Agree	Agree	Agree
Yes	Neither Agree or Disag	Agree	Disagree	Agree	Disagree	Agree
Yes	Neither Agree or Disag	Agree	Disagree	Agree	Disagree	Agree
Yes	Disagree	Neither Agree or Disag	Neither Agree or Disag	Agree	Neither Agree or Disag	Disagree
Yes	Disagree	Agree	Strongly Agree	Agree	Agree	Agree
Yes	Agree	Agree	Neither Agree or Disag	Neither Agree or Disag	Agree	Agree
Yes	Disagree	Strongly Agree	Agree	Strongly Agree	Strongly Disagree	Strongly Agree
Yes	Disagree	Neither Agree or Disag	Neither Agree or Disag	Disagree	Disagree	Disagree
Yes	Strongly Agree	Agree	Agree	Agree	Neither Agree or Disag	Agree
yes	Disagree	Neither Agree or Disag	Disagree	Disagree	Disagree	Disagree

Note. Resource from TPACK Survey Data.

Figure 22

Sample Post-TPACK Survey Data

F	G	H	I	J	K	L	
Please select yes or	I know how to solve	I can learn technolo	I keep up with impo	I frequently play ar	I know about a lot o	I have the technical	I
Yes	Agree	Agree	Disagree	Agree	Neither Agree or Disag	Neither Agree or Disag	A
Yes	Agree	Agree	Agree	Agree	Neither Agree or Disag	Agree	A
Yes	Neither Agree or Disag	Agree	Agree	Agree	Disagree	Neither Agree or Disag	S
Yes	Agree	Strongly Agree	Agree	Agree	Neither Agree or Disag	Strongly Agree	S
Yes	Agree	Agree	Agree	Strongly Agree	Agree	Strongly Agree	S
Yes	Agree	Agree	Agree	Agree	Neither Agree or Disag	Agree	S
Yes	Agree	Agree	Neither Agree or Disag	Agree	Neither Agree or Disag	Agree	A
Yes	Agree	Agree	Agree	Agree	Neither Agree or Disag	Agree	A
Yes	Agree	Agree	Agree	Agree	Neither Agree or Disag	Agree	S

Note. Resource from TPACK Survey Data.

Figure 23

Pre-TPACK using the Find and Select (Replace) in Excel to Quantify Data Collected.

F	G	H	I	J	K	L
Please select	I know how to solve	I can learn technolo	I keep up with impo	I frequently play ar	I know about a lot o	I have the technical
Yes	4	4	4	4	3	4
Yes	2	4	3	4	2	3
Yes	2	4	4	4	3	4
Yes	4	4	3	4	3	4
Yes	3	5	4	4	4	5
Yes	2	4	4	4	3	4
Yes	2	4	2	2	1	4
Yes	4	4	4	4	4	4
Yes	3	4	2	4	2	4
Yes	3	4	2	4	2	4
Yes	2	3	3	4	3	2
Yes	2	4	5	4	4	4
Yes	4	4	3	3	4	4
Yes	2	5	4	5	1	5
Yes	2	3	3	2	2	2
Yes	5	4	4	4	3	4
yes	2	3	2	2	2	2

Note. 1=Strongly Disgaree 2=Disagree 3= Neither Agree or Disagree 4=Agree
5 =Strongley Agree.

Figure 24

Post-TPACK using the Find and Select (Replace) in Excel to Quantify Data Collected.

F	G	H	I	J	K	L
Please select yes or	I know how to solve	I can learn technolo	I keep up with impo	I frequently play ar	I know about a lot o	I have the technical
Yes	4	4	2	4	3	3
Yes	4	4	4	4	3	4
Yes	3	4	4	4	2	3
Yes	4	5	4	4	3	5
Yes	4	4	4	5	4	5
Yes	4	4	4	4	3	4
Yes	4	4	3	4	3	4
Yes	4	4	4	4	3	4
Yes	4	4	4	4	3	4

Note. 1=Strongly Disagree 2=Disagree 3= Neither Agree nor Disagree 4=Agree
5 =Strongley Agree.

Participants and Non-Participants

Based on the recommendation of the TPACK questionnaire, the participants' responses were averaged for each of the seven domains of TPACK interactions. The researcher used spreadsheet formulas such as sums and average to calculate an average for each domain. In addition, the researcher used a spreadsheet to calculate an overall average of the seven domains for each participant in the case study and non-participants in the case study (Figure 30). The data were separated into two groups which included those who received individualized support using the TPACK framework and those who did not receive individualized support using the TPACK framework. The overall average percent of change was calculated between the Pre-and Post-TPACK survey for each participant and non-participant (Figures 25, 26, 27, 28, & 29). The findings indicated that the participant group had an average overall percent of change of 11.78% and the non-participant group had an average overall percent of change of -0.93%. Out of the participant group, five out of five had a positive percent of change from August 2020 to January 2021. Therefore, the findings indicated an increase in self-confidence using the TPACK framework to support teachers. Based on the Pre-TPACK survey, the researcher was able to identify and provide targeted support during the planning process of the integration of technology by using questions aligned with the TPACK framework. All participants demonstrated growth in the areas of initial support.

Figure 25

Sample Average of TPACK Domains

Participants	Pre-Survey TPACK - Overall Average Score	Post -Survey TPACK Overall Average Score	TK (Technology Knowledge)	Post TK	CK (Content Knowledge) Mathematics	Post CK
1 Teresa	3.11	3.70	2.17	3.33	4.00	4.00
7P	3.57	3.56	3.17	3.33	3.67	4.00
3 Anne	3.43	4.03	3.17	4.16	4.30	4.30
6E	3.73	3.61	3.67	3.83	4.00	3.67
8G	4.02	4.48	3.00	3.83	4.30	4.67
5 Karl	3.96	4.01	3.83	3.83	4.30	4.30
4 Catherine	4.09	4.66	3.00	3.83	4.00	5.00
2 Paulette	3.98	4.24	4.00	4.17	4.00	4.67
9N	4.83	4.28	3.83	3.30	5.00	5.00

Note. Green highlighting is the participants, and the grey highlighting is the non-participants.

Figure 26

Average of TPACK Domains with Participants

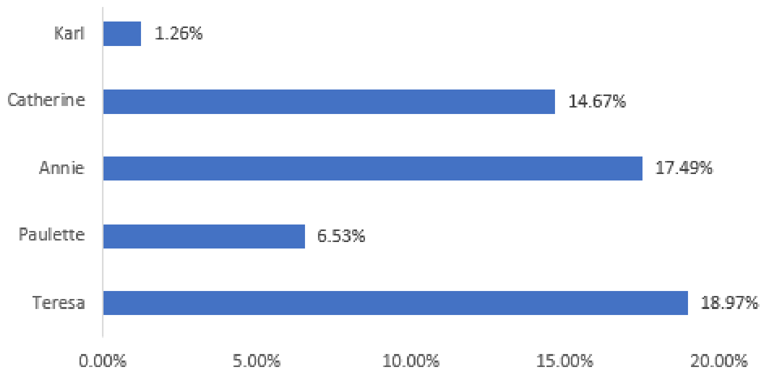
Participants in Case Study

Pre TPACK 1	Post TPACK 1	Pre TPACK 2	Post TPACK 2	Pre TPACK 3	Post TPACK 3	Pre TPACK 4	Post TPACK 4	Pre TPACK 5	Post TPACK 5	Domains
2.17	3.33	4	4.33	2.5	4.16	3	3.83	3.83	3.83	TK
4	4	4	4.67	4.33	4.33	4	5	4.33	4.33	CK
3.71	3.71	4	4.57	3.71	3.86	4.43	5	4	4	PK
3	4	4	4	4	4	5	5	4	4	PCK
3	4	4	4	2	4	4	5	4	4	TCK
2.89	3.89	3.89	4.11	3.44	3.89	4.22	4.78	3.56	3.89	TPK
3	3	4	4	4	4	4	4	4	4	TPACK
21.77	25.93	27.89	29.68	23.98	28.24	28.65	32.61	27.72	28.05	
3.11	3.704285714	3.984285714	4.24	3.425714286	4.034285714	4.092857143	4.658571429	3.96	4.007142857	

Note: Pre- and Post-TPACK Average of TPACK Domains with 5 Participants.

Figure 27

Case Study Participants Overall Percent of Change in TPACK



Note. Resource from TPACK Survey Data.

Out of the non-participant group, three out of four had a negative percent of change from August 2020 to January 2021. Therefore, the findings indicated a decrease in TPACK for the nonparticipants. As noted in the overall percent of change, three nonparticipants took the Pre- and Post-TPACK survey and had declines in TPACK knowledge. Out of the three that declined, one nonparticipant's TPACK knowledge declined by 11.39%. The other two non-participants had lower rates of change with TPACK knowledge on their post-survey. Only one in the nonparticipants' group had improvement in TPACK knowledge at the end of the first semester (Figures 28 and 29).

Figure 28

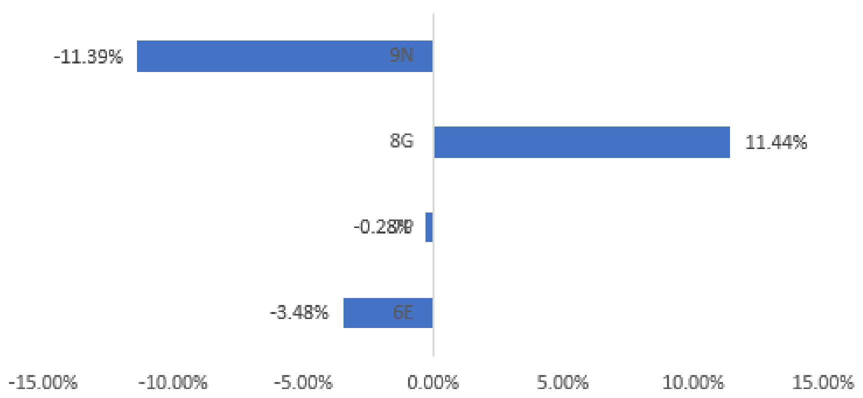
Average of TPACK Domains with Non-Participants

Pre TPACK 6	Post TPACK 6	Pre TPACK 7	Post TPACK 7	Pre TPACK 8	Post TPACK 8	Pre TPACK 9	Post TPACK 9
3.67	**3.83**	3.17	3.67	**2.83**	**3.83**	3.83	3.33
4.00	3.67	3.67	4.00	**4.33**	**5.00**	5.00	5.00
3.71	3.43	3.71	3.71	4.30	4.43	5.00	4.43
3.00	3.00	4.00	4.00	5.00	5.00	5.00	4.00
4.00	4.00	3.00	3.00	5.00	4.00	5.00	4.00
3.78	3.33	3.44	3.56	3.67	4.11	5.00	4.22
4.00	4.00	4.00	3.00	3.00	5.00	5.00	5.00
26.16	25.26	24.99	24.94	28.13	31.37	33.83	29.98
3.74	3.61	3.57	3.56	4.02	4.48	4.83	4.28

Note: Pre and Post TPACK Average of TPACK Domains with 4 -Non-Participants.

Figure 29

Non-Participants Overall Percent of Change in TPACK



Note. Resource from TPACK Survey Data.

Teresa's Initial Support and TPACK Growth

In Table 14, Teresa's initial support was in the knowledge areas of technological (TK), pedagogical content (PCK), technological content (TCK), and technological pedagogical (TPK). Teresa demonstrated growth in all areas of initial support and had the greatest gains with technology. Teresa also had growth greater than 0.5 in pedagogical content knowledge, technological content, and technological pedagogical knowledge.

Table 14

Teresa's Initial Support and TPACK Growth

Domain	Pre-TPACK	Post-TPACK
Technological Knowledge (TK)	2.17	3.33
Content Knowledge (CK)	4.00	4.00
Pedagogical Knowledge (PK)	3.71	3.71
Pedagogical Content Knowledge (PCK)	3.00	4.00
Technological Content Knowledge (TCK)	3.00	4.00
Technological Pedagogical Knowledge (TPK)	2.89	3.89
Technological Pedagogical and Content Knowledge (TPACK)	3.00	3.00

Note. Resource from TPACK Survey Data.

Paulette's Initial Support and TPACK Growth

In Table 15, Paulette's initial support was in the knowledge areas of content (CK), pedagogy (PK), technological pedagogical (TPK) and technological (TK). Paulette demonstrated growth in all areas of initial support and had the greatest gains with content. Paulette also had growth greater than 0.5 in pedagogy.

Table 15

Paulette's Initial Support and TPACK Growth

Domain	Pre-TPACK	Post-TPACK
Technological Knowledge (TK)	4.00	4.17
Content Knowledge (CK)	4.00	4.67
Pedagogical Knowledge (PK)	4.00	4.57
Pedagogical Content Knowledge (PCK)	4.00	4.00
Technological Content Knowledge (TCK)	4.00	4.00
Technological Pedagogical Knowledge (TPK)	3.89	4.11
Technological Pedagogical and Content Knowledge (TPACK)	4.00	4.00

Note. Resource from TPACK Survey Data.

Annie's Initial Support and TPACK Growth

In Table 16, Annie's initial support was in the knowledge areas of technological (TK), pedagogical (PK), technological content (TCK), and technological pedagogical (TPK). Annie demonstrated growth in all areas of initial support and had the greatest gains with technological content knowledge. Annie demonstrated growth greater than 0.5 in technological and 0.45 growth in technological pedagogical knowledge.

Table 16

Annie's Initial Support and TPACK Growth

Domain	Pre-TPACK	Post-TPACK
Technological Knowledge (TK)	3.17	4.16
Content Knowledge (CK)	4.30	4.30
Pedagogical Knowledge (PK)	3.71	3.85
Pedagogical Content Knowledge (PCK)	4.00	4.00
Technological Content Knowledge (TCK)	2.00	4.00
Technological Pedagogical Knowledge (TPK)	3.44	3.89
Technological Pedagogical and Content Knowledge (TPACK)	4.00	4.00

Note. Resource from TPACK Survey Data.

Catherine's Initial Support and TPACK Growth

In Table 17, Catherine's initial support was in the knowledge areas of technological (TK), content (CK), pedagogical (PK), technological content (TCK), and technological pedagogical (TPK). Catherine demonstrated growth in all areas of initial support and had the greatest gains with technological content and technological pedagogical knowledge. During the post- survey interview, Catherine changed her response to the technological, pedagogical, and content knowledge (TPACK) question to strongly agreed which quantified her score at five.

Table 17

Catherine's Initial Support and TPACK Growth

Domain	Pre-TPACK	Post-TPACK
Technological Knowledge (TK)	3.00	3.83
Content Knowledge (CK)	4.00	5.00
Pedagogical Knowledge (PK)	4.43	5.00
Pedagogical Content Knowledge (PCK)	5.00	5.00
Technological Content Knowledge (TCK)	4.00	5.00
Technological Pedagogical Knowledge (TPK)	4.11	4.78
Technological Pedagogical and Content Knowledge (TPACK)	4.00	4.00 (changed to 5.00)

Note. Resource from TPACK Survey Data.

Karl's Initial Support and TPACK Growth

In Table 18, Karl's initial support was in the knowledge areas of pedagogical (PK) and technological pedagogical knowledge (TPK). Karl demonstrated growth in all areas of initial support and had the greatest gains with technological pedagogical knowledge.

Table 18

Karl's Initial Support and TPACK Growth

Domain	Pre-TPACK	Post-TPACK
Technological Knowledge (TK)	3.83	3.83
Content Knowledge (CK)	4.30	4.30
Pedagogical Knowledge (PK)	4.00	4.28
Pedagogical Content Knowledge (PCK)	4.00	4.00
Technological Content Knowledge (TCK)	4.00	4.00
Technological Pedagogical Knowledge (TPK)	3.55	3.89
Technological Pedagogical and Content Knowledge (TPACK)	4.00	4.00

Note. Resource from TPACK Survey Data.

All participants demonstrated growth in their initial targeted support area of the TPACK domains. The first area, content technological knowledge, had a total increase of four points among the participants. The second area of growth was in technological pedagogical knowledge with a total increase of 2.68 among the participants. These survey findings were supported by the qualitative data.

Participants Group

Statistical Package for the Social Sciences (SPSS) was used to perform a paired-sample t-test for the participant group and then perform a paired t-test of the non-participant group as recommended by Green and Salkind (2008). A paired t-test (also known as dependent t-test) was conducted to evaluate whether the intervention of targeted support and training sessions within six months impacted the performance of the TPACK survey. Tables 19, 20, and 21, illustrate the results for the paired t-test. The results indicated that the mean for the post-survey (*M* = 4.1289*, SD* = *.35248*) was significantly greater than the mean of the pre-survey (*M* = 3.7146*, SD* = .42574), t (4) = 3.683, p=.021. In Table 19, the post scores on the TPACK survey increase, on average, by approximately 0.414 points. Using the formula $SE = \frac{\sigma}{\sqrt{n}}$, to calculate the standard error of the sample (SE) where $\sigma =$ sample standard deviation and n = sample size, the following was calculated $SE = \frac{.252}{\sqrt{5}}$ to obtain the 0.113 standards of mean error. A smaller standard means error indicates the sample closely represents the population. The 95% confidence interval for the difference between the Post- and Pre-TPACK surveys was CI [0.102, 0.727] (Table 21) and there were no missing cases. To determine the effect size of the difference between two means a Cohen's *d* test was conducted and the result was *d* = 1.647. The size of the effect is considered large if it is above 0.8.

Table 19

Participants Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	POST	4.1289	5	.35248	.15763
	PRE	3.7146	5	.42574	.19040

Table 20

Participants Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	POST & PRE	5	.807	.099

Note: p = .099

Table 21

Participants Paired Sample Test

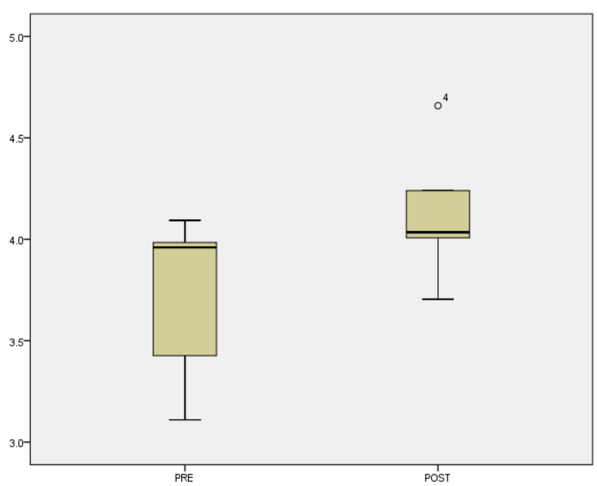
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	POST - PRE	.41429	.25150	.11248	.10200	.72657	3.683	4	.021

Note: Significant at **p < .05, two tailed.*

Since data were paired, there were no missing data matches for the sample. The boxplots in Figure 30 illustrate the difference between the two means and any overlapping within the distribution (Green & Salkind, 2008). Note that the graph indicates outliers within the data.

Figure 30

Participants: Boxplots of Pre- and Post-TPACK Survey



In summary, the paired t-test revealed a significant difference between the Pre- and Post-TPACK survey after interventions of targeted support and training occurred within six months.

There was evidence (t = 3.683, p = .021) that the targeted TPACK support and training improved the teachers' knowledge. Within this data set, the post scores on the TPACK survey improved, on average, by 0.414 points with a minimum score of 0 to a maximum score of 5.

Non-Participant Group

A paired-sample t-test was also conducted on the non-participant group to evaluate the non-participants' TPACK knowledge without receiving individualized training and support within six months. Tables 22, 23, and 24 illustrate the results for the paired t-test. The results indicated that the mean for the post-survey (*M* = 3.983*, SD = 0.467*) was not significantly greater than the mean of the pre-survey (*M* = 4.040*, SD* = .558), t (3) = -0.277 p = 0.80. Table 24 illustrates the scores on the Post-TPACK survey decreased, on average, by -0.058 points. Using the standard error (SE) of the sample formula: $SE = \frac{\sigma}{\sqrt{n}}$; where $\sigma =$ sample standard deviation, and n = sample size, the following was calculated $SE = \frac{.41548}{\sqrt{4}}$ to obtain the 0.208 standards of mean error. A smaller standard means error indicates the sample closely represents the population. The 95% confidence interval for the difference between the Post- and Pre-TPACK survey was CI [-0.719, 0.604] (Table 24) and there were no missing cases. To determine the effect size of the difference between two means a Cohen's *d* test was conducted. The result was *d* = 0.1385 and effects size is considered small if *d* = 0.2.

In summary, the paired t-test revealed no significant difference between the Pre- and Post-TPACK survey that occurred during the first semester. There was no evidence (t = -0.277, p = 0.80) that teachers' knowledge improved. As noted in Figure 31 for non-participants, there was a larger range in the Pre-TPACK than the Post-TPACK survey.

Table 22

Non-Participants Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	POST	3.9825	4	.46665	.23332
	PRE	4.0400	4	.55839	.27920

Table 23

Non- Participants Paired Samples Correlation

		N	Correlation	Sig.
Pair 1	POST & PRE	4	.685	.315

Note: p=.315

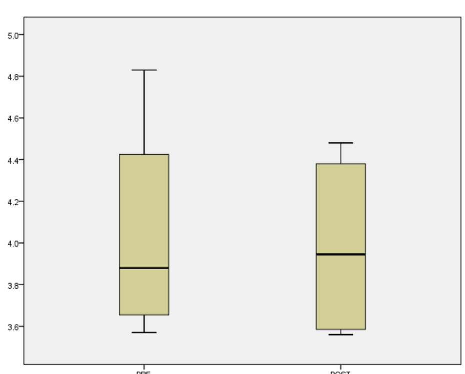
Table 24

Non- Participants Paired Sample Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	POST - PRE	-.05750	.41548	.20774	-.71862	.60362	-.277	3	.800

Figure 31

Non-Participants: Boxplots of Pre- and Post-TPACK Survey



In conclusion of part one, all teachers who received the individualized support and training intervention demonstrated an increase of knowledge on the Post-TPACK survey. Whereas three out of four teachers who did not receive individualized support and training intervention demonstrated a decrease of knowledge on the Post-TPACK survey. The findings for research question one demonstrated that targeted individualized support and professional development impacted newly hired secondary mathematics teachers' knowledge of technology, pedagogy, and content integration during instruction.

Part 2: Key Findings A (Qualitative Data)

This section presents findings from multiple data points which includes interviews, observations, member checks, artifacts, and field notes to address research question two.

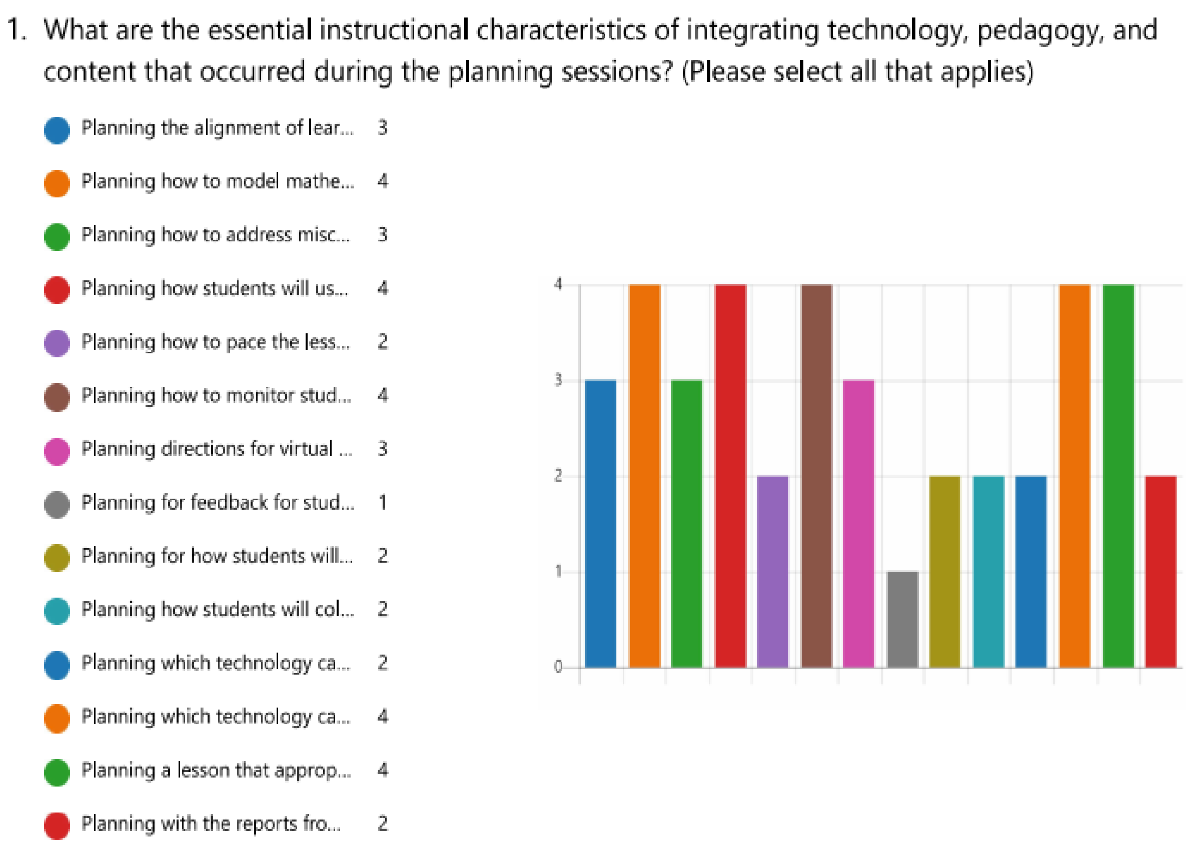
2. What are the essential instructional characteristics of integrating technology, pedagogy, and content knowledge that are developed during planning and implementation?

The five key findings for identifying the essential characteristics to planning and implementation of technology in a classroom included: (1) Planning how to model mathematics using the Technology (Teacher Models) (2) Planning how the students would use the technology tools to demonstrate their understanding (Students' Perform), (3) Planning how to monitor students' progress with technology (Monitor Progress), (4) Planning which technology can be used to enhance students learning (Tools to Enhance Learning), and (5) Planning a lesson that appropriately combines mathematics, technologies, and teaching approaches.

There were fourteen emerging findings for the essential characteristics of planning and implementation of technology. A member check was conducted by emailing four questions to the participants who received more than 10 hours of support. The questions and results from the member check are found in Figures 32 and 34. The emerging findings that received the highest selections were then checked with multiple data points from participants, cross-referenced to confirm the key findings, and used to identify findings that were supported by other data points that emerged.

Figure 32

Member Check Essential Characteristics for Planning using TPACK.



Note: Resource Participants' Member Check Survey.

There was an open-ended question that allowed participants to add additional comments on the essential characteristics for planning with the integration of technology. The participants' comments follow.

Annie's Comment

> It is important for the instructor to understand how to use the technology so when an issue may pop up for the kids the teacher will know how to get through it successfully. The teacher must have a backup plan using technology just in case something does go wrong with our original plan.

This statement supported the two emerging findings which were (1) planning how to model mathematics using technology, and (2) planning how the students will use technology tools to demonstrate their understanding. Teachers needed to understand how to use technology to assist students and issues that occur when students were using technology.

Paulette's Comment

> I love the Desmos activities and the activity builder to engage students online and track performance/participation. The geometry tools are also super engaging to allow students and teachers to demonstrate geometry concepts virtually.

This comment supported two emerging findings which were (3) planning how to monitor students' progress with technology, and (4) planning which technology can be used to enhance student learning.

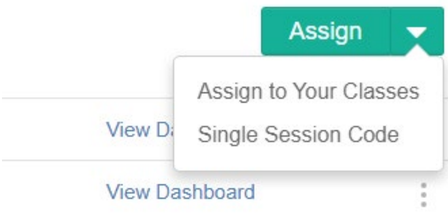
Teresa's Comment

> In this virtual learning teaching model, it is hard to have students collaborate. They are encouraged to ask and answer questions. Feedback is difficult, particularly with Desmos, as the student cannot go back and see their work/answers.

Desmos has two ways for students to access the activities which include managing classes or a single session code (Figure 33). The difference between the two ways to access Desmos for students to return to their work and see feedback from their teacher when a teacher uses a class code instead of a single code.

Figure 33

Desmos Class or Single Code



Note: Resource Desmos Activities

Catherine's Comment

"Mrs. Rojas and I have been co-teaching and utilizing Desmos Graphing Calculator to enhance students' learning." Catherine's comment on the essential characteristics for planning with the integration of technology was co-teach and utilizing Desmos Graphing Calculator to enhance students' learning. This comment supported one of the emerging findings: (4) planning which technology can be used to enhance students learning. The same method occurred with the strategies that supported the integration of technology.

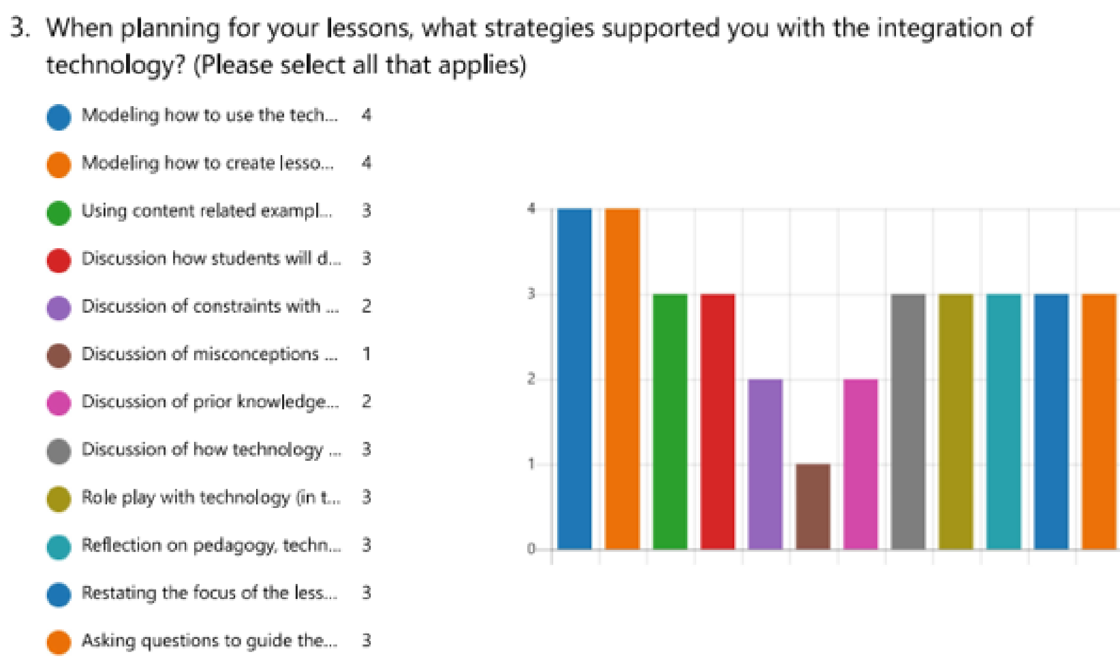
The four key findings for strategies that support the planning and implementation of technology include: (1) modeling how to use the technology, (2) modeling how to create lessons with technology, (3) using content related examples, and (4) discuss how students will demonstrate their understanding of the content with technology.

There was an open-ended question that allowed participants to add additional comments on strategies to support integration of technology. Only one additional comment was made from Teresa:

> In discussing, the use of various technologies for lessons, sometimes the collaborative thought process led from an initial technology to another that may have been better for the students to use.

Figure 34

Member Check Strategies to Support the Integration of Technology



Note: Resource Participants' Member Check Survey.

This comment was an initial emerging key finding that included discussion of constraints with technology and discussion of how students will demonstrate their understanding of the content with technology. Using content-related examples and discussion on how students will demonstrate their understanding of the content with technology was added as a key finding after the multiple data checkpoints with field notes and artifacts were examined.

Key Finding One: Planning How to Model Mathematics Using the Technology

To verify the emerging findings, the researcher re-examined all data points for each participant and identified the key comments that aligned with essential characteristic (1) planning how to model Mathematics using technology (teacher does/teacher moves) (Technology and Content). The researcher then cross-referenced the comments to confirm the key findings.

Teresa

On September 20, 2020, Teresa and I met by Zoom during her planning to discuss a Desmos Activity that she was planning to implement with her Pre-AP Algebra 1 classes as a synchronous lesson. Within the Desmos Activity, several components could be added to an activity which included the Desmos Calculator. The standards of learning for the lesson were evaluating expressions for given replacement values for the variables. Teresa planned to allow the students to practice using the graphing calculator along with evaluating expressions. Students have already practiced evaluating expressions without a calculator. Therefore, the lesson was a continuum of developing mathematical concepts and introducing them to the Desmos Graphing Calculator. The purpose was to allow students to confirm their answers and learn how to input mathematical expressions in a calculator since this was the first time that students would be using the Desmos Graphing Calculator. This was evident from comments Teresa made during planning (Table 25). As I observed on September 22, 2020, Teresa explained to her classes how to locate keys on the Desmos graphing calculator as noted in the observation and implementation (Table 25). Teresa was able to model how to use Desmos Graphing Calculator in a Desmos Activity and in Canvas which is embedded in the navigation bar for students to access for their assignments. Teresa's reflection of the activity and modeling the evaluation of algebraic expressions using technology was "I was 100% loving it." The researcher's field notes from September 20, 2020, were that Teresa planned to use the dashboard in student view to model how to use the Desmos Calculator and how to use the Desmos calculator in Canvas.

Table 25

Participant 1 (Teresa) Planning how to Model Mathematics Using Technology.

Planning Interview	**Observation and Implementation**	**Artifact and Reflection**	**Field Notes**
Line 593-594 (Synchronous Developing & Introducing Lesson) "Getting them to use the graphing calculator along with the content of the order of operations and evaluating expressions."	**Line 212 -214** (Observation notes) "And down here at the bottom are your squares and cubes an absolute value bracket of parentheses all your functions over here is divide multiply subtract and add and of course, there are numbers."	Modeled how to use Desmos Graphing Calculator in a Desmos Activity and Canvas **Line 310** (Reflection) "I was 100% loving it."	(Field notes-after planning interview) The teacher planned to use the dashboard in student view to model how to use the Desmos Calculator in the activity then demonstrates how to use the Desmos Calculator in Canvas.

In summary, Teresa demonstrated how to use the Desmos Graphing Calculator in a Desmos Activity to model how to evaluate expressions using key features within the graphing calculator. Then, Teresa demonstrated how to access and use the Desmos Graphing Calculator for future assignments in Canvas. Overall, Teresa was pleased with her synchronous lesson and students were able to demonstrate their understanding in the Desmos Activity and on future assignments.

Paulette

On October 5, 2020, Paulette and I met to discuss a Desmos Activity for Logic that she planned to implement with her high school Geometry classes in a synchronous learning environment. This was the first time she implemented a Desmos Activity with her Geometry class, and it was an introduction to logic statements. Paulette was using class Notebook in

Microsoft, IXL, and worksheets in Canvas for students to practice. This was her first-time teaching Geometry, so she requested for us to meet weekly to unpack the learning objectives and priority standards. Likewise, this was the first time that Paulette taught at an alternative high school that had semester courses. Therefore, Paulette had less time to teach the content, especially during this pandemic year. At the beginning of the school year, it took time for students and teachers to get adjusted teaching virtually. Paulette was concerned about teaching Geometry for the first time and not having enough time to complete the curriculum prior to the state examination in January 2021. She also expressed concerns about not knowing whether the students understood the content because the students were not responding and all she saw were little black boxes with their names on them. Prior to the planning sessions, I created a Desmos Activity using the resources from the Geometry Canvas module which aligned to the current standards that she was planning on teaching. The goal was to create an interactive lesson in which students demonstrate their understanding of the mathematical concepts. This activity was emailed prior to our planning session for her to review and make suggestions for modifications. During the planning interview, Paulette discussed how she planned to model for the students to use technology to demonstrate their understanding of concepts. Paulette modeled what she planned to say to her students during class “Let’s go into Desmos and you can write on this screen” (Table 26). Students were able to type in their responses or write their responses using the draw features in Desmos. During the observation, Paulette stated to her class “I’ll demonstrate it for you.” The artifact and reflections were teacher planned and included the slides that she would model for the students, and which slides the students would complete. As noted in the field notes, Paulette was using a scaffolding method of both understanding the concepts and modeling how to use the technology for students.

Table 26

Participant 2 (Paulette) Planning how to Model Mathematics Using Technology.

Planning Interview	Observation and Implementation	Artifact and Reflection	Field Notes
(Synchronous Introducing Lesson) The teacher stated what she planned to say to students "Let's go into Desmos and you can write on this screen."	The teacher models how to do problems and students responded to questions. Teacher: “I'll demonstrate it for you.”	Desmos Activity The teacher planned which slides that she would model to help to use the technology tools. Students need to know how to use the tools to answer the questions.	(Field notes after the planning interview) The teacher planned to model how to write on a Desmos Activity slide and respond to different types of questions using a scaffolding method for logic and using the digital tools.

In summary, the teacher used a scaffolding modeling method of the mathematical content and technology to ensure that the students could demonstrate their knowledge by modeling mathematics using technology. In the contextual environment, Paulette knew that her students struggled in staying engaged and submitting their assignments. The teacher wanted to model the mathematics using the technology tool so the students could successfully write and respond to the questions and engage in the activity.

Annie

On December 2, 2020, Annie and I met to discuss her Desmos Activity on writing linear equations from ordered pairs, slope, y-intercept, and a graphed line for a synchronous lesson which was an introduction lesson (Table 27). This lesson was designed to model how to write linear equations using the Desmos Activity and within the PowerPoint to post in Canvas. Within Desmos Activities, there are teacher guides with lesson plans created for each activity. The teacher guides provide an overview of the activity, checklist, learning targets, and outline of the activity screens to make notes and plan teacher moves.

Table 27

Participant 3(Annie) Planning how to Model Mathematics Using Technology.

Planning Interview	Observation and Implementation	Artifact and Reflection	Field Notes
(Synchronous Developing Lesson) **Line 75** "Yeah, so it's like the was a call that **I do, we do, you do** type thing."	The teacher models how to do the problem algebraically in a PowerPoint and with Desmos Teacher has done prior Desmos activities with students. They were comfortable working in Desmos. **Line 55** (observation notes) "I will do one with you than the one after that we're going to do together."	Desmos Activity and PowerPoint The teacher planned to use the I do we do, and you do model. Post Reflection on Lesson Students was able to draw "triangles to create the slope or use the slope formula" with the draw features and calculator component in the activity. **Lines 73-75**	The teacher decided to copy slides from the Desmos Activity and create a PowerPoint with notes and the Desmos activity within the PowerPoint so that students can have the notes and activity in one place.

In summary, the teacher plans to model using the "I Do, We Do, and You Do" strategy to support the mathematical concepts using the digital tools. As noted in the reflection, students were able to use the draw features to create slope triangles, draw features to show work, or use the calculator component within Desmos. The teacher decided to copy the screen slides from the Desmos activity into a PowerPoint which was uploaded in Canvas for review.

Catherine

On December 14, 2020, Catherine and I planned a synchronous lesson for her Pre-AP Algebra 1 students on a review of writing linear equations (Table 28). Catherine planned to model how to access the Canvas Textbook Activity and how to use the Desmos Graphing Calculator in Canvas to confirm writing linear equations when given points of a line and when linear equations are in different forms (slope-intercept form, point-slope form, and standard form). Students worked in collaborative groups in breakout rooms for ten minutes then presented their problems to the class using Zoom whiteboard and the Desmos Graphing Calculator. To increase student engagement, Catherine decided to utilize breakout rooms for small group discussions. She decided to create mixed groups of highs and lows so they can help each other. Catherine used the "I Do" model approach demonstrating how to access the assignment and how to use the Desmos Graphing Calculator in Canvas. She provided directions on what students were expected to do. The students used the "We Do" model in collaborative groups in breakout rooms in Zoom. The teacher visited the groups to ensure everyone was on task. After ten minutes, students presented their problems to the class using a Zoom whiteboard and Desmos Graphing Calculator in Canvas. Catherine reflected on the implementation of her lesson and was pleased that students were able to successfully access the Desmos Calculator and the activity in Canvas during the breakout rooms. As noted in the field notes, the researcher assisted with fixing broken links so that students could access Desmos Graphing Calculator.

Table 28

Participant 4 (Catherine) Planning how to Model Mathematics Using Technology.

Planning Interview	Observation and Implementation	Artifact and Reflection	Field Notes
(Synchronous Practicing Lesson) The teacher planned to model how to access the activity in the Canvas modules and how to use the Desmos Graphing Calculator in canvas. **Line 55** "And I will give them some explicit instructions on what to do." **Line 112** "Planning to model how to access and use to the Desmos Graphing Calculator…in Canvas."	The teacher used the "I do" "We do" "You do" model how to use the Desmos Graphing Calculator in Canvas and how to find the review activity in Canvas modules. **Line 22** "I'm gonna share my screen…5.2 textbook breakout room activity and how to use Desmos."	Desmos Graphing Calculator in Canvas and Activity in Module. The teacher was pleased that students were able to successfully access the Desmos Graphing Calculator and the activity in Canvas which she checked on the students in breakout rooms.	The researcher modeled how to use the Desmos Graphing Calculator in Canvas. And fixed the broken link so that the Desmos calculator would be accessible to students.

In summary, Catherine modeled how to use the Desmos Graphing Calculator to confirm the equation of the line and verify the different forms of the equation using a point-slope form, slope-intercept form, and standard form. During the planning interview, we planned out how to use the Desmos Graphing Calculator to model linear equations and justify the equation of the line. Based on the reflection, the teacher was pleased that the students could successfully locate the activity in Canvas and the Desmos Graphing Calculator.

Karl

On January 26, 2020, Karl and I met on Zoom to discuss Desmos Graphing Calculator and Desmos Activities. Karl was taking one of my online self-paced Desmos Canvas Courses since November 2020. Although Karl wanted to learn more about Desmos Activities and requested to build an activity for the next unit of study on Polynomials, there were a lot of transitions and circumstances that occurred before Karl introduced the activity to his classes. This included students returning to school on a hybrid model in February 2021 and snow days in which in-person and virtual learning were canceled. The activity was moved back several times before launching. Initially, the lesson was designed to be a practice of a synchronous lesson with breakout rooms on dividing polynomials with remainders and spiral reviewing functions by writing equations with restricted domain and range to create a snowman using the Desmos Graphing Calculator. Karl planned to model for students his snowman in the Desmos Graphing Calculator without the equations to see an example and “model for them a long division problem” as a warm-up. When Karl introduced the activity, students had difficulty getting into the Desmos Activity (Table 29).

Table 29

Participant 5 (Karl) Planning how to Model Mathematics Using Technology.

Planning Interview	Observation and Implementation	Artifact and Reflection	Field Notes
(Synchronous Practice) **Line 163** “my modeling will be showing them an image minus all of the equations.” **Line 165** “model for them a long division problem that.”	“students had difficultly logging on to Desmos. Activity changed from a synchronous activity to asynchronous.”	Reflection –follow-up meeting modification was made to activity. Students had a choice to use the handheld paper or Desmos Activity – Then use the Desmos Graphing to Design their snowman.	The researcher suggested meeting the day prior to implementation. The teacher felt comfortable launching the activity and chose not to meet until the next day.

After meeting with Karl, we discussed changing the activity as an asynchronous lesson and providing students the option to do a Desmos Activity with the built-in graphing calculator or on paper to create the snowman. Karl planned to model how to create the snowman using the Desmos Graphing Calculator and activity.

In summary, Karl modeled his snowman and discussed the Desmos Activity with his classes. As planned, Karl modeled how to use the digital tools in the Desmos Activity to work out problems, however, the activity needed to be modified due to various contextual situations that occurred.

Key Finding Two: Planning How Students Use the Technology Tools

To verify the emerging findings, the researcher re-examined all data points for each participant and identified key comments that aligned with essential characteristic (2) planning how students would use the technology tools to demonstrate their understanding of mathematics (Technology and Pedagogical**)**. The researcher then cross-referenced the comments to confirm the key findings.

Teresa

On September 20, 2020, Teresa and I discussed how students could demonstrate their understanding of mathematics using digital tools. She wanted the students to confirm their answers using the Desmos Graphing Calculator. In the Desmos Activity, Teresa included brackets and the absolute value signs because "some of the students were confused on that the other day" (Table 30). Using the Desmos Graphing Calculator to confirm their answers to evaluating expressions provided feedback to the teacher and students. Students were given a problem to identify the mistake and explain their thinking and allowed the students to demonstrate their understanding of mathematics by identifying errors using the Desmos Graphing Calculator and explaining their thinking in the Desmos Activity.

Table 30

Participant 1 (Teresa) How Students Will Use Digital Tools to Demonstrate Their Understanding.

Planning Interview	**Observation and Implementation**	**Artifact and Reflection**	**Field Notes**
(Synchronous Developing Lesson) **Line 308-309** we'll switch over to Desmos, and then they can confirm their solutions. **Line 216** In the Desmos Activity "I make sure I include the brackets and the absolute value signs. So, some of them were confused on that the other day."	Students used the Desmos Graphing Calculator within the Desmos Activity to confirm their answer to the evaluating expressions and order of operations. Students had to identify the mistake in a worked problem then explain whether it was correct or incorrect.	Students used the Desmos Graphing Calculator within a Desmos activity.	Nearpod was used to check homework. Students posted the answers to the homework on the collaboration board. Students worked on problems within a Desmos activity using digital tools to confirm and justify their thinking.

In summary, Teresa planned for students to demonstrate their understanding of mathematics using the Desmos Graphing Calculator and Teresa created a textbox within the activity for students to justify their thinking and respond to questions. Students worked on problems within a Desmos activity using digital tools to confirm and justify their thinking.

Paulette

On October 5, 2020, Paulette and I held a planning interview for Desmos Activities for her Algebra 1 class. The learning target was for students to solve multi-step equations, identify special cases when there was no solution or infinitely many solutions, and confirm their solutions using the Desmos Graphing Calculator within a Desmos Activity. First, students had to work out the problems then confirm their solutions using the Desmos Graphing Calculator. The students were able to demonstrate understanding by using the draw features or typing in their response to the problems within the Desmos Activity (Table 31).

Table 31

Participant 2 (Paulette) How Students will use Digital Tools to Demonstrate Their Understanding.

Planning Interview	Observation and Implementation	Artifact and Reflection	Field Notes
(Synchronous Developing Lesson) Teacher- "I can solve multiple-step equations, identify special cases, and confirm my solution using a Desmos Graphing Calculator."	Students typed in or used the draw features to respond to problems in a Desmos Activity.	The teacher planned for each slide how students would respond using the technology tools.	The teacher planned how the student would demonstrate their understanding by confirming their solutions with the Desmos Graphing Calculator and use the draw features to show their work.

In summary, the teacher planned for students to use the Desmos Graphing Calculator to confirm their solutions and use the text and sketch components within the Desmos Activity to demonstrate their understanding of mathematics. Desmos Graphing Calculator allows for students to graph equations to verify the solution based on where the line intercepts the x-axis and identify special cases if it does not intercept the x-axis.

Annie

On October 20, 2020, Annie and I met for a planning interview to discuss an asynchronous lesson on finding the slope of the line and graphing linear equations in slope-intercept form. Annie was planning to provide students with a Nearpod Activity that contained a built-in video for review, components where students could write or draw the slope of a line when given two points or given a line. At the end of the activity, students had to match equations with the correct graphs. There were detailed directions along with examples on how to use the draw features and respond to answers. As noted in the field notes from the asynchronous lesson planning session, we unpacked the standard to answer the questions on what students must know and be able to do and how they will do it prior to finalizing the Nearpod activity (Table 32). The students were able to use the digital tools to demonstrate an understanding of slope and graphing linear equations in slope-intercept form.

Table 32

Participant 3 (Annie) How Students Will Use Digital Tools to Demonstrate Their Understanding.

Planning Interview	Observation and Implementation	Artifact and Reflection	Field Notes
(Asynchronous Practice Lesson) Demonstrate their understanding using the digital tools with a coordinate grid and draw tools. **Line 57-58** "they can type it in, or they can draw or write it in." **Line 111** "Using the formula or creating slope triangles" to find the slope of a line.	We used the data report from Nearpod to assess students' understanding, identify any misconceptions, and determine the next steps. Overall, 80% of the students were able to successfully demonstrate their understanding of the concepts.	Nearpod Activity for Asynchronous lesson on Determining the slope of lines and graphing linear equations. **Artifact** We included detailed directions such as "use the draw feature to find the slope of the line (rise/run)" and components with worked examples to model with a built-in video as a review if needed. Their open-ended questions…	(Field notes from Asynchronous Lesson) Researchers and teachers unpacked the standard to answer what do students have to know and be able to do? How will they do it? We embedded the activity in Canvas. We emerged three activities into a Nearpod.

In summary, 80% of the students were able to demonstrate their understanding of the concepts. As planned, Annie used the Nearpod Activity for students to demonstrate their understanding of the concepts. The report allowed Annie to determine the next steps for learning and identify any misconceptions.

Catherine

On December 15, 2020, I observed Catherine's lesson on writing linear equations given two points in different forms which included slope-intercept form, point-slope form, and standard form. After the teacher modeled how to access the activity, she worked out a problem using the whiteboard and then confirmed with the Desmos Graphing Calculator. The students collaborated and presented how to write linear equations (Table 33).

Table 33

Participant 4 (Catherine) How Students Will Use Digital Tools to Demonstrate Their Understanding.

Planning Interview	**Observation and Implementation**	**Artifact and Reflection**	**Field Notes**
(Synchronous Practice Lesson) December 14th **Lines 112-113** **'**we do have in our canvas modules. So, they have access to the Desmos graphing calculator." **Lines 61-64** "the kids' language objective is they can speak, listen, write, and read with comprehension… to solve problems more than one way."	(Observation notes) Students worked in groups to complete the assignment in canvas on writing equations in a slope-intercept form then confirm the solution by graphing the equations and the order pairs and equations in different forms after returning from breakout rooms. One student worked out the problem on the whiteboard in Zoom. Another student would graph the order pairs then the equation in the Desmos Graphing Calculator to confirm that the lines go through the points graphed.	Reflection on Lesson By allowing the students to demonstrate their understanding to class, they are listening to each other communicate. Teacher Reflection **Line 134**: Line "I'm glad that the kids are engaging even doing this virtual learning."	(Field notes after observations) Students were given co-host rights to share a screen to demonstrate their understanding of writing the equation of a line given two points, or point and slope, or graph. Using the Zoom whiteboard to solve the problem algebraically then confirm solutions using the Desmos Graphing Calculator.

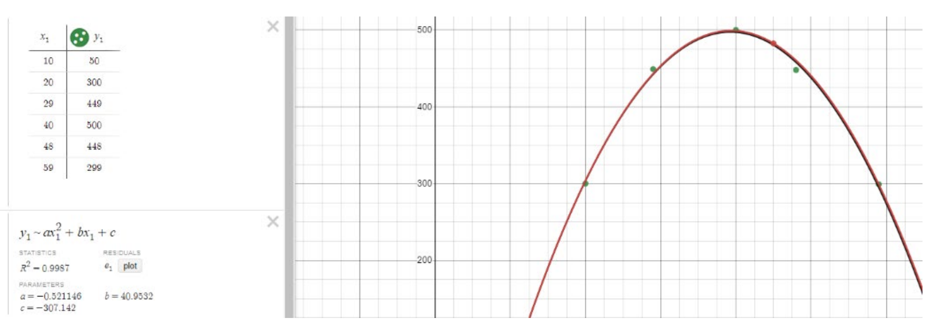
In summary, students demonstrated their understanding of concepts by presenting as a group how to write linear equations. Students worked out the problem on the whiteboard in Zoom and then used the Desmos Graphing Calculator to confirm their answers. As the teacher planned, students were able to speak, listen, write, and comprehend how to write linear equations in more than one way.

Karl

On January 26, 2020, Karl provided a written reflection on teaching the curve of best fit with quadratic regression. Karl participated in a self-paced individualized Canvas Desmos Graphing Calculator course in which teachers reflected on a lesson that they planned to use the Desmos Graphing Calculator. In Karl's written reflection, he stated "using Desmos, I taught Curve of best fit (Quadratic regression). The speed and accuracy were amazing. The students were intrigued by the way Desmos gave them the R-factor which let them know the accuracy of the equation of the parabola." In summary, Karl planned a lesson with the Desmos Graphing Calculator on quadratic regression. Figure 35 represents an example of how students demonstrated understanding of quadratic regressions and the R-Factor when determining the accuracy of the regression equation.

Figure 35

Quadratic Regression



Key Finding Three: Planning How to Monitor Students' Progress with Technology

To verify the emerging findings, the researcher re-examined all data points for each participant and identified key comments that aligned with essential characteristic (3) planning how to monitor student progress with technology (pedagogy and technology). The researcher then cross-referenced the comments to confirm the key findings.

Teresa

On September 20, 2020, Teresa and I planned how she would use the teacher dashboard in Desmos Activity to monitor students' progress during the synchronous lesson. As noted in the planning interview Teresa asked, "I have the opportunity to see the dashboard without them seeing the dashboard?" and she was able to switch to student or teacher views. She used the pacing feature in the dashboard so that students could not move ahead without her (Table 34). Teresa was able to provide feedback during the lesson using the teacher dashboard. In the reflection, she indicated feeling comfortable with the lesson.

Table 34

Participant 1 (Teresa) Planning How to Monitor Student Progress with Technology.

Planning Interview	Observation and Implementation	Artifact and Teacher Reflection	Field Notes
Line 284 "I could even have them copy those four problems down so that when we work them in the Desmos, they can put their answers in their notes." **Lines 593-595** So, "I have the opportunity to see the dashboard without them seeing the dashboard?" "I think it'll be based on the pacing, that they can't go on without me?"	Teacher monitored the students in Dashboard and provided feedback throughout the activity to students using the teacher and student view in the dashboard. Students' names were anonymous by given them mathematician names.	The teacher was able to monitor progress in class using Desmos dashboard **Lines 1-2** "Yes, I am feeling more comfortable. And things went so smoothly today, it just made me feel even better."	The teacher asked students questions as they worked through the activity because she was able to view students' work.

In summary, Teresa planned to use the teacher dashboard and switch between the student and teacher views to monitor student progress. Being able to monitor student's work made Teresa feel more comfortable and she felt better about her lesson. Teresa was able to view students' work in a virtual setting.

Paulette

On October 5, 2020, we planned for how Paulette would monitor students' progress in a Desmos Activity, and she claimed "Desmos helps you create that class where teachers can monitor students' progress in real-time." She stated, "it's a gamechanger as far as just seeing my little black boxes on Zoom" (Table 35). The dashboard assisted in the pacing of the lesson and allowed for Paulette to monitor students' understanding of the concepts and provide feedback to the students.

Table 35

Participant 2 (Paulette) Planning How to Monitor Student Progress with Technology.

Planning Interview	**Observation and Implementation**	**Artifact and Teacher Reflection**	**Field Notes**
(Synchronous Introducing Lesson) **Lines 583-587** "For one, just being able to see it." a game-changer as far as just seeing my little black boxes on Zoom and not getting them to unmute and answer." **Line 111**. Desmos helps you create that class" referencing traditional classroom when you can walk around the classroom checking students' progress in real-time. **Line 592** "I think being able to do it and do it in a private way." feedback to students	The teacher used the dashboard to monitor students' understanding of the activity and provide feedback. The teacher asked questions during the lesson to deepen the students' understanding of the mathematics **Line 21** "can you explain what's going on?"	Desmos Activity Lines 19-20"I'm just watching the dashboard and watching them do it." **Line 30**"Its mimic class."	The researcher provided direct training on how to use the dashboard in Desmos Activities to facilitate an asynchronous lesson and check for students' understanding.

In summary, Paulette planned how she was going to use the Desmos Dashboard to monitor students' progress and pace students during the lesson. She watched the dashboard as students worked on problems and asked questions in real-time as they worked on each problem. In a virtual environment, using a teacher dashboard, to monitor the students' understanding of concepts was a "gamechanger" for Paulette.

Annie

On December 2, 2020, Annie planned to provide the students with a warm-up to check for understanding of prior concepts. She utilized the teacher dashboard in Desmos to provide feedback for her class (Table 36). On November 4, 2020, Annie planned an asynchronous lesson using Desmos Activities for both 7^{th} Grade mathematics and Pre-AP Algebra 1. Students were supposed to complete the activity and a formative quiz to assess their understanding. On November 5 and 6, 2020, Annie was monitoring students' progress on completing the asynchronous assignments and noticed that several students were working on the Desmos Activity when she was logged into Desmos. Annie was able to provide feedback to students by sending messages within the Desmos Activity. Annie provided feedback with computational layers within the activities so that students were able to confirm their understanding of the concepts prior to taking a quiz. An example of the computational layers activity was the volume of a prism would not fill up if the answer was not correct. Students were given immediate feedback during the asynchronous lessons. Based on the reflection, students who completed the asynchronous Desmos Activity did well on their quizzes.

Table 36

Participant 3 (Annie) Planning How to Monitor Student Progress with Technology.

Planning Interview	Observation and Implementation	Artifact and teacher Reflection	Field Notes
On December 2, 2020, (Synchronous Developing Lesson) Annie planned to use the teacher dashboard to monitor and pace students. **On November 4th,** Annie planned to use the computational layers in Desmos to provide feedback and For students to complete a formative quiz for an asynchronous lesson. Computational Layers (Asynchronous Practice Lesson) (11-4) **Line 85-86** (7th Grade Mathematics) And if you get it wrong, it's not going to fill up completely. You're not going to get that checkmark.	**On December 3, 2020**- Observations Note Only two students from the Desmos dashboard had difficulty with the warm-up. Annie encouraged the students to check their work. **Line 20** "are missing the y-intercept or slope." During the asynchronous lesson on **November 5th and 6th,** Annie noticed that some of her students were in the Desmos Activity working, she was able to send a message to provide feedback as students were working.	**Dec 3:** Desmos Activities on Writing Linear Equations from a graph, points, and slope and a point. **Nov 5 & 6** Asynchronous lesson reflection on formative activity and quizzes. **Line 270** Students the ones who did it did well on the quiz, the last week they got it. But the ones who did not attempt to do this activity struggle because they didn't practice.	Planning Technology/ Pedagogy Pacing students. dashboard, using the computational layers and send feedback through Desmos Activities to students.

In summary, asynchronous lesson planning occurred on how to use the dashboard to monitor students' progress. During the asynchronous lesson, Annie planned feedback through the computational layer codes and by being logged on at the same time as the students. Using both dashboard and computational layers feedback in an asynchronous lesson assisted in student self-monitoring and teacher progress monitoring.

Catherine

On December 14, 2020, Catherine planned to allow the students to co-host and present how to write linear equations and use the Desmos Graphing Calculator to confirm their answer. Catherine planned to monitor the students' progress by using a rubric as they presented and to visit breakout rooms when they worked collaboratively in groups (Table 37).

Table 37

Participant 4 (Catherine) Planning How to Monitor Student Progress with Technology.

Planning Interview	Observation and Implementation	Artifact and teacher Reflection	Field Notes
(Synchronous Practice Lesson) **Line 115-117** "co-host and they share their screen. They go in and put in Desmos graphing calculator up and they are just explaining as they go. What they did had a step-by-step how to solve their problem" "rubric that we use that this particular time has 20 points and problems, some math content."	The teacher visited all the breakout rooms as students worked on the problems collaboratively.	Teacher reflection – Giving students accountability for their understanding. I utilized. **line 155** "cooperative learning" Reflecting on getting increasing collaboration in breakout rooms.	Worked with the teacher to create preassigned breakout rooms and practiced joining and assigning breakout rooms.

In summary, Catherine planned to monitor students' progress by visiting the Zoom breakout rooms. She also planned to use a rubric during their presentation to monitor student understanding of the mathematical concepts and how to use the Desmos Graphing Calculator. Catherine wanted to provide an opportunity for students to be accountable by allowing them to work collaboratively and to demonstrate their understanding of mathematical concepts as they presented.

Karl

When planning the Desmos activity, Karl initially planned for students to work in breakout rooms and that he would be “popping in and out of the breakout rooms to monitor students’ progress.” Due to snow days and technology issues, the lesson became an asynchronous lesson so, he monitored the understanding of the mathematical concepts based on the completion of the task.

Key Finding Four: Planning which Technology can be Used to Enhance Students Learning

To verify the emerging findings, the researcher re-examined all data points for each participant and identified key comments that aligned with essential characteristic (4) planning which technology can be used to enhance students learning. The researcher then cross-referenced the comments to confirm the key findings.

Teresa

On September 20, 2020, Teresa planned to use Desmos Graphing Calculator to clear up any misconceptions. She stated that “They’re not fully developed in the idea that minus five is the same as negative five. So, that would be a misconception I can address as they’re trying to input things into the calculator” (Table 38). During the observation of the lesson, the teacher used the Desmos Graphing Calculator within the activity to confirm student answers to problems. After the implementation of the lesson, Teresa reflected on how she felt the students became more comfortable with the Graphing Calculator and their understanding of the mathematical concepts which increased their confidence.

Table 38

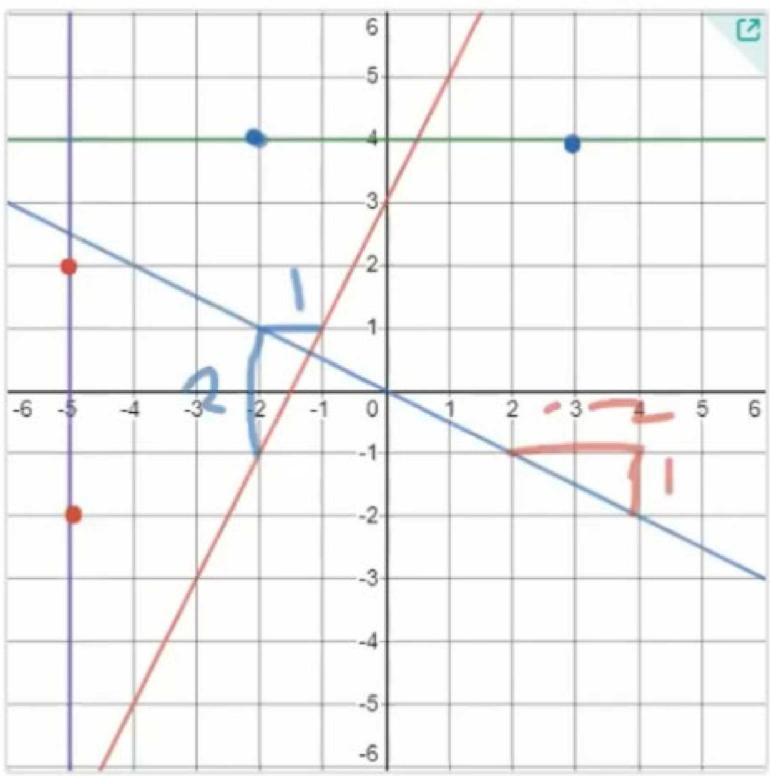
Participant 1(Teresa) Planning Which Technology Can Be Used to Enhance Student Learning.

Planning Interview And reflection	Observation and Implementation	Artifact	Field Notes
Sept. 20, 2020 **Lines 188-190** (Synchronous lesson) "Well, is that minus five or negative five?" which is a common misconception. They're not fully developed in the idea that minus five is the same as negative five. So, that would be a misconception I can address as they're trying to input things into the calculator."	(Observations Notes) The teacher provided notes, vocabulary, and examples of order of operations and evaluating expressions. Students used the Desmos Graphing Calculator within a Desmos activity to confirm their solutions to problems as they worked out the problems.	Desmos Activity with a Graphing Calculator component to build confidence and learning how to use the calculator. The teacher felt "they're comfortable."	(Field notes after observations) Students were asked to explain "Why" if the answer was correct or incorrect within the Desmos Activity which allowed the teacher to assess students' understanding and help to determine the next steps of instructions.
Asynchronous Lesson planning on **November 3rd for Line 41** Identifying slope, and y-intercept, and graphing a line from the slope-intercept form and equation. **Line 77** manipulation of the tools and accuracy of plotting the points and drawing the line, whether they do it with the pencil tool or the line tool, getting it lined up correctly.	Reviewed the data in Desmos Activity to determine the next steps in instruction. **Lines 80-84** **"**Most of them did pretty well with the zero and undefined, and most of them did pretty well with just finding the slope. Here's an eight over four, which could have been reduced."	Desmos Activity and Results from Asynchronous work.	The teacher copied and pasted Desmos Slides to review any misconceptions as a warmup prior to a quiz. Due to constraints with returning to work (for feedback) and students not allowed to have Desmos accounts. The teacher decided to used PowerPoints' draw tools for homework and quiz.

On November 3, 2020, Teresa and I met for an asynchronous planning interview. The learning targets included identifying slope, y-intercept, and graphing a line from the slope-intercept form and equation. Teresa wanted the students to plot points and draw lines by using the pencil or line tool, so Teresa decided to build a Desmos Activity. The digital tools were available to enhance student learning of slope, y-intercept, and graphing linear equations in a virtual learning environment (Figure 36).

Figure 36

Desmos Draw Tools



Note. Sample of how students use the draw tools.

The Desmos Activity allowed Teresa to determine the next steps for instruction. She was able to copy and paste the Desmos slide to review student misconceptions prior to the quiz. Due to constraints returning to the Desmos Activity later for review (Students were not allowed to create a Desmos account) and difficulty providing individualized feedback, Teresa decided to use PowerPoint draw tools for the homework and quiz.

In summary, technology was used to clear up misconceptions by using the Desmos Graphing Calculator. Initially, the Desmos activity was used to assist students in graphing linear equations using the line and draw tool. Because students were unable to return to their work, Teresa decided to use PowerPoint tools in Canvas to allow students practice and to receive individualized feedback that enhanced their understanding of the concepts.

Paulette

On November 3, 2020, Paulette and I had a planning interview for her asynchronous Geometry class on relationships with angles and sides in a triangle. Although students had prior knowledge on classifying triangles and the sum of the interior angles of a triangle, Paulette stated that she wanted "instructional videos as well as some activities to go along with the new material" to be built in the Desmos Activity (Table 39). She wanted the students to work at their own pace and watch the video then move back and forward between the screens. The new knowledge for the student was ordering the sides by length, given angle measures, ordering the angles by degree measure, given side lengths, determining whether a triangle exists, and determining the range in which the length of the third side must lie. Paulette planned to have instructional videos within the activity to enhance student learning. She wanted students to review during the asynchronous lesson then practice more during the synchronous class time. By providing instructional videos with activities in advance, Paulette was enacting aspects of a flipped classroom (Tucker, 2012; Blended Learning, 2020) which was deliberately planned during our interview session. The activities consisted of reviewing prior concepts in which computational layers were added to the activity for feedback during the asynchronous lesson to enhance student learning of the concepts. For example, the card sort check would let students know if they had matched all or half of the cards correctly and suggested that they go back and review if not correct. Paulette could send messages to students to encourage them and provide feedback.

Table 39

Participant 2 (Paulette) Planning Which Technology Can be Used to Enhance Student Learning.

Planning Interview And reflection	**Observation and Implementation**	**Artifact**	**Field Notes**
Asynchronous designed lesson On **November 5, 2020**, on Relationships of angles and sides within a triangle added instructional videos embedded in Desmos Activity as a review. **Line 10-12** "I wanted to make sure there was some instructional video to it, as well as some activities to go along with the new material." Students should have prior knowledge that the "sum of a triangle is 180." **(line 27)** and "classifying triangles by sides and angles." **(Line 31)**	"Students work at their own pace" "They can watch the video and then they get to play it again if they miss something and go back a screen and go forward a screen." The teacher viewed the teacher dashboard during the asynchronous activity and was sending feedback in Desmos.	Desmos Activity embedded in the canvas. Asynchronous Activity 11/9/2020 Reflection **Line 181-182"**When I do send the message or the feedback thing that they will see on the page key events will pay attention to what I say up there."	Supported teacher with embedding videos to review concepts as students worked through the concepts. Assisted with adding computational layers to provide feedback to students. For example, the card sort to check if they are all right, half right, and to go back and try it again.

In summary, Paulette planned which technology to use to enhance student learning by providing instructional video supports and feedback with computational layers. Students were able to work at their own pace during the asynchronous lesson. Paulette planned a built-in review of prior knowledge concepts and vocabulary needed for the new learning.

Annie. On December 2, 2020, Annie planned for students to use the draw features in a Desmos Activity for students to find the slope of the line and identify the y-intercept (Table 40).

Table 40

Participant 3 (Annie) Planning Which Technology Can be Used to Enhance Student Learning.

Planning Interview And reflection	Observation and Implementation	Artifact and Reflection	Field Notes
On ***December 2, 2020,*** Synchronous Lesson – Annie planned for Students to use the draw feature in a Desmos Activity to find the slope of the line and to identify the y-intercept. Students may use the graphing calculator to confirm their solutions. Annie planned for "students to notice the equations can be in the different forms and be the same line." **(Line 56)**	**Line 29** "you should have had y equals -x – 4. I saw someone also write y equals -1x - 4 both answers are correct." Using Both Methods for finding slope and "you get the same answer" Rise and run then using the slope formula.	**Line 81-84** Reflection on Activity "Overall, the technology being able to check their work once they have equations plugging it into the Desmos Graphing Calculator, they can see that it does go actually through the points." "Able to address that misconception right there and then." Computational Layers within the Desmos Activity to provide feedback.	Identify which technology will model students understanding of x and y intercepts by graphing using the digital draw tool in Desmos and identify any misconception. (X and Y intercepts flipping the coordinates and going through the origin)

She planned that the students would use the Desmos Graphing Calculator component in the activity to confirm their equations and to discover that the equations can be written in different forms and be the same line. This included the slope-intercept form, point-slope form, and standard form. During the observation, Annie was able to provide feedback that y = -x - 4 is the same as y = -1x - 4. Students were able to use both methods of finding the slope of a line by rise over run or using the slope formula to discover it would give them the same answer. Using Desmos Activity builder and Desmos Graphing Calculator, students were able to confirm their answers and the teacher was able to provide feedback on errors like flipping the x and y intercepts.

In summary, Annie planned to use a Desmos Activity and Desmos Graphing Calculator to investigate the different forms of a linear equation and build an understanding of the slope formula and rise over run representing the change in y over the change in x. Based on the reflection, computational layers were added to provide additional feedback during class to enhance student understanding. The computational layers add individualized feedback based on input.

Catherine

On December 15, 2020, Catherine used breakout rooms to enhance student learning by creating a collaborative learning environment. Catherine incorporated a student-centered approach in learning concepts.

> Catherine stated, … And the students were definitely engaged. One student presented. They came back from the breakout room and then the other ones, if I asked a question, then they chimed in and they answered the question. So, they have engagement and participation…It's all about explaining the concept so that they can model it, play with it, collaborate with one another. That collaboration is a whole big piece to it. They're talking to each other; they're working it out. So that lesson, it went quite well. I was very pleased with it.

The students used the Desmos Graphing Calculator in their breakout rooms and during their explanation to confirm solutions by sharing their screen and demonstrating how to find solutions.

Karl

In a synchronous lesson, Karl used the Desmos Graphing Calculator to increase student engagement and understanding of the concepts. Karl stated, "students were able to manipulate the tables to see a dynamic change in the graphs and equations." His students were able to develop conceptual understanding between the tables, equations, and graphs for quadratic regressions.

Key Finding Five: Planning a Lesson that Appropriately Combines TPACK

To verify the emerging findings, the researcher re-examined all data points for each participant and identified key comments that aligned with essential characteristic (5) planning a lesson that appropriately combines mathematics, technologies, and teaching approaches (TPACK). The researcher cross-referenced the comments from the post-survey to confirm the key finding. An open-ended question on the pre- and post-survey asked participants to "Describe a specific episode where they effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what mathematics was used" (Table 41).

Based on the post-survey results, all participants were able to describe how they combined technology, content, and pedagogy within their classes. All participants described how they incorporated Desmos within their classes. Based on the results of the post-survey, all participants' reflections aligned with the individualized support provided throughout the first semester. Teresa described how she used Desmos activity to practice identifying slopes of lines and y-intercepts. Paulette described a lesson on solving systems of equations by graphing within a Desmos activity and using a Desmos Graphing Calculator. Annie described the “I Do, We Do, and You Do” method with Desmos when teaching linear equations. Catherine described the Desmos Graphing Calculator and activities to demonstrate slope, slope-intercept form, regressions, and scatter plots. Karl described using the Desmos Graphing Calculator to demonstrate and model mathematical concepts as well as using breakout rooms. Both Karl and Paulette completed an online self-paced Canvas Desmos Course which offered asynchronous and synchronous opportunities to engage in conversations on the integration of Desmos in a virtual learning environment with other teachers. Karl’s reflection was mentioned earlier in this chapter on the Desmos Graphing Calculator with quadratic regressions.

Table 41

Participants Based on Post Survey Reflections.

Participants	Written Reflection Response to the Open-ended Question
Teresa	Slope intercept in Algebra. I taught with notes and students using graphs to find slopes and y-intercepts. I used a DESMOS activity to practice identifying the slopes of lines and their y-intercepts.
Paulette	I taught a lesson on solving for a Systems of Equations by graphing using a Desmos activity. In the first few slides, I demonstrated the process for plotting the two equations by hand and finding the intersection (solution) and students had a couple to do independently. Then in the later slides, I embedded the Desmos graphing calculator so students could experience entering the equations and seeing the intersection point. Students could verify their accuracy for the systems solved by hand with the Desmos app's solution.
Annie	I have used Desmos when teaching writing linear equations for my algebra class. I often use the I do, We do, You do method when teaching. I modeled how to write equations when given a set of points. The use of Desmos allowed me to see how the students found the slope and ultimately the equation to the points given. I also used computational layers to allow Desmos to give the students feedback on the answers they submit.
Catherine	When we use the Desmos Graphing Calculator and the various Desmos Activities, the students can engage, demonstrate and model mathematical concepts. We have used the Desmos Graphing Calculator to demonstrate Slope, slope-intercept form and, the students have used Desmos to determine the line of best fit--scatter plots and regression.
Karl	In addition to Desmos, which most students find fascinating... I have used breakout rooms. Their task, for example, was to make a digital bulletin board explaining a certain math concept discussed in class. I enjoy having other students explain how to solve a problem and watch them use technology as well. It is good for students to hear more than my voice. I move from breakout room to breakout room to help students.

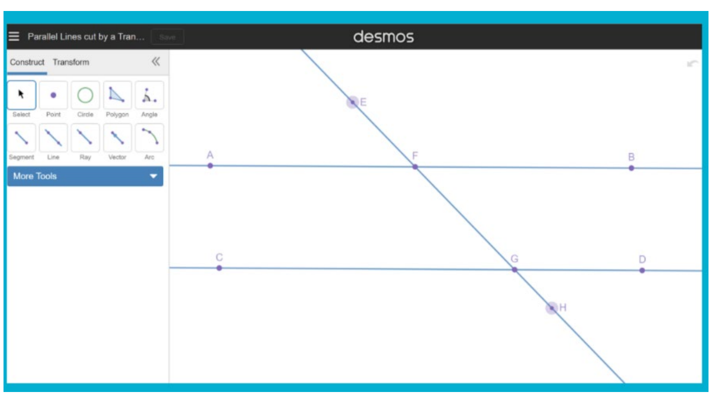
Note. Resource from TPACK Survey Data.

Paulette

In addition to weekly planning sessions, Paulette participated in a self-paced Canvas Desmos Geometry Course. Teachers who participated in the course had to plan and implement a lesson using Desmos Geometry Tools. Paulette stated the Desmos Geometry Tools "increased student engagement." We discussed the planning and implementation of the lesson using the TPACK model. Students used the "pre-made set of parallel lines" link with the transversal shown in Figure 37 to investigate the angles formed by parallel lines and a transversal. Paulette demonstrated how to measure angles using the Desmos Geometry Tools. She encouraged the students to complete the remaining measures. Then the teacher adjusted the transversal and asked students to remeasure the angles. Paulette stated, "Students began to see the relationship among the eight angles formed by parallel lines and a transversal line."

Figure 37

Desmos Geometry Tools: Parallel Lines with One Transversal Line

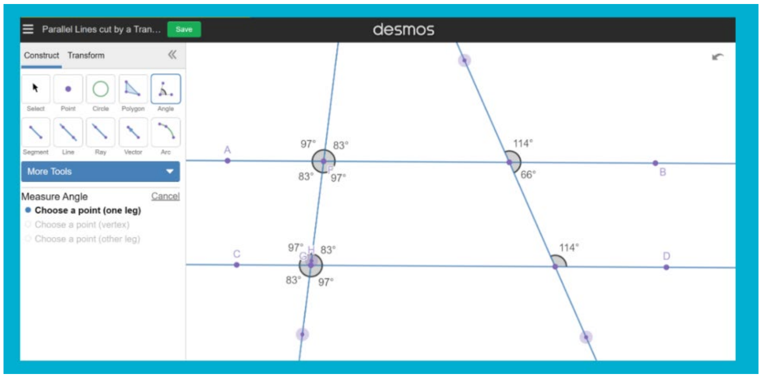


Note. Resource from Participant's Reflection

Paulette scaffolded by adding a second transversal (Figure 38) and students were able to measure all the angles and developed a conceptual understanding of alternate interior angles, alternate exterior angles, corresponding angles, and consecutive angles. The Desmos Geometry tools solidified the concepts of congruent angles and supplementary pair angles.

Figure 38

Desmos Geometry Tools: Parallel Lines with Two Transversal Lines



Note. Resource from Participant's Reflection

In summary, Paulette's reflection demonstrated planning with technology, content, and pedagogy. The integration of digital tools enhanced learning and stimulated student engagement. Students were able to develop a deeper understanding of the mathematical concepts using the Desmos Geometry Tools.

In conclusion of Part-Two A analysis, the five key findings from the qualitative data analysis included (1) Planning how to model mathematics using the Technology (Teacher Models), (2) Planning how the students would use the technology tools to demonstrate their understanding (Students Perform), (3) Planning how to monitor students' progress with technology (Monitor Progress), (4) Planning which technology can be used to enhance students learning (Tools to Enhance Learning), (5) Planning a lesson that appropriately combines mathematics, technologies, and teaching approaches. There were multiple data points used to determine the key characteristics for planning and implementation of technology during instruction. These key findings addressed research question two on the essential instructional characteristics of integrating technology, pedagogy, and content knowledge that is formed during planning and implementation.

Part 2: Key Findings B (Qualitative Data)

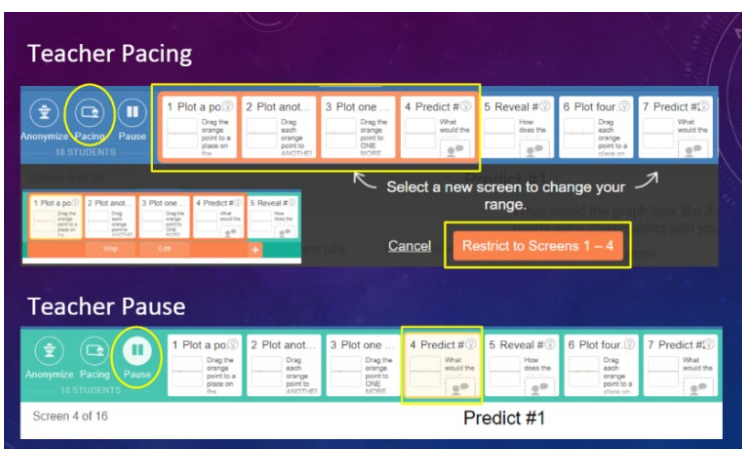
In research question number three, "what strategies support teacher integration of technology during instruction?" there were four key findings that supported the planning and implementation of technology. These key findings include (1) modeling how to use the technology, (2) modeling how to create lessons with technology, (3) using content-related examples, and (4) discussing how students will demonstrate their understanding of the content with technology.

Strategies Supported Teacher Integration of Technology

In modeling how to use technology, the researcher would model how to search for the Desmos Activities, how to assign a Desmos activity to a class using a single session code, how to embed the activity in Canvas modules, how to use the dashboard (Figures 39 and 40), and how to use the teacher guide within each Desmos Activity. The dashboard consists of pacing and pausing the lesson based on planned discussion or modeling and students' responses.

Figure 39

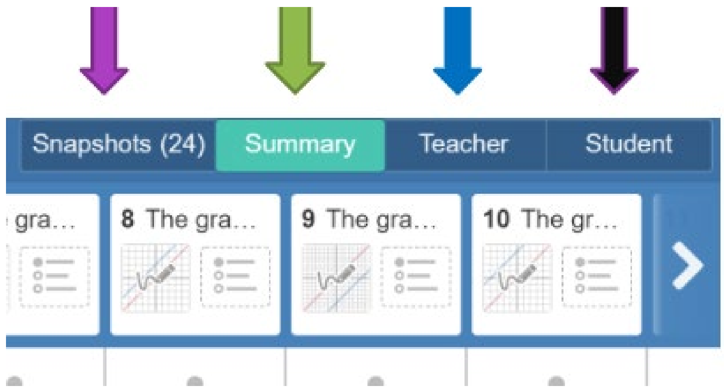
Dashboard Pacing and Pause



Note. Resource from Desmos Activities

Figure 40

Dashboard Views

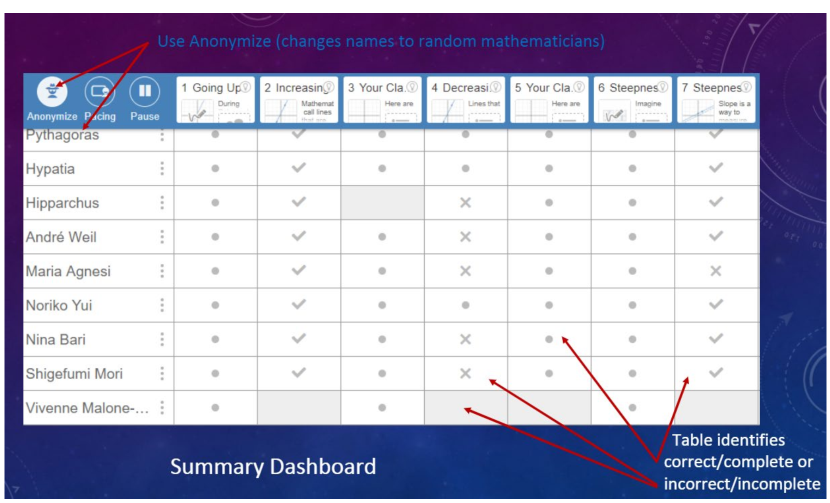


Note. Resource from Desmos Activities

The dashboard allows the teacher to view a summary of the classwork, a teacher view of an individual student's work, and a view of what students are viewing. The anonymize function changes the students' names to mathematicians for privacy in responses (Figures 41). Teachers can display responses as individuals or overlap in presentation mode (Figures 42).

Figure 41

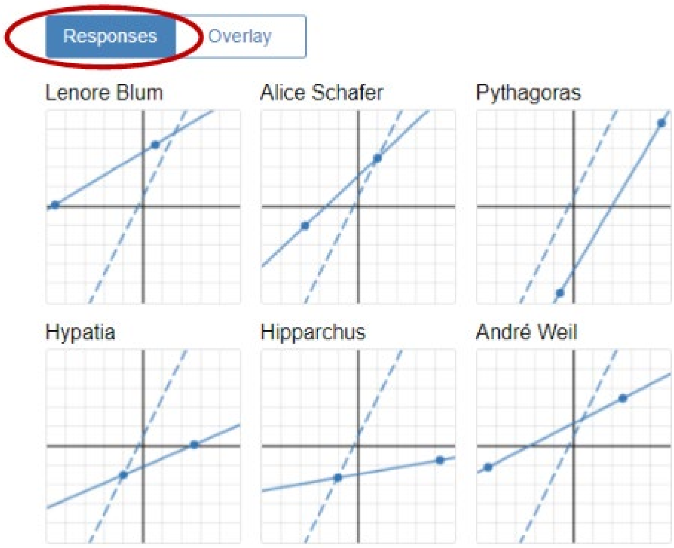
Anonymize (change names to random mathematicians)



Note. Resource from Desmos Activities

Figure 42

Sample of Students' Responses

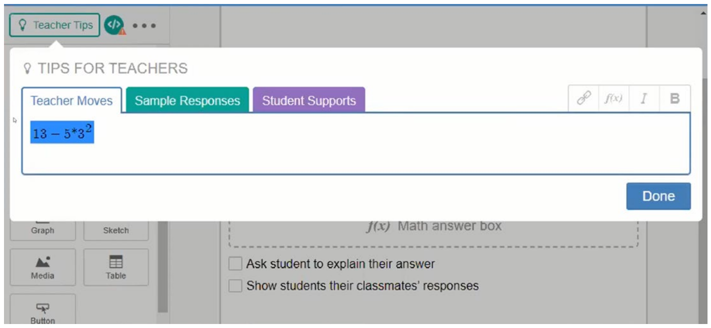


Note. Resource from Desmos Activities

For key finding two, the researcher modeled how to create a lesson with Desmos Activities for each participant in three stages. In the first stage, we would edit an existing Desmos activity. In the second stage, we created a Desmos Activity using the various components depending on the concept and pedagogy strategies. In the third stage, we added computational layers. The researcher often used the annotate features in Zoom when assisting a participant. Teresa had difficulty with building her activity because she input the expression only in the Teacher moves and not the math input type (Figures 43 and 44). Another example of assisting in creating Desmos Activity was adding a table for responses. The researcher used the annotated tools in Zoom to assist with creating a table (Figures 45 and 46).

Figure 43

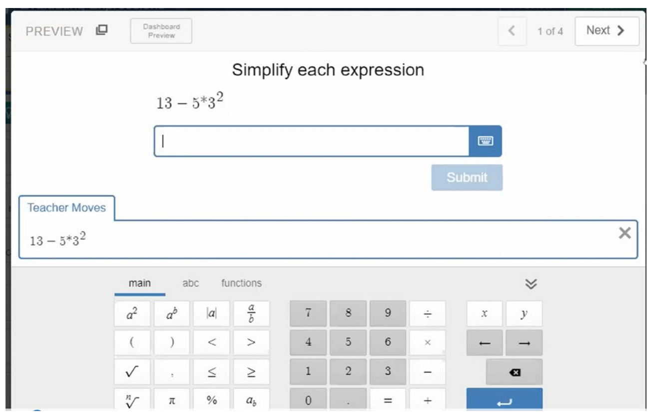
Teacher Move



Note. Resource from Desmos Activities

Figure 44

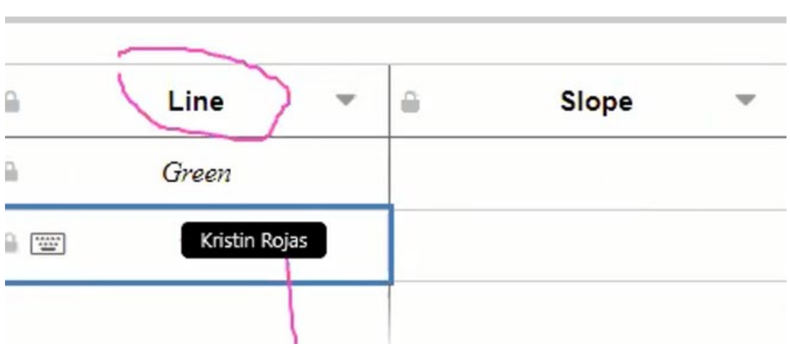
Text Input



Note. Resource from Desmos Activities

Figure 45

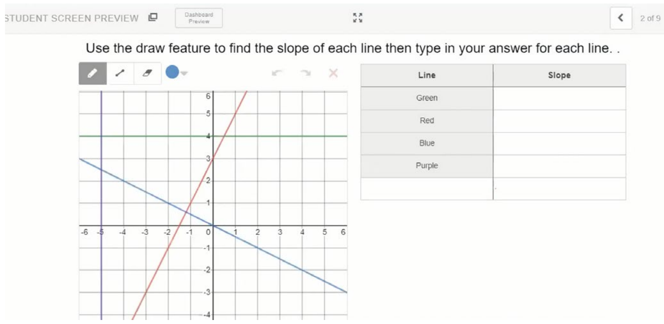
Annotated Directions



Note. Resource from Desmos Activities

Figure 46

Corrected Table

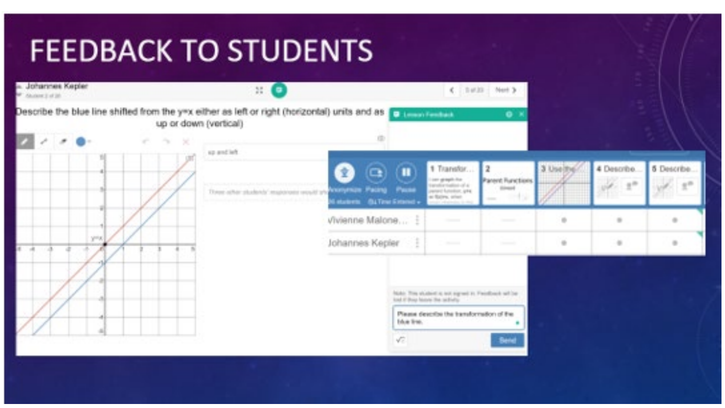


Note. Resource from Desmos Activities

In a virtual environment, providing feedback to students was critical in the learning stages. When participants created activities, identifying the stages of learning within a lesson impacted the design. These stages included introducing, developing, practicing, or applying. Depending on what learning stage, the mathematical concepts being taught impacted the feedback and virtual learning environment. Feedback can be individualized within the Desmos Activity in response to students' work. Computational Layers assisted in providing direct feedback to students on their understanding, especially during asynchronous lessons (Figure 47).

Figure 47

Feedback to Students



Note. Resource from Desmos Activities

The researcher reviewed content examples that utilized technology prior to the planning interview for participants. Often the researcher would email sample activities from Canvas modules or state resources, As noted in the field notes, the researcher reviewed resources within the Canvas modules, state lesson plans, and Desmos activities.

9/12/2020 Field Notes (Prior to meeting):

Researcher: Reviewed resources in the Canvas module, units of study, and Desmos activities. The researcher has been working with Teresa on implementing Desmos Activities in a virtual setting and emailed an error analysis problem from state resources. Scheduled meeting with Teresa to start planning lessons for the week. Early last week, we discussed chunking concepts that flow together.

Based on the conversations, the examples would be modified, or different activities would be used to best meet the needs of students within each learning environment. The researcher had discussions with participating teachers on how students will demonstrate their understanding of mathematics using technology in the different learning environments.

9/12/2020 Field Notes (After meeting)

Researcher: Teresa created a Desmos activity to provide practice with the Desmos graphing calculator and allow the students to confirm their answers. Teresa needed support for the questions to appear in student view in the Desmos activity. We fixed the problem by editing the activity. I explained where the questions go and how to check student views while editing. Teresa and I discussed how students would use the technology to demonstrate their understanding of mathematics. We added an error analysis problem from the state practice problems. We discussed algebra tiles as a virtual manipulative. Teresa felt that the algebra tiles were too much new technology for her and the students. We discussed that the students need to become comfortable with the graphing calculator and know how to confirm their solutions. We discussed homework modification to Canvas resource to reduce the number of problems and allow students choice. We also discussed quizzes for formative assessment at the end of the week.

In summary, the four key findings on strategies that support the planning and implementation of technology included modeling how to use the technology, modeling how to create lessons with technology which included Desmos, Nearpod, and other technologies. The researcher prepared for individualized meetings by reviewing resources and standards of learning. Lastly, the researcher discussed how students should demonstrate their understanding of mathematics using the technology tools.

In conclusion of Part Two B analysis, four strategies supported the teachers' integration of technology during instruction: (1) modeling how to use the technology, (2) modeling how to create lessons with technology, (3) using content-related examples, and (4) discussing how students will demonstrate their understanding of the content with technology. There were multiple data points and artifacts that were used to identify the strategies.

Part 3: Confirm the Findings

In part three, the key findings were aligned with the TPACK survey and confirmed through follow-up survey interviews. The key findings from essential characteristics of planning and implementing the integration of technology, pedagogy, and content knowledge were aligned to the survey questions and interview questions (Appendix N). During the interviewing of Pre- and Post-survey results for each participant, the researcher asked the following questions:

1. Does your answer to this statement reflect how you felt at the beginning of the year? If so why or why not?

2. Does your answer to this statement reflect how you felt at the end of the semester? If so why or why not?
3. Describe your thinking for your answer to this statement.
4. How would you explain your response to this statement?
5. Would you change any of your responses? If so why or why not?

Teresa

On March 8, 2020, Teresa and I met in Zoom to discuss her Pre- and Post-TPACK survey results. I shared only the results of Teresa's Pre- and-Post-TPACK survey using an Excel spreadsheet and sharing my screen in Zoom (Figure 48). The researcher provided her an opportunity to elaborate on her thinking. Based on the results of the Pre- and Post-TPACK survey, Teresa demonstrated growth on her Post-TPACK survey by 64% (18 out of 28 closed questions) from the Pre-TPACK survey results. Teresa confirmed that all responses were correct. For the technology knowledge questions, Teresa stated that "experiences and practices and learning who to reach out to, and not just giving up" and "I feel like my confidence in learning technology has improved." In response to learning new technology, Teresa stated that "Well, at the beginning of the year, I felt like I didn't know anything." Teresa felt she had increased her knowledge in learning new technology which was evident by her comment "Yes, because I think once I figured out or had you help me learn some of this technology, then I would go in, on my own and play around with it, to see what else I could do with it." Teresa had a decrease in knowledge from the beginning of the semester for the question "I can assess student learning in multiple ways." Her response at the beginning of the year agreed and at the semester it disagreed. Teresa's comment was it is the "virtual environment" and she elaborated by explaining:

I guess if you know if all I get is what they submit and they do not show any work and I can't see what they're doing and they don't come and ask for help, I have no way to know how to help them. I don't know how to reach them in the virtual which is sad but honest.

Figure 48

Participant 1 (Teresa) Pre- and Post-TPACK

F	G	H	I	J	K	L
Please select yes or	I know how to solve	I can learn technolo	I keep up with impo	I frequently play ar	I know about a lot o	I have the technical
yes	Disagree	Neither Agree or Disag	Disagree	Disagree	Disagree	Disagree
Yes	Agree	Agree	Disagree	Agree	Neither Agree or Disag	Neither Agree or Disag

On the survey question that stated "I can choose technologies that enhance the content for a lesson" improved from neither agree or disagree to agree. Teresa stated, "yes and I think part of that comes from the exposure of these different technologies and programs that are out there." On the survey question that stated "I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches" Teresa responded the same neither agree nor disagree at the beginning of the year and semester. She responded, "I think I still need assistance with figuring out what goes together." An open-ended question on the survey asked to "Describe a specific episode where you effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what mathematics was used." Teresa was able to describe an example of combining content, technologies, and teaching approaches unlike her response at the beginning of the year (Table 42). Teresa described a lesson that combined technology, content, and pedagogy whereas at the beginning of the year she stated, "I do not have this experience."

Table 42

Teresa's Pre- and Post-TPACK Lesson Description

Pre-TPACK Lesson Description	Post-TPACK Lesson Description
I have not taught in 5 years, so I do not have this experience.	Slope intercept in Algebra. I taught with notes and students using graphs to find slopes and y-intercepts. I used a DESMOS activity to practice identifying the slopes of lines and their y-intercepts.

The last two optional open-ended questions on the Post-TPACK survey asked: What support has been helpful for you with the integration of technology in secondary mathematics (Optional)? What additional support do you need during the second semester (Optional)? Teresa responded, "Kristen Rojas has been very instrumental in helping me to understand the new technologies and how to integrate them into my virtual teaching." The purpose of these questions was to identify any additional support that occurred throughout the semester and any additional support needed during the second semester.

Paulette

On March 1, 2021, Paulette and I met by Zoom to discuss her Pre- and Post-TPACK survey results. I shared the results of Paulette's Pre- and Post-TPACK Survey using an Excel spreadsheet and sharing my screen in Zoom (Figure 49). We went through all the questions to confirm her responses and provide her an opportunity to elaborate on her thinking. Based on the results of the Pre- and Post-TPACK survey, Paulette demonstrated growth on her Post-TPACK survey by 32% (9 out of 28 closed questions) from the Pre-TPACK survey results. Paulette confirmed that all responses were correct.

Figure 49

Participant 2 (Paulette) Pre- and Post-TPACK

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Please sel	I know ho	I can learn	I keep up	I frequent	I know ab	I have the	I have suf	I can use a	I have var	I know ho	I can adap	I can adap	I can asse	I can use a
Yes	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
Yes	Agree	Agree	Agree	Strongly A	Agree	Strongly A	Strongly A	Strongly A	Agree	Strongly A	Strongly A	Agree	Strongly A	Strongly A

On the survey question that stated "I know how to solve my own technical problems" Paulette's response of "agree" remained the same. Paulette stated that "yes, somewhat now just I feel like with distance learning we pretty much have to do a lot of problem-solving ourselves, so I do a lot of googling, I Google." She also added that her "undergraduate degree is in computer information systems." Paulette demonstrated growth in technology from agree to strongly agree with the statements "I frequently play around with the technology" and "I have the technical skills I need to use technology." She commented that "Yes, definitely it's, the more we do it, you know, the better we get at it, the more comfortable we get at it." Paulette had growth the statements "I have sufficient knowledge of mathematics" and "I can use a mathematical way of thinking" (Table 43). Paulette had the greatest increase in pedagogy and content knowledge which was an area-focused support.

Table 43

Paulette's Pedagogy (PK) and Content (CK) Knowledge

Question	Pre-TPACK	Post-TPACK
I know how to assess student performance in a classroom. (PK)	Agree	Strongly Agree
I can adapt my teaching based upon what students currently understand or do not understand. (PK)	Agree	Strongly Agree
I can assess student learning in multiple ways. (PK)	Agree	Strongly Agree
I can use a wide range of teaching approaches in a classroom setting. (PK)	Agree	Strongly Agree
I have sufficient knowledge of mathematics. (CK)	Agree	Strongly Agree
I can use a mathematical way of thinking. (CK)	Agree	Strongly Agree

Paulette stated, “we've definitely had to figure out ways...you know pretty much the primary way with my population of students, not being willing to, you know, stay on video.” Being able to identify what students understand, Paulette stated “I've definitely just, you know, pulling out the big ideas and when they struggle with it go back and maybe pull a prerequisite skill.” Lastly, Paulette demonstrated growth in the question “I am thinking critically about how to use technology in my classroom” from agree to strongly agree. Paulette stated that she “loves technology” and “always loved using it” in her classroom. She believes “the more confidence we can build in them the better they're going to be and all their education and jobs.”

An open-ended question on the survey asked to “Describe a specific episode where you effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what mathematics was used.” Paulette was able to describe an example of combining content, technologies, and teaching approaches in both Pre- and Post-TPACK (Table 44)

Table 44

Paulette’s Pre- and Post-TPACK Lesson Description

Pre-TPACK Lesson Description	Post-TPACK Lesson Description
This summer I taught Math 7 to a group of students through Google classroom. I had not used a classroom before, so it was fun learning it as I taught the 8-week course. For one lesson on the Law of Large Numbers, students were given a link to a virtual number cube and a .pdf document they opened in Kami to track their rolls. We then combined the data on a group document and noted that experimental probability became closer and closer to matching theoretical for rolling 1-6.	I taught a lesson on solving for a Systems of Equations by graphing using a Desmos activity. In the first few slides, I demonstrated the process for plotting the two equations by hand and finding the intersection (solution) and students had a couple to do independently. Then in the later slides, I embedded the Desmos graphing calculator so students could experience entering the equations and seeing the intersection point. Students could verify their accuracy for the systems solved by hand with the Desmos app's solution.

The last two optional questions on the Post-TPACK survey asked:

> What support has been helpful for you with the integration of technology in secondary mathematics? (Optional)
>
> What additional support do you need during the second semester? (Optional)

Paulette's response was to continue using training opportunities with Desmos activities' computation layer, more on the Desmos Geometry tools, and engaging ideas for Algebra Function Data Analysis (AFDA) students.

Annie

On March 17, 2021, Annie and I met in Zoom to discuss her Pre- and Post-TPACK survey. I shared Annie's Pre- and Post-TPACK Survey using an Excel spreadsheet and sharing my screen in Zoom (Figure 50).

Figure 50

Participant 3 (Annie) Pre- and Post-TPACK

Please select yes or	I know how to solve	I can learn technolo	I keep up with impo	I frequently play ar	I know about a lot o	I have the technical
Yes	Disagree	Agree	Disagree	Disagree	Strongly Disagree	Agree
Yes	Agree	Strongly Agree	Agree	Agree	Neither Agree or Disag	Strongly Agree

We went through all the questions to confirm her responses. The researcher provided her an opportunity to elaborate on her thinking. Based on the results of the Pre- and Post-TPACK survey, Annie demonstrated growth on her Post-TPACK survey by 36% (10 out of 28 closed questions) from the Pre-TPACK survey. Annie confirmed that all responses were correct. For technology and technological pedagogical knowledge, Annie demonstrated the most growth (Table 45).

Table 45

Annie's Technology (TK) and Technological Pedagogical Knowledge (TPK)

Questions	Pre-TPACK	Post-TPACK
I know how to solve my own technical problems. (TK)	Disagree	Agree
I can learn technology easily. (TK)	Agree	Strongly Agree
I keep up with important new technologies. (TK)	Disagree	Agree
I frequently play around with technology. (TK)	Disagree	Agree
I know about technologies that I can use for understanding and doing mathematics. (TPK)	Disagree	Agree
I have the technical skills I need to use technology. (TK)	Agree	Strongly Agree
I know about a lot of different technologies. (TK)	Strongly Disagree	Neither Agree or Disagree

Annie stated, "That with more practice and working with it, I got more comfortable with it." She also demonstrated growth with the statement "I can adapt my teaching based upon what students currently understand or do not understand and I can adapt my teaching style to different learners." Her comment was "Yeah. I didn't know at the beginning of the year. This, virtual learning was, made me a little bit nervous. …I can do it now." There was one statement that Annie demonstrated a decline: "I know how to organize and maintain classroom management." Annie compared her one year of experience with teaching virtual:

> Yeah. 'Cause I thought from a traditional school, with my experience, I felt I could, but with being online, and trying to get everybody on board, and doing what they need to be doing when I need them to do it. It was, it's been challenging, virtually. So, for the ones that, I have a handful that I have no problems with, but then I have those that it's like, are you there? Hey, what's going on? I need to click this link, click this link, click this link.

> But the fact that I'm not in front of them is out of my control, so I feel like that's what affects my classroom management. That's not being able to make sure I can get everybody on board.

Annie explained that not being able to make sure everyone understands what to do has made teaching in a virtual environment difficult. There were two more questions that Annie demonstrated growth which included, "I can provide leadership in helping others to coordinate the use of the content, technologies, and teaching approaches at my school and/or district" and "I can choose technologies that enhance the content for a lesson."

An open-ended question on the survey asked respondents to "Describe a specific episode where you effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what mathematics was used." Annie was able to describe examples of combining content, technologies, and teaching approaches (Table 46).

Table 46

Annie's Pre- and Post-TPACK Lesson Description

Pre- TPACK Lesson Description	Post-TPACK Lesson Description
I have taught/supported math special education for grades 5-8. I have used IXL, Khan Academy, and Moby Max. I have used IXL to target a specific topic I noticed the student struggled with and assigned problems for them to complete to help them practice those skills. I would explain the topic in a certain way and IXL would explain the topic, so the student would have different strategies to use.	I have used Desmos when teaching writing linear equations for my algebra class. I often use the I do, we do, you do method when teaching. I modeled how to write equations when given a set of points. The use of Desmos allowed me to see how the students found the slope and ultimately the equation to the points given. I also used computational layers to allow Desmos to give the students feedback on the answers they submit.

The last two optional questions on the Post-TPACK survey asked:

> What support has been helpful for you with the integration of technology in secondary mathematics? (Optional)
>
> What additional support do you need during the second semester? (Optional)

Annie stated, "I have been meeting with Kristin Rojas (Researcher) and Sara (pseudonym for mentor) from the county to help me learn the technology, content, and how to best use it in class." Annie received support from her mentor and the math specialist for secondary mathematics (Researcher) during 2020-2021. She also participated in new teacher induction training sessions with the researcher and secondary coordinator for mathematics.

Catherine

On March 22, 2021, Catherine and I met in Zoom to discuss her Pre- and Post-TPACK survey results. I shared Catherine's Pre- and Post-TPACK Survey using an Excel spreadsheet and sharing my screen in Zoom (Figure 51). We went through all the questions to confirm her responses. The researcher provided her an opportunity to elaborate on her thinking. Catherine demonstrated growth on her Post-TPACK survey by 64% (18 out of 28 closed questions) from the Pre-TPACK survey results. Catherine confirmed that most of her responses were correct. The areas of greatest growth were content and technological pedagogy knowledge. She indicated that four of the statements from the Post-TPACK survey should be changed (Table 47).

Figure 51

Participant 4 (Catherine) Pre- and Post-TPACK

Please select yes or	I know how to solve	I can learn technolo	I keep up with impc	I frequently play ar	I know about a lot o	I have the technical	I have sufficient kn
Yes	Disagree	Agree	Neither Agree or Disag	Agree	Disagree	Neither Agree or Disag	Agree
Yes	Agree	Agree	Agree	Agree	Neither Agree or Disag	Agree	Strongly Agree
					agree	strong agree	

Table 47

Catherine's Changes to Responses

Questions	Pre-TPACK	Post-TPACK	NEW Responses Post-TPACK
I know about a lot of different technologies.	Disagree	Neither Agree or Disagree	Agree
I have the technical skills I need to use technology.	Neither Agree or Disagree	Agree	Strongly Agree
My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom.	Agree	Agree	Strongly Agree
I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches.	Agree	Agree	Strongly Agree

On the statement, "I know about a lot of different technologies," Catherine stated she would change it to "I agree." For the statement that said, "I have the technical skills I need to use technology," Catherine stated that she would change it to "strongly agree." For the statement, "My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom," she changed her response to "strongly agree." Catherine explained her thinking:

> Well, as I have grown over the past 20 years, I have incorporated technology in my lessons, whereby it helps the kids more so than anything. Because I've come on board in this climate that we're in now, I have incorporated more technology, and the kids have grasped it… The learning environment prepares... Because see, back in 2000, when I went back and got my BS in Mathematics and my Master's in Mathematics in 2004... I

> believe was 2007... They were not using as much technology as we are nowadays, but now we're using more technology incorporated in our lesson plans…. The only thing that they were concerned about, I said... Texas Instrument, that graphing calculator like that. But now we're able to teach virtually with more technologies. So, I can say because of the learning environment, that we're in now, has helped me to incorporate more technology.

Catherine considers that her experiences in teaching have caused her to think more deeply about technology and how it influences the teaching approaches that she uses within her classroom. The last response that Catherine changed from "agree" to "strongly agree" came from the statement "I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches." Catherine elaborated:

> I feel that my pedagogy has really developed this year by using technology in the classroom a little more often. And the type of technology that we're using now has really enhanced the students' learning as well as mine. I'm just excited.

Catherine expressed that she strongly agreed now because "I have graduated!"

An open-ended question on the survey asked "Describe a specific episode where you effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what mathematics was used." Catherine was able to describe examples of combining content, technologies, and teaching approaches (Table 48). In Catherine's Pre-TPACK lesson, she described several technology software programs whereas on the Post-TPACK response, she described the type of technology and how students would use the technology to demonstrate their understanding of mathematics. Catherine stated that she used the Desmos Graphing Calculator and Desmos Activities to "engage" students and allow them to "demonstrate and model their understanding of mathematical concepts" for slope, slope-intercept form, scatter plots, and regressions.

Table 48

Catherine's Pre- and Post-TPACK Lesson Description

Pre-TPACK Lesson Description	Post-TPACK Lesson Description
In past years, I have used Kahoot, Jlabs, and Google Classroom as teaching strategies. By using Kahoot, it allowed the students to work collaboratively in groups to sharpen their skills. I used J-labs as a form of reinforcing skills and assessment. PowerPoint Presentations were uploaded via Google Classroom. I have used the document camera to display math warm-up exercises and various mathematical documents. I utilized the SmartBoard as a teaching tool. I even have my YouTube account: Teaching Math still up and running which allowed students to view extra teaching.	When we use the Desmos Graphing Calculator and the various Desmos Activities, the students can engage, demonstrate and model mathematical concepts. We have used the Desmos Graphing Calculator to demonstrate slope, slope-intercept form and, the students have used Desmos to determine the line of best fit--scatter plots and regression.

The last two optional questions on the Post-TPACK survey asked:

> What support has been helpful for you with the integration of technology in secondary mathematics? (Optional)
>
> What additional support do you need during the second semester? (Optional)

"Rojas, (Researcher), has been very helpful working with the Pre-AP Algebra I CLT. Rojas and I have been co-teaching using technology (Desmos Graphing Calculator) in the classroom. By having her as a co-teacher, she helped me incorporate/integrate technology within my lesson plans." As noted by Catherine, the researcher co-taught nine classes with Catherine to build her confidence in incorporating and integrating technology and those classes were documented as training sessions to support her learning. The observation data were collected only when Catherine taught the lesson.

Karl

On March 24, 2021, Karl and I met in Zoom to discuss his Pre- and Post-TPACK survey results. I shared Pre- and Post-TPACK Survey using an Excel spreadsheet and sharing my screen in Zoom (Figure 52). We went through all the questions to confirm his responses and the researcher provided him an opportunity to elaborate on his thinking. Based on the results of the Pre- and Post-TPACK survey, Karl demonstrated growth on his Post-TPACK survey by 14% (4 out of 28 closed questions) from the Pre-TPACK survey results. There were two questions that Karl decreased his knowledge on the closed questions which was a 7% (2 out of 28 closed questions) decline. Karl confirmed that all responses were correct. Karl has a background in technology, and he likes to learn new things on his own. In response to “I know how to solve my technical problems,” there was no change. This is evident by his comment:

> I'm a certified Apple teacher, so I like to problem solve and I don't like to ask right away. It's kind of a pet peeve of mine when teachers ask too early. So, I try and figure it out on my own. And so, I think I, except this single code, with this code. But we've been doing it for a month. So, I think I can ask that one question, but I don't have a problem doing that stuff.

Figure 52

Participant 5 (Karl) Pre- and Post-TPACK

Please select yes or	I know how to solve	I can learn technolo	I keep up with impo	I frequently play ar	I know about a lot o	I have the technical	I have sufficient kn	I can use a mathem
Yes	Agree	Agree	Agree	Agree	Neither Agree or Disag	Agree	Strongly Agree	Agree
Yes	Agree	Agree	Agree	Agree	Neither Agree or Disag	Agree	Agree	Strongly Agree

In response to the statement, “I can learn technology easily” there was no change from the beginning of the year to the semester. Karl stated:

> Yeah, I had never done Canvas until August and I read some things about it, I watched a lot of YouTube, which I kind of used to make fun of kids for watching YouTube on how to learn things. And I attended all of “Instructional Technology Coach”, preschool things. I didn't miss one. Going back, I probably shouldn't have gone to all of them because they were so overwhelming, but I just listened and watched and learned.

Karl also stated, “Yeah, to me my new technology was Canvas, was Desmos, was Nearpod. I had not done any of those before.” The statements that Karl demonstrated growth in are noted in Table 49.

Table 49

Karl’s TPACK Growth

Questions	Pre-TPACK	Post-TPACK
I can use a mathematical way of thinking.	Agree	Strongly Agree
I know how to organize and maintain classroom management.	Neither Agree Or Disagree	Agree
My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom.	Disagree	Neither Agree or Disagree
I can use strategies that combine content, technologies, and teaching approaches.	Disagree	Agree

Karl stated that he was “More comfortable” and that his education program was more than an undergraduate degree that assisted with his knowledge of technology:

> The education program was back in the nineties, early nineties, there wasn't much technology. So that's why I disagreed at the time. And then I thought later that, well, it was more than just my undergrad degree that I had. And when I was my graduate, we did technology. So, I waffled.

Karl felt that having more options with technology and being able to teach content improved his approach to teaching and learning within his classroom. He stated:

> I remember that one. I didn't think at the beginning of the year I had choices. I thought I had to use certain like things that were given to me, so I wasn't selecting anything. And then I found out very quickly, you can use what you want.

The two statements that Karl decreased were "I have sufficient knowledge about mathematics" and "I can adapt my teaching based upon what students currently understand or do not understand." His reasoning was "It's just figuring out all of the ways that the kids could do it and didn't do it the right way, even though it's not the way I would teach." Karl expressed that his collaborative learning team did not teach Desmos Graphing Calculator, so it was difficult to teach transformations in a virtual setting.

The last two optional questions on the Post-TPACK survey asked:

> What support has been helpful for you with the integration of technology in secondary mathematics? (Optional)
>
> What additional support do you need during the second semester? (Optional)

"My CLTs have been amazingly helpful. I cannot think of anything. My supervisor is extremely supportive and helpful."

Lastly, an open-ended question on the survey asked "Describe a specific episode where you effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what mathematics was used." Karl was able to describe examples of combining content, technologies, and teaching approaches (Table 50)**.**

Table 50

Karl's Pre- and Post-TPACK Lesson Description

Pre-TPACK Lesson Description	Post-TPACK Lesson Description
I taught a College Algebra lesson with 12th-grade students with multiple skill backgrounds in math. For all students to succeed, I grouped students by level to give direct instruction to them based on their knowledge. Secondly, I then moved the students where groups were "mixed by ability". I challenged each group with a problem and asked them to help each other before coming to the front of the classroom to present and explain their solution. Students were using an app called Explain Everything which allowed them to use technology and "mirror" their work to my screen in the front of the class. This activity allowed students to teach other students while I assisted and monitored their progress. I noticed the struggling students listening to the other students and learning from them.	In addition to Desmos, which most students find fascinating... I have used breakout rooms. Their task, for example, was to make a digital bulletin board explaining a certain math concept discussed in class. I enjoy having other students explain how to solve a problem and watch them use technology as well. It is good for students to hear more than my voice. I move from breakout room to breakout room to help students.

In summary, 80% of participants (4 out of 5) confirmed that their responses were correct and that they did not want to make any changes. Catherine wanted to make changes to four of her responses to reflect her TPACK knowledge. Based on the unchanged data results from the TPACK survey, Karl had the least amount of growth and the smallest percent of change in the average TPACK score.

Part 4: Amount of Individualized Support and Training

When considering the amount of individualized support, the researcher used the total time she worked with individual participants on planning and implementation of the integration of technology within the content area in which they teach. The amount of time spent on pedagogy was also tracked. Table 51 provides the number of individualized support hours provided for each participant in the study and the amount of growth that occurred between the Pre- and Post-TPACK surveys.

Table 51

Individualize Support Hours and Amount of Growth on TPACK Survey

Teresa	Paulette	Annie	Catherine	Karl
46 hours	20 hours	18 hours	47 hours	4 hours
0.59 TPACK	0.26 TPACK	0.60 TPACK	0.57 TPACK	0.05 TPACK

The mean of individualized support was 27 hours with a standard deviation of 18.84. The mean amount of growth in the difference between Pre- and the Post-TPACK survey was 0.4140 with a standard deviation of 0.2405 (Table 52). Regression on the Amount of TPACK Growth *(outcome)* to the time spent on individualized support *(predictor)* had a suggested moderate positive impact on TPACK growth indicated by a Pearson correlation of r = .762 (Figure 53).

Table 52

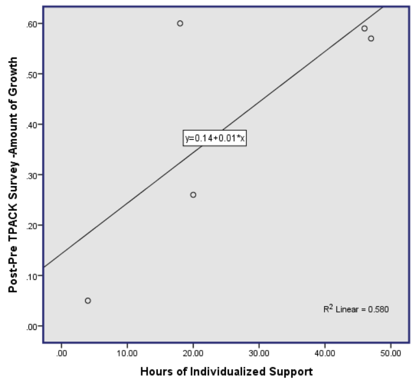
Descriptive Statistics

	Mean	Std. Deviation	N
Hours	27.0000	18.84144	5
Difference	.4140	.24805	5

Note: Resource recorded hours of support.

Figure 53

Individualized Support and Amount of TPACK Growth



When comparing the amount of support using the TPACK model during planning and implementation to the growth of the Post-TPACK survey, all participants demonstrated overall growth in TPACK knowledge through individualized support (Table 53). Only one non-participant demonstrated growth in TPACK knowledge during the first semester. The data in Table 53 indicate there was a change in knowledge for the participants who had individualized support using the TPACK model during planning and implementation.

Table 53

Participants and Non-Participants Pre- and Post-TPACK Survey Scores and Hours of Support with the TPACK Model

Participants (P) and Non-Participants (NP)	Pre-Score	Post -Score	Difference	Number of hours for Individual Support with TPACK
P1	3.11	3.70	0.59	42
P2	3.98	4.24	0.26	20
P3	3.43	4.03	0.60	18
P4	4.09	4.66	0.57	47
P5	3.96	4.01	0.05	4
NP6	3.73	3.61	-0.12	0
NP7	3.57	3.56	-0.01	0
NP8	4.02	4.45	0.43	0
NP9	4.83	4.28	-0.55	0

The key findings for qualitative data were aligned with quantitative growth in TPACK knowledge on the Post-TPACK survey (Appendix O). The initial area of support was identified from the Pre-TPACK survey to provided intervention and customized support. Based on the Post-TPACK survey for each participant, the intervention was impactful. The participants demonstrated growth in all areas of identified support within the first semester. The triangulation of the multiple data points supported the findings (Appendices N and O).

Part 5: Triangulation

According to Patton (2015), four types of triangulations can be done in an evaluation: 1) data sources, 2) different investigators, 3) theory triangulation within the same data set, and 4) methodological triangulation. For this study, the researcher used data sources for triangulation which included observations, semi-structured interviews, member checks, field notes, artifacts, and surveys to converge the five key findings. These key findings that addressed research question two on the essential characteristics of integrating technology, pedagogy, and content knowledge that is formed during planning and implementation converged with quantitative data to address research question one on the impact of individualized support on newly hired secondary mathematics teachers.

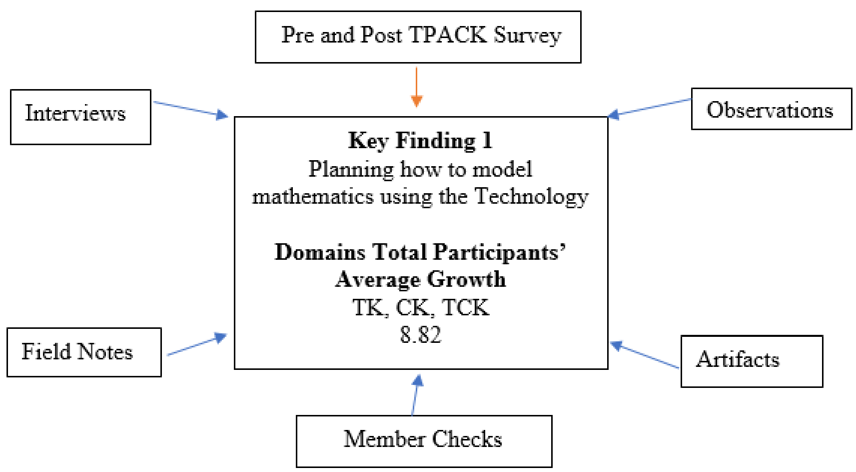
Key Finding 1 Convergence Evidence

The first key finding was planning how to model mathematics using technology (Figure 54). The data came from the four participants within the study which included interviews, observations, field notes, artifacts, member checks, and surveys. Three domains aligned with the first key finding: technology knowledge (TK), content knowledge (CK), and technological content knowledge (TCK). Within the TCK domain survey, question number eighteen stated "I know about technologies that I can use for understanding and doing mathematics." Within the

CK domain survey, question number eight stated "I can use a mathematical way of thinking." Within the TK domain survey, question number five stated "I know about a lot of different technologies." The total participants' average growth in the study which included the CK, TK, and TCK domains was 8.82 (Appendices N and O).

Figure 54

Key Finding 1 Convergence Evidence



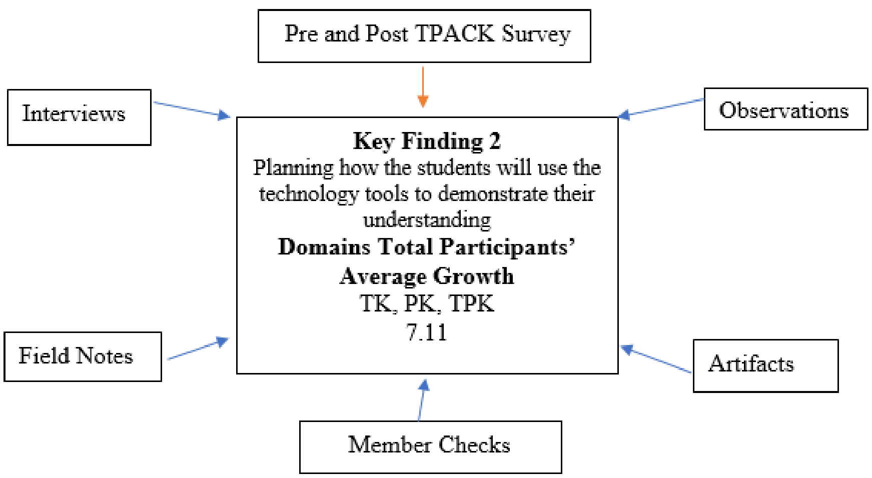
Note: Resource modified figure from Yin (2018) Convergence of Evidence (p.129).

Key Finding 2 Convergence Evidence

The second key finding was planning how students will use the technology tools to demonstrate their understanding (Figure 55). The data came from the five participants within the study which included interviews, observations, field notes, artifacts, member checks, and surveys. Two domains aligned with the second key finding: technology knowledge (TK), pedagogical knowledge (PK), and technological pedagogical knowledge (TPK). Within the TPK domain survey, question number twenty-two stated "I am thinking critically about how to use technology in my classroom." Within the TK domain survey, question number five stated "I know about a lot of different technologies." Within the PK domain survey, question number fifteen stated, "I am familiar with common student understandings and misconceptions." The total participants' average growth in the study which included the TK, PK, and TPK domains was 7.11 (Appendices N and O).

Figure 55

Key Finding 2 Convergence Evidence



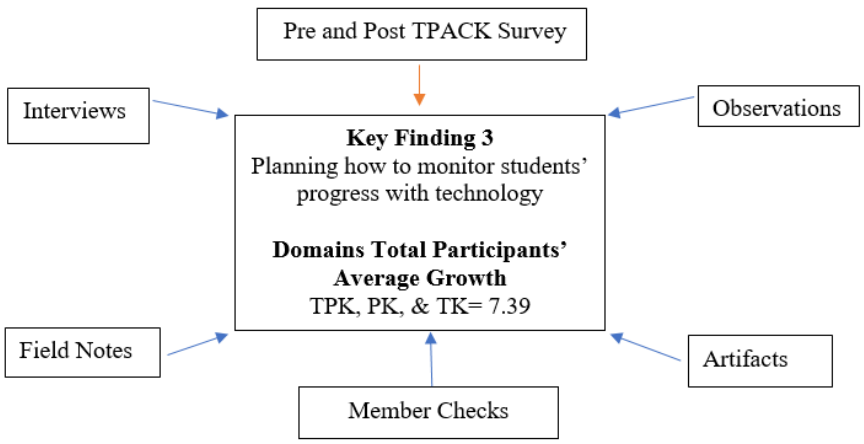
Note: Resource modified figure from Yin (2018) Convergence of Evidence (p.129).

Key Finding 3 Convergence Evidence

The third key finding was planning how to monitor students' progress with technology (Figure 56). The data came from the five participants within the study which included interviews, observations, field notes, artifacts, member checks, and surveys. Three domains aligned with the third key finding: technological knowledge (TK), technological pedagogical knowledge (TPK), and pedagogical knowledge (PK). Within the TPK domain survey, question number nineteen stated, "I can choose technologies that enhance the teaching approaches for a lesson." Within the TK domain survey, question number six stated "I have the technical skills I need to use technology." Within the PK domain survey, question number ten stated "I know how to assess student performance in a classroom." The total participants' average growth in the study which included the PK, TK, and TPK domains was 7.39 (Appendices N and O).

Figure 56

Key Findings 3 Convergence Evidence



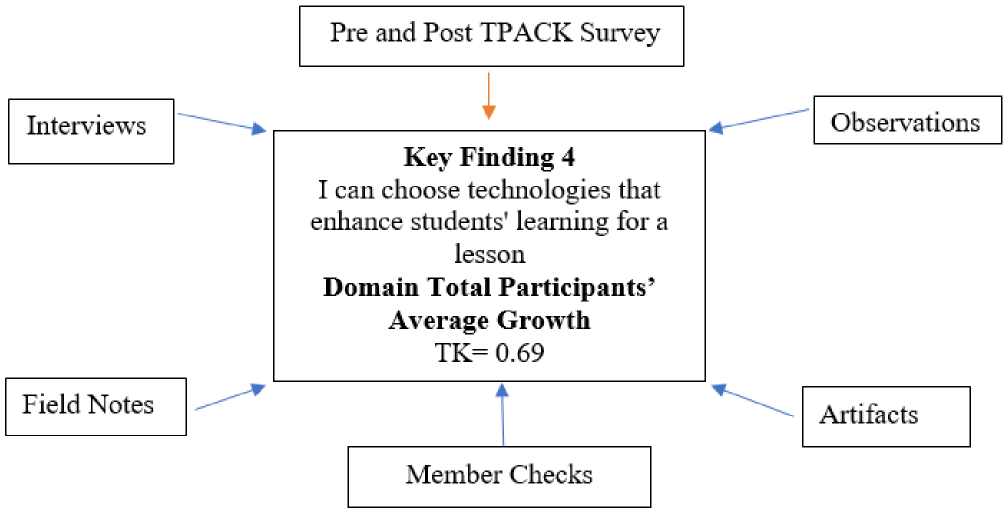
Note: Resource modified figure from Yin (2018) Convergence of Evidence (p.129).

Key Finding 4 Convergence Evidence

The fourth key finding was planning which technology can be used to enhance student learning (Figure 57). The data came from the five participants within the study which included interviews, observations, field notes, artifacts, member checks, and surveys. There was one domain that aligned with the fourth key finding: technological pedagogical knowledge (TPK). Within the TPK domain survey, question number twenty stated, "I can choose technologies that enhance students' learning for a lesson." The total participants' average growth in the study which included the TPK domain was 0.69 (Appendices N and O).

Figure 57

Key Findings 4 Convergence Evidence



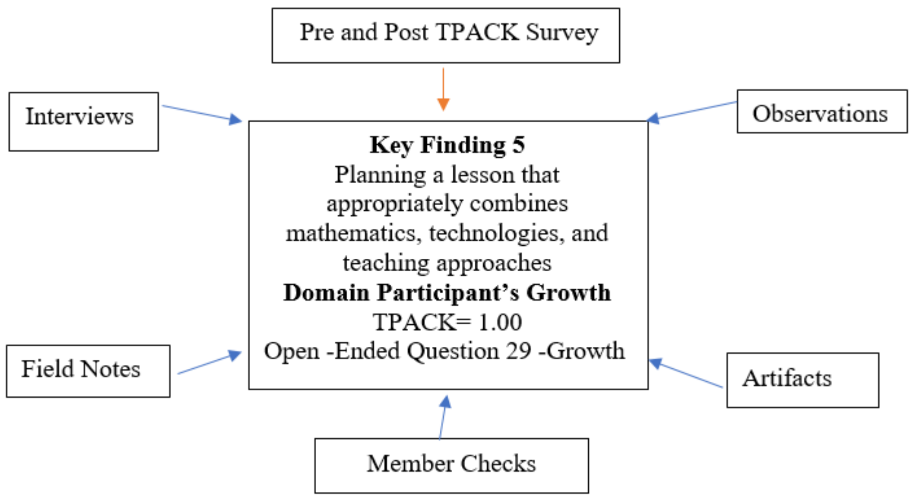
Note: Resource modified figure from Yin (2018) Convergence of Evidence (p.129).

Key Finding 5 Convergence Evidence

The fifth key finding was planning a lesson that appropriately combines mathematics, technologies, and teaching approaches (Figure 58). The data came from the five participants within the study which included interviews, observations, field notes, artifacts, member checks, and surveys. There was one domain that aligned with the fifth key finding: technological, pedagogical, and content knowledge (TPACK). Within the TPACK domain survey, question number twenty-eight stated, "I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches." The total participant's average growth in the study which included the TPACK domain was 1.00 (Appendices N and O). There was only one participant on the survey that demonstrated growth on the closed question, but all participants were able to describe lessons that combine TPACK.

Figure 58

Key Findings 5 Convergence Evidence



Note: Resource modified figure from Yin (2018) Convergence of Evidence (p.129).

Chapter Five Summary

The participants in the case study demonstrated an increase in their TPACK knowledge with individualized support planning sessions based on interviews, observations, field notes, artifacts, and survey results. The key findings for the essential characteristics of planning and implementation of technology integration included: (1) planning how to model mathematics using the technology, (2) planning how the students will use the technology tools to demonstrate their understanding, (3) planning how to monitor students' progress with technology, (4) planning which technology can be used to enhance students learning, and (5) planning a lesson that appropriately combines mathematics, technologies, and teaching approaches. Additional findings surfaced during the research based on the strategies used during training and support for planning and implementation of technology sessions. Four findings supported the planning and implementation of technology in which field notes and artifacts were used to confirm the findings: (1) modeling how to use the technology, (2) modeling how to create lessons with technology, (3) using content-related examples, and (4) a discussion on how students will demonstrate their understanding of the content with technology.

CHAPTER 6

DISCUSSION AND RECOMMENDATIONS

This chapter provides an overview of the findings aligned with prior research and contextual information. The implications to this study are described in relation to the literature and to teachers' training models and mentoring. Finally, the primary contributions of this study are presented along with suggestions for future research using the TPACK model.

Implications of TPACK Survey to Identify Areas of Support

The first implication for this case study involves using the TPACK survey to differentiate and customize training for teachers by identifying areas of support. Based on prior research, Niess et al. (2009) conducted a study on in-service teachers to determine the impact of a week-long professional development of teachers' TPACK knowledge and used the different stages of accepting or rejecting technology which included recognizing, accepting, adapting, exploring, or advancing. In this research, participants' TPACK knowledge was assessed at the beginning of the school year, followed by providing resources and individualized support that was customized at each stage. The researcher provided direct training on technologies that were differentiated based on the needs of the teacher. As Teresa stated in her confirmation interview on the Pre- and Post-TPACK surveys, "Well, in the beginning of the year, I felt like I didn't know anything." This was in contrast to Paulette's statement that she "loves technology" and "always loved using it" in her classroom. These teachers were at different stages of recognizing, accepting, adapting, exploring, and advancing which impacted the type of technology support needed. Teresa had not taught in five years, so she was unfamiliar with technological tools like Desmos and had not used technology activities as part of her instruction. Differentiating and customizing teachers' training, similar to the Just-In-Time model which provides teachers with strategies for implementation that corresponds to the needs within the contextual environment (Beckett, 2000), was evident in supporting this study's new teaching hires. Based on the identified area of customized support for all participants at the beginning of the year, participants' TPACK knowledge improved on the post-survey. The amount of support varied widely depending on the needs of each individual teacher.

Limitation of TPACK Survey

The limitations of using the TPACK survey in this study included aspects of the history, maturation, regression, selection, mortality, and diffusion of treatment (Creswell, 2009). The history of this case study was that it was carried out during a worldwide pandemic and a time of uncertainty in education. This pandemic uprooted traditional teaching and forced experienced and novice teachers out of their familiar teaching practices. Initially the untraditional teaching could be viewed as a limitation, but it became an opportunity to investigate an innovative approach for supporting all newly hired secondary mathematics teachers. The survey provided an opportunity for teachers to participate in support with the integration of technology using the TPACK framework. The invitation to participate in this study resulted in some teachers who completed the TPACK surveys but did not engage in the individualized support. Likewise, this case study had a group of teachers who completed the surveys and received individualized support intervention with TPACK. If teachers had less than a year of experience, they were assigned a formal mentor and received pedagogy training with content at the division level. Teachers who had more than one year of experience received an informal mentor to provide support as needed.

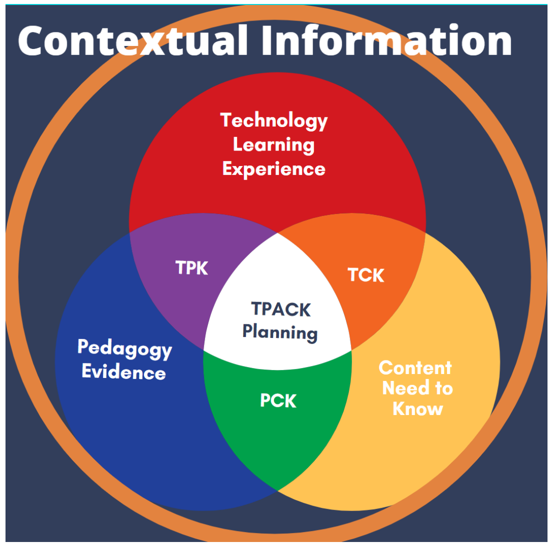
Maturation occurs when participants' experiences change during the study (Creswell, 2009). The study consisted of a diverse group of teachers with various backgrounds, experiences, and education levels. Regression can occur for participants who have extreme scores, and it was noted previously that two nonparticipants performed opposite in growth and decline. Nonparticipant number eight revealed on the open-ended questions "working with my mentor, has been the greatest support." Nonparticipant eight was the only teacher that demonstrated growth from the nonparticipant group. Nonparticipant nine rated her TPACK knowledge at the beginning of the year the highest of all nonparticipants and participants in the study. There were no participants who dropped out of the case study with support and 100% of participants completed the pre-and post-survey. It should be noted that diffusion of treatment can occur when participants communicate with each other (Creswell, 2009), but since all support was individualized using Zoom, there was no issue with participant diffusion.

Implications of Using TPACK Model for Virtual Planning

Teachers must plan for instruction with the integration of technology and reflect on the implementation of the technology and how it supported student learning and misconceptions. Using the TPACK model as a planning framework for unpacking technology to enhance teaching and learning was critical to this study. Utilizing the school district curriculum units of study that consist of a framework of the three stages of *Understanding by Design Process* (Wiggins & McTighe, 2005), along with the TPACK model and planning interview questions, participants designed and implemented lessons that integrated technology. The combination of TPACK and units of study generated a TPACK Design Process Model. This TPACK Design Model identified what students needed to know content-wise, what was the evidence, and what was the technology learning experiences along with the contextual information that encompassed the learning environment (Figure 59).

Figure 59

TPACK Design Process Model



Note. Modified diagram based on TPACK model and Understanding by Design Process.

Technological and content knowledge interaction occurred when the teacher modeled what students needed to know and provided the learning experiences using technology. Technological and pedagogical knowledge interaction occurred when the teacher planned how the students would demonstrate their knowledge of mathematics using technology. Another interaction with technological and pedagogical knowledge occurred when the teacher monitored students on the Desmos activity dashboards and provided feedback to students using computational layers. The use of the technology provided evidence for the teacher and students on learning mathematics. The last interaction with pedagogical and technological knowledge occurred when participants planned the use of technology based on prior formative assessments and used technology to confirm solutions as a method of enhancing student learning. The final key finding with essential characteristics of planning and implementing technology was combining appropriate technology, content, and pedagogy. This was a combination of knowing the content and what students need to know, knowing the pedagogy of identifying the evidence of student learning, and knowledge of technology to enhance the learning experiences.

The Implication with Contextual Knowledge in Virtual Classroom

Knowing how technology can be used to build on prior knowledge to develop new epistemologies or enhance existing knowledge is critical in the interactions with content and pedagogical techniques (Koehler & Mishra, 2009). Each teacher has a different learning environment within the interactions of TPACK components. Therefore, one must consider contextual knowledge when planning and implementing the use of technology within a classroom.

In this study, the researcher provided support that was individualized to meet the needs of the teachers within the content area that they teach, the strategies of knowing how to teach their students with technology integration. The researcher and participants had to consider the type of lesson that was to be planned and whether it was asynchronous or synchronous. Likewise, one had to know if the lesson was introducing, developing, practicing, or applying. Identifying characteristics of each class as plans were developed for instruction also needed to support all learners and provide equity access to the content and use of the digital tools. This was evident as Paulette planned her asynchronous lesson for students by including review videos of prior geometry concepts that were learned in a previous mathematics course. Knowing the contextual environment of her school having a high percentage of chronic absenteeism rate of 68.9%, Paulette wanted to ensure students were able to access prior knowledge of concepts needed for new learning. She provided detailed directions and examples for the practice problems on angle and side relationships within a triangle. In her synchronous lesson, which was an introduction lesson, Paulette modeled the use of digital tools to measure angles formed by parallel lines and a transversal then scaffolded the content when adding a second transversal. Knowing that her students needed extra support with technology and content, Paulette created an equitable learning environment that provided opportunities for students to be successful in identifying and making connections among angles.

Implications of Comprehending Technology

Based on Rogers' (1995) model on the diffusion of innovations, there are five stages in adopting and rejecting technology in teaching and learning. These stages include recognizing, accepting, adapting, exploring, and advancing. This study aided teachers in recognizing and accepting technology. If teachers do not know how to use the technology for designing and implementing lessons, then they will not use it, or the lesson will not go as planned. This was evident with Karl implementing a Desmos activity for the first time with his classes. Karl did recognize the new technology, accept the technology, and adapt to engage in planning to use the new technology, but did not have time to fully explore and advance the technology. There was confusion on whether to use a single session code or class code. Because the students did not have accounts with Desmos, the class code was not the best option. Karl and I had to meet again for clarification on implementation using Desmos activities. All the other participants were able to successfully launch their lesson with technology because we practiced and generated the single session code during the co-planning session. Two out of the five requested for the researcher to be present during the first launch of a new technology activity to help assist with any technology issues. For technology to be integrated effectively, teachers need to fully comprehend all aspects of the technology which include the design and implementation process. Knowing how to use the technology and how to create lessons with the technology using content examples along with discussing how the students will interact with the technology to demonstrate their understanding was important to the teachers. As noted by Knowles (1988), adult learners desire immediate application of new learning. During the 2020-2021 pandemic school year, this immediate need to know and understand technology became imperative.

The Implication of Software and Lesson-Focused Support

According to Harris et al. (2009), there are five models of professional development with technology. These models are software-focused, use of sample lessons, technology-based educational reform efforts, standardized professional development workshops, or technology-focused teacher education courses (Davies & West, 2014). In this study, the researcher used a software-focused model by collaborating with the participant to identify what type of technology would enhance teaching and learning. The study was a lesson-focused design to customize lessons to meet the needs of teaching and learning based on the contextual environment. Harris, et al. (2009) noted that there is not enough evidence to conclude these models improve learning outcomes. Most training for teachers measure the effectiveness of the professional development and desired objectives of the professional development. Based on the findings from the study, when training and support were customized to meet the needs of the teachers in a virtual learning environment, the outcome had a positive impact on implementation. When considering the type of support given within this study using software and lesson-focused design, the TPACK model supported the learning outcomes.

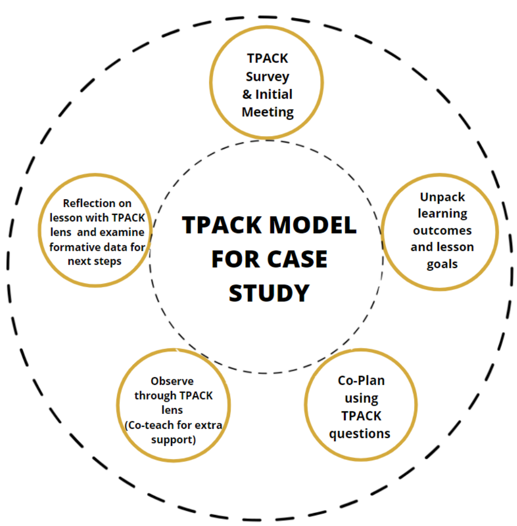
Implications of Virtual Professional Development with TPACK Model

The fourth implication of this study was professional development using the TPACK model when supporting teachers during planning and implementation of technology using the TPACK framework. According to the National Center for Education Statistics (NCES), to maintain a sustainable workforce of new teachers, there needs to be ongoing professional development with mentoring by their teaching peers (NCES, 2011). The NCES study found that when allowed to reflect, novice teachers were more concerned with the planning and implementation of the lesson than effective strategies. This study found that teachers were able to successfully implement their lessons when a trainer or mentor supported new teachers with co-planning lessons. An opportunity to improve new teachers' practice in action and for them to learn from their mistakes with a supportive culture of educators may aid in a sustainable workforce.

Additionally, the methods used in this research are like a consultant and collaborative model by Idol et al. (1995) and an instructional model from Rosenfield et al. (2008). As the researcher worked with individual teachers, different strategies were used. For all participants, the researcher used the TPACK survey to diagnose teacher's needs which included content, pedagogy, and technology. The researcher used questions and paraphrasing for understanding. Goals were created with participants to target the desired learning outcomes. These and other diagnostic areas of support in technology, content, and pedagogy provided to participants are illustrated in Figure 60.

Figure 60

TPACK Model for Case Study



Implications of Post Survey Interviews on Findings

By implementing a follow-up interview from TPACK surveys, the information collected provided deeper insight by identifying and confirming the responses of each participant in the study. There have been prior studies that have used TPACK to identify where participants are with their understanding. According to Yin (2018), using the convergent evidence of multiple data sources, “strengthens the construct validity” (p.128) of the case study. This method of triangulation “increases the confidence” and the “accuracy of the event” (p.129). In this mixed-methods case study with an intervention, the researcher used multiple data sources and member checks to converge on the key findings.

All participants learned how to use technology such as the teacher dashboard in Desmos activities. Discussions with participants encompassed how to use the pausing and pacing features as well as strategies suggested by Smith et al. (2020). These strategies consist of anticipating student’s responses, monitoring student work, selecting student work, sequencing student solutions, and connecting student solutions. Based on the pre-survey results, individual participants needed customized training with knowing how the technology can be used to monitor student progress, pedagogy support on how to support individual needs of students with misconceptions, along with the intersection of the domains to combine the technological and pedagogical knowledge need for implementation. Therefore, the findings from both the qualitative and quantitative data converged to confirm the findings.

Summary of Key Implications

As noted in Merriam and Bierema (2014) research, adult learners value the connection between experience in new learning. To bridge the gap between theory and practice, adult learners need personalization when trying something new and an expert's support. According to

Knowles (1984), adult learning is optimal when the learner is involved in the learning process, including diagnosing, planning, implementing, and evaluating their understanding. All participants and nonparticipants were provided professional development at the division level at the beginning of the year. This study provided participants and nonparticipants an opportunity to identify their support areas through a pre-survey. Those who chose to participate in the study used the TPACK framework during planning sessions with the researcher then implemented technology during instruction to enhance student learning. As noted in chapter two, pedagogical and technological knowledge requires seeking the appropriate technology to maximize student learning (Bos, 2011). The interaction of technology, pedagogy, and content consists of a lesson design for technology learning mathematics (Niess, 2008; Thompson & Mishra, 2007). After the end of a semester, participants and nonparticipants evaluated their learning with a post-survey and then there was a reflection interview with participants. This study confirmed the findings of Polly (2011) that teachers need to know how to apply TPACK when planning and implementing a lesson using technology. Using the TPACK framework with the integration of technology, pedagogy, and content-specific lessons improved adult learning through the immediate application of new learning and increased their knowledge in identified support areas. The key implication was personalization in adult learning that was customized to meet the adult learners needs. As noted in chapter one, Matherson et al. (2010) noted teachers need proper training that is authentic and sustainable.

In chapter one, Lawless and Pellegrino (2007) identified critical components for appropriate professional development that aligns with instructions in a given content. These components included professional development related to instruction, the content focus aligned to student learning outcomes, and the impact of teachers' knowledge of technology integration within their content area. The training and support provided in this study was Just-In-Time learning that corresponded to the adult learners needs within their contextual environment. Beckett (2000) noted that an essential component in adult learning is the information needed to improve performance or complete a task. The participants within the study were teaching during a pandemic and in a virtual environment. Due to the uncertainty of the virtual learning environment, the Just-In-Time training and the integration of digital technology within a lesson to enhance learning using the TPACK model provided the immediate skills needed for implementing a lesson. Likewise, the Just-In-Time training in this study involved individualized, tailored training to meet the specific requests or concerns of the adult learner, as noted in Redding and Kamm's (1999) research. Likewise, as Niess (2009) indicated in a follow-up interview with a prior undergraduate student who only used technology once for three years, the theory to practice was not transferable. Therefore, the personalization of adult learning was a key factor within this study for newly hired secondary mathematics teachers.

As noted in chapter two, Learner-Centered Professional Development (LCPD) that incorporates developing TPACK knowledge and providing support with technology integration offers practical learning opportunities (Polly, 2011). A key implication of this study was personalized learning which was learner-centered professional development that incorporated TPACK during the planning sessions and reflection on implementation. To bridge the gap between teachers' knowledge, using the TPACK framework and LCPD with support influences transferable and sustainable implementation of technology integration to enhance student learning (Polly, 2011). Likewise, for teachers to integrate technology successfully within their classrooms, there needs to be professional development opportunities aligned with instructions, implemented over time, and includes opportunities for teachers to reflect on implementation

(Matherson et al., 2014). This study included multiple planning sessions over time and allowed teachers to reflect on best practices of integration of technology to enhance student learning of mathematics. In addition, Koh (2019) conducted a study on scaffolding TPACK design for supporting teachers' pedagogical change in a graduate course. Koh's analysis supported the findings within this study that indicated an increase of teachers' self-efficacy on pre and post-surveys when providing scaffolded support using the TPACK framework with the integration of technology when developing lessons.

Therefore, learner-centered professional development based on the specific areas of support that incorporate developing TPACK knowledge and providing help with the integration of technology provides an effective transferable learning opportunity for teachers. Due to the uncertainty of the virtual learning environment, this study provided Just-In-Time training and support using the TPACK model to integrate digital technology. This support provided the immediate skills needed to implement a mathematics lesson in a virtual setting. Adult learners need personalized support, which includes learner-centered professional development that is authentic, transferable, and sustainable within their contextual environment.

RECOMMENDATIONS

After conducting and reflecting on this case study, it was obvious there is more to learn about how to support newly hired secondary mathematics teachers using the TPACK model and survey. The findings and discussion include strategies to consider when supporting novice and experienced teachers in a virtual learning environment. The findings and discussion also identified essential characteristics to contemplate when planning and implementing a lesson that integrates technology in content areas along with the strategies that support teaching and learning.

Several other emerging implications occurred when teaching in a pandemic year. Eight implications emerged from this study: (1) using the TPACK survey to customize training for newly hired mathematics teachers by identifying areas of support, (2) using the TPACK model for planning, (3) contextual knowledge in virtual classrooms, (4) comprehending technology, (5) implications of software-focused and lesson-focused planning, (6) virtual professional development with TPACK model, (7) level of support with TPACK Planning, and (8) TPACK survey follow-up interviews for validation. There were many contextual situations that teachers were not used to handling which impacted their self-efficacy as a teacher in a virtual learning environment. These implications could impact practitioners in planning and implementing technology to enhance teaching and learning.

Recommendations for Practitioners

First, practitioners should utilize the modified TPACK survey for different content areas at the secondary level. Likewise, the survey could be used for elementary teachers to identify their strengths and for areas of support for content knowledge along with technology and pedagogy. As discussed in chapter one, many teachers earned degrees at a time when instructional technology was not as fully developed and, "often have inadequate experiences with using digital technology for teaching and learning" (Koehler et al., 2013, p. 2). Likewise, teacher preparation programs vary, and novice teachers come with different levels of understanding regarding the integration of technology within their subject area.

Second, practitioners using the TPACK model for planning should consider the five essential characteristics of a lesson plan in mathematics that align with the TPACK framework. The five key findings of essential characteristics include (1) planning how to model mathematics using the technology (teacher models), (2) planning how the students will use the technology tools to demonstrate their understanding of mathematics (students perform), (3) planning how to monitor students' progress with technology (monitor progress), (4) planning which technology can be used to enhance student learning (tools to enhance learning), and (5) planning a lesson that appropriately combines mathematics, technologies, and teaching approaches.

Third, practitioners should consider the contextual information within the learning environment when planning for technology, content, and pedagogy to create equitable instruction for all learners. As discussed in chapter two and also found in this study, TPACK interaction of all three core components is the foundation of effective teaching with technology. Knowing how technology can be used to build on prior knowledge to develop new epistemologies or enhance existing knowledge is critical in the interactions with content and pedagogical techniques (Koehler & Mishra, 2009). Each teacher has a different learning environment within the interactions of TPACK components therefore, one must consider contextual knowledge when planning and implementing the use of technology within a classroom (Mishra, 2019).

Fourth, practitioners who support or train educators to integrate technology should be checking for comprehension of technology before implementation. Teachers need to fully comprehend the design and launching of a new technology activity within their classroom. This recommendation is based on Rogers' (1995) model that explains the five-stage process of adopting and rejecting technology in teaching and learning. Based on the findings from the qualitative data collected in this study, it is obvious how important the recognizing and accepting steps in Rogers' (1995) model are for newly hired teachers. When a teacher has fully comprehended the design and implementation of technology, the new technology activity can be effectively launched and implemented.

The fifth recommendation for practitioners who support or train educators in implementing technology within their classroom is for them to use software-focused and lesson-focused training and support. Using a software and lesson-focused combination for training and support provides relevance and just-in-time training. Just-in-time strategies for implementation corresponds to the needs of the learner within the contextual environment (Beckett, 2000). In this study, the researcher used software-focused support by collaborating with the participant to identify what type of technology would enhance teaching and learning. The study was a lesson-focused design to help teachers customize lessons that meet the teaching and learning needs based on the contextual environment. Harris et al. (2009) noted that there was not enough evidence to conclude these models improved learning outcomes in their study. However, based on the findings from this study, when training and support were customized to meet the needs of the teachers in a virtual learning environment, the outcome had a positive impact on implementation.

The sixth consideration for practitioners who support educators in the implementation of technology, would be to use TPACK for mentoring and professional development. Based on the researcher's background as a mathematics professional development specialist, the researcher used a blended approach with the TPACK model during professional development. The recommended model that was used included: (1) identifying areas of support using the TPACK survey and initial meetings for background information, (2) unpacking learning outcomes and goals, (3) co-planning and questioning aligned with the TPACK framework and units of study, (4) observations and co-teaching if extra support was needed, and (5) post-implementation reflection on a lesson with examination of formative data and discussion of next steps. Throughout the process, rapport and trust were built with the educator. This was evident within this study based on the contextual information provided and the qualitative data collected in teachers' reflections.

Recommendations for Researchers

The first recommendation for researchers is to consider the level of support with the TPACK framework for in-service teachers. Does the amount of support impact TPACK knowledge? If so, how should support be tiered? The American Institutes for Research (AIR) released a report for ongoing professional learning within a tiered support model (AIR, 2020). The recommendation from AIR consists of instructional experts working directly with individual educators and providing support through data-driven instruction. Mentoring within tiered support is generally defined as a form of professional development that occurs when new knowledge is formed from a classroom. The recommendation is to provide ongoing support across a continuum of high, medium, and low support. As the mentor and teachers continue with success, the level of support decreases.

The second recommendation for TPACK survey researchers is to follow up with an interview on the closed questions to provide a deeper understanding of participant reasoning and thinking. In this study, the interview follow-up from Pre- and Post-TPACK survey provided a voice for the participants and more accurate interpretations of data. Interviews aid with validation of the survey data. Also, the survey used in this study revealed details on participants' prior background with technology that would not have surfaced otherwise.

Future research on using the TPACK survey and model should be conducted in other content areas and professional development structures. This study focused on newly hired mathematics teachers, but researchers should look at other disciplines, professional learning communities, or collaborative learning teams. Research on other content areas or professional development models should contain rich contextual information on different learning environments such as laboratory settings.

Chapter Six Summary

In chapter six, an overview of the findings as well as the limitations and implications of this study were presented. Implications included: using the TPACK survey to customize training for teachers by identifying areas of support, using the TPACK model for virtual planning, contextual knowledge in virtual classrooms, comprehending technology, implications of software-focused and use of sample lessons, virtual professional development with the TPACK model, level of support with TPACK Planning, and TPACK survey interviews. Finally, the primary contributions of this study were identified as well as suggestions for future research using the TPACK model.

Final Summary

As teachers plan for instruction, technology integration is an important factor in the planning and implementation process. This case study with an intervention focused on investigating the essential characteristics of planning and implementing lessons with newly hired secondary mathematics teachers. To bridge the gap between theory and practice, adult learners need personalization when trying something new and an expert's support. According to Knowles (1984), adult learning is optimal when the learner is involved in the learning process, including diagnosing, planning, implementing, and evaluating their understanding. Using the TPACK framework with the integration of technology, pedagogy, and content-specific lessons improved adult learning through the immediate application of new learning and increased their knowledge in identified support areas. The key implication was personalization in adult learning that was customized to meet the adult learners needs.

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APPENDICES

APPENDIX A: HUMAN SUBJECTS REVIEW APPROVAL

OLD DOMINION UNIVERSITY

OFFICE OF THE VICE PRESIDENT FOR RESEARCH

aaalac INTERNATIONAL PROUDLY, AN AAALAC ACCREDITED PROGRAM

Physical Address
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Office of Research
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DATE: August 13, 2020

TO: Philip Reed
FROM: Old Dominion University Education Human Subjects Review Committee

PROJECT TITLE: [1643359-1] A Case Study on the Relationship Between Targeted Support Using TPACK Model for Newly Hired Secondary Mathematics Teachers
REFERENCE #:
SUBMISSION TYPE: New Project

ACTION: DETERMINATION OF EXEMPT STATUS
DECISION DATE: August 13, 2020

REVIEW CATEGORY: Exemption category # 2

Thank you for your submission of New Project materials for this project. The Old Dominion University Education Human Subjects Review Committee has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will retain a copy of this correspondence within our records.

If you have any questions, please contact Laura Chezan at (757) 683-7055 or lchezan@odu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Old Dominion University Education Human Subjects Review Committee's records.

Prince William County
PUBLIC SCHOOLS
Providing A World-Class Education

July 14, 2020

Kristin McKitrick-Rojas
7854 Wilcoxen Farm Place
Manassas, VA 20111

Dear Ms. McKitrick-Rojas,

The purpose of this letter is to let you know that your request to conduct research, titled "*A Case Study on the Relationship between Targeted Support Using TPACK Model and the Integration of Technology with Newly Hired Secondary Mathematics Teachers,*" in Prince William County Public Schools (PWCS) has been reviewed by PWCS leadership.

Your request has been **approved**. Please ensure that all identifying information has been removed in the final reporting of the study. Thank you for your interest in PWCS as a research site, and we wish you success with your study.

Sincerely,

Michael T. Neall, Ph.D., NBCT
Supervisor of Program Evaluation

APPENDIX B: APPROVAL TO USE TPACK SURVEY

Crawford, Denise A [SOE] Tue, Jun 16, 10:20 AM (12 days ago)

to me

Dear Kristin,
Thanks for your interest in using our TPACK survey. You have our permission to use the survey for your research study! Sounds very interesting – good luck!

Best,
Denise Crawford

Denise A. Schmidt-Crawford
Professor
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Apple Distinguished Educator (2003)

TPACK SURVEY RELIABILITY OF THE SCORES

Reliability of the Scores (from Schmidt et al, 2009).

TPACK Doman	Internal Consistency (alpha)
Technology Knowledge (TK)	.86
Content Knowledge (CK)	
Social Studies	.82
Mathematics	.83
Science	.78
Literacy	.83
Pedagogy Knowledge (PK)	.87
Pedagogical Content Knowledge (PCK)	.87
Technological Pedagogical Knowledge (TPK)	.93
Technological Content Knowledge (TCK)	.86
Technological Pedagogical Content Knowledge (TPACK)	.89

TPACK SURVEY

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

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
TK (Technology Knowledge)					
1. I know how to solve my own technical problems.					
2. I can learn technology easily.					
3. I keep up with important new technologies.					
4. I frequently play around the technology.					
5. I know about a lot of different technologies.					
6. I have the technical skills I need to use technology.					
CK (Content Knowledge)					
Mathematics					
7. I have sufficient knowledge of mathematics.					
8. I can use a mathematical way of thinking.					
9. I have various ways and strategies of developing my understanding of mathematics.					
PK (Pedagogical Knowledge)					
10. I know how to assess student performance in a classroom.					
11. I can adapt my teaching based upon what students currently understand or do not understand.					
12. I can adapt my teaching style to different learners.					
13. I can assess student learning in multiple ways.					
14. I can use a wide range of teaching approaches in a classroom setting.					
15. I am familiar with common student understandings and misconceptions.					
16. I know how to organize and maintain classroom management.					

PCK (Pedagogical Content Knowledge)					
17. I can select effective teaching approaches to guide student thinking and learning in mathematics.					
TCK (Technological Content Knowledge)					
18. I know about technologies that I can use for understanding and doing mathematics.					

TPK (Technological Pedagogical Knowledge)					
19. I can choose technologies that enhance the teaching approaches for a lesson.					
20. I can choose technologies that enhance students' learning for a lesson.					
21. My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom.					
22. I am thinking critically about how to use technology in my classroom.					
23. I can adapt the use of the technologies that I am learning about to different teaching activities.					
24. I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.					
25. I can use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework in my classroom.					
26. I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school and/or district.					
27. I can choose technologies that enhance the content of a lesson.					
TPACK (Technology Pedagogy and Content Knowledge)					
28. I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches.					

29. Describe a specific episode where you effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what mathematics content you taught, what technology you used, and what teaching approach(es) you implemented. If you have not had the opportunity to teach a lesson using technology, please indicate that you have not.

APPENDIX C: PARTICIPANT CONSENT FORM

INFORMED CONSENT DOCUMENT
OLD DOMINION UNIVERSITY

PROJECT TITLE: A Case Study on the Relationship Between Targeted Support Using TPACK Model for Newly Hired Secondary Mathematics Teachers

INTRODUCTION

The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. This study is **A Case Study on the Relationship Between Targeted Support Using TPACK Model for Newly Hired Secondary Mathematics Teachers in Prince William County Public Schools.**

RESEARCHERS

Kristin McKitrick-Rojas, M. Ed, Ed.S., Investigator, Doctoral Candidate, College of Education, Department of STEM and Professional Studies, Old Dominion University. Dr. Reed, as the Principal Investigator, Faculty Advisor, Supervisor, College of Education, Department of STEM and Professional Studies, Old Dominion University.

DESCRIPTION OF RESEARCH STUDY

Several studies have been conducted looking into the subject of how the TPACK framework can be used with pre-service teachers and in-service teachers. This study will explore how to support teachers using the TPACK Framework with the integration of technology within classrooms. The purpose of this study is to identify the essential characteristic of integration of technology, pedagogy and content knowledge that is formed during planning and implementation.

If you decide to participate, then you will join a study involving research of using the TPACK framework for planning and implementation of technology that is used within mathematics classrooms. If you say YES, then your participation will consist of at least one 45-minute planning and implementation using the TPACK model interview session and at least one observation of how technology is being used within classroom either virtual zoom classroom or in a traditional classroom setting.

EXCLUSIONARY CRITERIA

You should have completed the TPACK survey. To the best of your knowledge, you should not have any reason that would keep you from participating in this study.

RISKS AND BENEFITS

RISKS: If you decide to participate in this study, then you may face a risk of some psychological discomfort as you recall past experiences in reflecting on the questions asked in the interview, depending on your individual experiences. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified. Materials, while confidential, may be subject to federal subpoena but every effort will be made to protect the confidentiality of the participants.

There are no direct benefits for participating in the study other than providing support in planning and implementation of technology during instruction.

COSTS AND PAYMENTS

Kristin McKitrick-Rojas wants your decision about participating in this study to be absolutely voluntary. Yet, she recognizes that your participation may pose some of your time during planning.

Kristin McKitrick-Rojas is unable to give you any payment for participating in this study.

NEW INFORMATION

If Kristin McKitrick-Rojas finds new information during this study that would reasonably change your decision about participating, then she will give it to you.

CONFIDENTIALITY

Kristin McKitrick-Rojas will take reasonable steps in maintaining confidentiality of data. Interview responses will not be linked to your name or other directly identifiable information. The de-identified information could be used for future research without additional informed consent from the subject. All research materials, including questionnaires, interview recordings, and transcripts will be kept within a password protected electronic environment and observations notes and written reflections will be kept in a locked filing cabinet prior to its processing. Additionally, all data will be stored for at least five years after the project closes. Five years after the conclusion of the study, the data (responses to the interview) will be destroyed. The results of this study may be used in reports, presentations, and publications; but Kristin McKitrick-Rojas will not identify you. Of course, your records may be subpoenaed by court order or inspected by government bodies with oversight authority.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study at any time. Kristin McKitrick-Rojas reserves the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of (…harm, injury, or illness…) arising from this study, neither Old Dominion University nor Kristin McKitrick-Rojas are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participation in any research project, you may contact Kristin McKitrick Rojas kmcki004@odu.edu or 910-233-8246; Dr. Philip Reed preed@odu.edu or 757-686-4576. Dr. Laura Chezan the chair of the DCEPS Humans Subjects Review Committee at lchezan@odu.edu at Old Dominion University, or the Old Dominion University Office of Research at 757-683-3460 who will be glad to review the matter with you.

VOLUNTARY CONSENT

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. Kristin McKitrick-Rojas should have answered any questions you may have had about the research. If you have any questions later on, then she should be able to answer them:

Kristin McKitrick Rojas kmcki004@odu.edu or 910-233-8246

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. Laura Chezan the chair of the DCEPS Humans Subjects Review Committee at lchezan@odu.edu or the Old Dominion University Office of Research, at 757-683-3460.

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

Subject's Printed Name & Signature	Date

INVESTIGATOR'S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

Investigator's Printed Name & Signature	Date

APPENDIX D: INTERVIEW QUESTIONS

Interview Questions

Questions

Pre-Interview Questions before planning

1 How can I support you with technology, pedagogy, and content?

1. What instructional technology would you like to use with your classes?

Questions during planning intervention

2. What are the learning standards within your lesson? (content)
    a. Why do students need to know this concept?
    b. How will students demonstrate their thinking of mathematics?
    c. How will you know that they understood the concept?

3. How will you implement the instructional task? (instructional task)
    a. How would students use representation for the task?
    b. How will students follow specific guidelines or parameters?

4. How are students using technology during instructions? (technology)
    a. How are students using Desmos activities, Desmos Geometry, Desmos graphing utilities, and/ or Desmos Scientific calculators during instructions?
    b. How are students using the virtual manipulatives during instructions?
    c. How do the technologies enhance students' learning for a lesson?
    d. What are the constraints and affordances of this technical tool?

5. Why have you decided to use these instructional strategies within your lesson? (Pedagogy)
    a. How will you access student performance during instruction?
    b. How will you adapt to different learners?
    c. How would you address common misconceptions?

Post-Interview Questions after planning

6. What are the next steps to implement the technology and instructional task?

7. How has the planning session been helpful?

Post Observation and/or Implementation Questions after implementation

Follow-up-Reflection after Observations and/or Implementation of Lesson

8. Describe some significant moments within your lesson and how technology was used for student learning.

9. How would you change the lesson to improve student learning using pedagogy, technology, and/or content?

APPENDIX E: RELATED RESEARCH QUESTIONS

R1. How does targeted individualized support and professional development impact newly hired secondary mathematics teachers' knowledge of technology, pedagogy, and content integration during instructions?

TPACK Survey

RRQ1 How does technology knowledge impact instructions that combine mathematics, technologies, and teaching approaches?
RRQ2 How does content knowledge impact instructions that combine mathematics, technologies, and teaching approaches?
RRQ3 How does pedagogical knowledge impact instructions that combine mathematics, technologies, and teaching approaches?
RRQ4 How do prior years of teaching experiences impact the integration of technology, pedagogy, and technology?

R1. How does targeted individualized support and professional development impact newly hired secondary mathematics teachers' knowledge of technology, pedagogy, and content integration during instructions?

R2. What are the essential instructional characteristics of integrating technology, pedagogy, and content knowledge that are formed during planning and implementation?

R3. What strategies support the teachers' integration of technology during instruction?

Observations Questions

RRQ 1 How are teachers using graphing utilities and/ or calculators during instructions?
RRQ 2 How are teachers using instructional technology activities during instructions?
RRQ 3 How does the preparation and planning of instructional technology, content, and pedagogy impact the implementation of a lesson?
RRQ 4. How does the use of formative assessment within instructional technology impact the teacher's perception of students' conceptual understanding of mathematics?

Interview Questions

RRQ 1. How do teachers' reflections impact the integration of technology, pedagogy, and technology?
RRQ 2. How does individualized support with instructional technology impact the implementation of digital technology during a lesson?
RRQ 3. How does the creativity level impact integrated technology, pedagogy, and content?

Written Reflection

How were technology, content, and teaching approaches used in a classroom lesson to impact student learning?

Related Research Questions and TPACK Survey with Interview Questions Alignment Continued

Related Research Questions & TPACK Survey Questions	Interview Questions
RR1 How does technology knowledge impact instructions that combine mathematics, technologies, and teaching approaches? **TPACK Questions (1-6) and (19-26)** (Appendix B)	How are students using technology during instructions? (during planning intervention) What instructional technology would you like to use with your classes? (pre-intervention question) What are the next steps to implement the technology and instructional task? (post-intervention question)
RR2 How does content knowledge impact instructions that combine mathematics, technologies, and teaching approaches? **TPACK Questions (7-9) and (18)** (Appendix B)	How are the learning standards being used within your lesson? (during planning intervention)
RR3 How does pedagogical knowledge impact instructions that combine mathematics, technologies, and teaching approaches? **TPACK Questions (10-16) and (17)** (Appendix B)	How will you implement the instructional task? (during planning intervention) Why have you decided to use these instructional strategies within your lesson? (during planning intervention)
RR4 How do prior years of teaching experiences impact the integration of technology, pedagogy, and content? **TPACK Questions (28- 29)** (Appendix B)	Describe some significant moments within your lesson and how technology was used for student learning. (follow-up after implementation) How would you change the lesson to improve student learning using pedagogy, technology, and/or content?

Related Interview Questions with Probing Questions Continued

Interview Questions During Planning	Probing Interview questions
How are the learning standards being used within your lesson? **(Content Knowledge)**	Why do students need to know this concept? In what ways will students demonstrate their thinking of mathematics? Tell me how will you know that the students understood the concept?
How are students using technology during instructions? (during planning intervention) **(Technology Knowledge)**	In what ways are students using Desmos activities, Desmos Geometry, Desmos graphing utilities, or Desmos Scientific calculators during instructions? Which virtual manipulatives are being used during instructions? What technologies will be used to enhance students' learning? What are the constraints and affordances of this technical tool?
How will you implement the instructional task? (during planning intervention) (**Instructional Task)**	What representation would students use for the task? What will be specific guidelines or parameters for this task?
Why have you decided to use these instructional strategies within your lesson? **(Pedagogy Knowledge)**	In what ways will you access student performance during instruction? Tell me how will you plan to adapt the lesson for different learners? In what ways, will you address common misconceptions?

Related Research Questions with Interview Questions and Reflection Alignment Continued

Related Research Questions	Interview Questions
RRQ1. How do teachers' reflections impact the integration of technology, pedagogy, and technology?	Describe some significant moments within your lesson and how technology was used for student learning. (follow-up after implementation)
RRQ2. What strategies support the teachers' integration of technology during instructions?	How has the planning session been helpful? (post-intervention question)
RRQ3. How does the creativity level impact integrated technology, pedagogy, and content?	How would you change the lesson to improve student learning using pedagogy, technology, and/or content?

APPENDIX F: OBSERVATIONAL DATA COLLECTION FORM

Resource: Merriam, S. B. (2009). Qualitative research: A guide to design and implementation. Jossey-Bass (p.120-121)

Physical Setting	What is the physical environment like? What resources and technology are in the setting?
Participants	Describe who is in the scene, how many people, and their role.
Activities and Interactions	What is going on? Is there a definable sequence of activities? What norms or rules structure the activities and interactions? How do people interact with the activity and one another? How are people and the activity connected? When did the activity begin? How long does it last? Is it a typical activity or unusual?
Conversations	What is the content of conversations in this setting?
Subtle Factor	What is nonverbal communication such as physical space and other cues?
Own Behavior	What is my role within the observations?

APPENDIX G PROTOCOLS FOR INTERVIEW, OBSERVATION, AND WRITTEN REFLECTION

Interview Protocols

Welcome and Instructions for Interviewing

Thank you for agreeing to participate in an individualized support session using information technology and other instructional technologies within Secondary Mathematics Classrooms. As a teacher, you are being asked to participate in a research study exploring support using the TPACK Framework and integration of information technology within your classroom. Your participation will contribute to the knowledge of supporting teachers with the integration of technology in classrooms. The purpose of this study is to identify the essential characteristics of integration of technology, pedagogy, and content knowledge that is formed during planning and implementation.

Your participation is completely voluntary. It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study. You may choose not to participate at all, or to answer some questions and not others. You may also change your mind at any time and withdraw as a participant from this study with no negative consequences.
I am going to record the discussion, so please speak clearly and remember that the tape-recorder will not pick up actions such as nodding in agreement. Interview responses will not be linked to your name or other directly identifiable information. Names will be removed from the data and given a pseudonym. All research materials, including recordings, and transcripts will be kept within a password-protected electronic environment.

We will introduce ourselves using first names only and check that the tape recorder is picking up our voices. Please review the consent form for participating in the study. Thank you again for your participation.

OBSERVATIONAL PROTOCOLS

Observation Protocols

Prior to Observations

Thank you for allowing me to observe your classroom today using information technology and other instructional technologies within a secondary mathematics classroom. As a teacher, you are being asked to participate in a research study exploring support using the TPACK Framework and integration of information technology within your classroom. Your participation will contribute to the knowledge of supporting teachers with the integration of technology in classrooms. The purpose of this study is to identify the essential characteristics of integration of technology, pedagogy and content knowledge that is formed during planning and implementation.

Your participation is completely voluntary. It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study. You may choose not to participate at all, or to answer some questions and not others. You may also change your mind at any time and withdraw as a participant from this study with no negative consequences.

Observation notes will not be linked to your name or other directly identifiable information. Names will be removed from the data and given a pseudonym. All research materials will be kept within a password protected electronic environment and/or a locked cabinet. Please review over the consent form for participating in the study. Thank you again for your participation.

OBSERVATIONAL Written Reflections

Written Reflections Protocols

Prior to Written Reflection

Thank you for agreeing to complete the written reflection on the integration of technology, pedagogy, and content knowledge used within a mathematics classroom. The purpose of this study is to identify the essential characteristics of integration of technology, pedagogy, and content knowledge that is formed during planning and implementation.

Your participation is completely voluntary. It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study. You may choose not to participate at all, or to answer some questions and not others. You may also change your mind at any time and withdraw as a participant from this study with no negative consequences.

Your written reflection will not be linked to your name or other directly identifiable information. Names will be removed from the data and given a pseudonym. All research materials will be kept within a password-protected electronic environment and/or a locked cabinet.

Please review the consent form for participating in the study. Thank you again for your participation.

OBSERVATIONAL Written Reflections

Written Reflection of Implementation

1. Describe how you have been using the technology within your lessons?

2. How did the students use technology for learning?

3. Describe a specific episode where you effectively demonstrated or modeled combining content, technologies, and teaching approaches in a classroom lesson. Please include in your description what mathematics content you taught, what technology you used, and what teaching approach(es) you implemented.

APPENDIX H: SAMPLE CODEBOOK AND LOG

Sample Coding Log

Initial Coding Teresa Reflection on Post Asynchronous Lesson (November 8th)

Category	Definition	#lines
Technology	Knowledge of operating digital technologies (Herring et al., 2016, p.16)	12,13, 53, 59, 91, 92,111, 170, 172, 238, 240, 244, 253,254, 255, 463, 464, 533, 534, 535
Pedagogy	Process and practices or strategies of teaching and learning (Herring et al., 2016, p.16)	8, 26, 27, 35, 36, 42, 62, 63, 67, 69 70, 93, 94, 95, 106,101, 102, 106, 130, 142, 143, 158, 191, 195,210,211,212, 213,214, 229, 239, 230, 252, 260, 261, 262, 279, 293, 294, 295, 299, 300, 301, 407, 462, 531,532
Content	Knowledge of Subject Matter	44, 54, 58, 60, 61, 62,71,80,81, 82,83,84, 171, 182, 200, 209, 262, 263, 289, 461
Other	Learning environment or Contextual Information	48, 96, 97, 162, 176, 190, 324, 325, 327, 329, 330, 332, 324, 325, 327, 329, 330, 332, 344, 336,337, 339, 341, 342, 344, 367,368, 369, 370, 374, 378, 385, 386, 402,403, 485, 489, 490, 554, 555,556

Focused Coding

Category	Definition	#lines
Technology	Knowledge of operating digital technologies (Herring et al., 2016, p.16)	12
Technology Content Knowledge (TCK)	The interaction of TK and CK (Herring et al., 2016, p.16) Example: Graphing Calculators and Content	53, 54, 170,171, 172

Technology Pedagogy Knowledge (TPK)	The interaction of TK and PK (Herring et al., 2016, p.16) Example: Monitoring students' progress and feedback with technology	8, 13, 58, 59, 111, 238, 239, 240, 244, 252, 253,254, 255,531,532, 533, 534, 535
Pedagogy	Process and practices or strategies of teaching and learning (Herring et al., 2016, p.16)	42, 106, 68, 69, 106, 130, 142, 143, 158, 191, 196, 279, 293, 294, 295, 299, 300, 201, 407
Pedagogy Content Knowledge (PCK)	Pedagogy Content Knowledge (PCK) (Herring et al., 2016, p.16) Example: scaffolding the content and misconceptions within the content	60, 61, 62, 63, 70, 71, 75, 80, 81,82,83,84, 26, 27, 209, 210, 211,212, 213,214 260, 261, 262,263
Content	Knowledge of Subject Matter	44. 71, 200, 289
Technology Pedagogy and content knowledge (TPACK)	The interaction of TK, PK, and CK (Herring et al., 2016, p.16)	91, 92, 93, 94, 95, 461, 462, 463, 464
Other	Learning environment or Contextual Information	1, 48, 96,97, 162, 176
Asynchronous	Online or distance learning where the learner accesses curriculum content but does not interact with the teacher or others in real-time. It allows students to learn at different times and in different places.	Line 2
Synchronous	Online or distance learning where the student can ask questions, dialogue, gain feedback, and/or interact with the teacher(s) in real-time. Some examples include virtual classrooms, live webinars, streaming in real-time, or video conferencing.	
Emotions	Concerns, upset, frustrated, excited, comfortable, at easy	1, 162, 190, 402, 403, 554, 555, 556
Students	Engaged or not engaged, struggling or exceeding attendance	167, 324, 325, 327, 329, 330, 332, 344, 336,337, 339, 341, 342, 344, 367,368, 369, 370, 374, 378 385, 386
Technology Issues	Canvas, HUB, Zoom, TEAMS, Desmos, Nearpod, internet connectivity, and other	485, 489, 490,

APPENDIX I: SAMPLE EMAIL

Good afternoon,

Welcome to…!

My name is Kristin Rojas, I am a Secondary Mathematics Professional Development Specialist for PWCS. I have included a link and a QR code to an optional questionnaire below. The purpose of this questionnaire is to identify areas that we can support you during the school year with mathematics, technology, and teaching strategies. Technology is a broad concept that can mean a lot of different things. For this questionnaire, technology is referring to digital technology/technologies. That is, the digital tools we use such as computers, laptops, iPads, handhelds, interactive whiteboards, software programs, etc.

Thank you for taking the time to complete the survey.

Questionnaire for Support and Training 2020-2021 school year click on the link below or scan the QR code:

https://tinyurl.com/yd5fmunk

-

If you have any questions, please email me at rojaskl@pwcs.edu.

APPENDIX J: SAMPLE INITIAL CODING

Initial Coding Read Through Yellow- Technology/ Green- Content / Turquoise-Pedagogy / Grey-Other

Subject 1:
Correct.

Researcher:
And our goal is that they'll use Desmos, but we'll also embed it in Canvas. So they-

Subject 1:
Oh, right. Embedded into Canvas, right.

Researcher:
Yeah. Okay. The there, so we're using Desmos activities and they're going to be involved in doing graphing. We're hoping... So, how does these technologies hopefully enhance students' learning? Do you see any kind of constraints with the technology tools? I know we were talking about being able... Just for them to go with the table to identify their line, which line they're going to actually be talking about the slope, which is what you did [crosstalk 00:04:38].

Subject 1:
Right. And also just the manipulation of the tools and accuracy of plotting the points and drawing the line, whether they do it with the pencil tool or the line tool, getting it lined up correctly.

Researcher:
With this being an asynchronous lesson that you're planning, it's probably going to be important that the directions are clear because they're not going to have you probably right there. Is that what you're-

Subject 1:
Correct. And I've tried to give them a couple of practice screens as we transition from one skill activity. Like in figuring out the slope, a lot of them can visually look at the screen and count it out, but some of them may still want to use the drawing tools, the pencil tool. So, I set up a screen for them to just focus on the drawing tool. And then, later when they're plotting, drawing the lines, I've set up a screen so that they can just practice plotting points and using the line tool to connect them in a line.

Researcher:
That's awesome. Do you mind walking through this student view so that we can look and see if everything's clear for the student?

Subject 1:
No, not at all. That's not a problem. I think I'm sharing my screen, correct?

Researcher:
Yeah.

Subject 1:

kristin rojas
Embedded Into Canvas
Reply

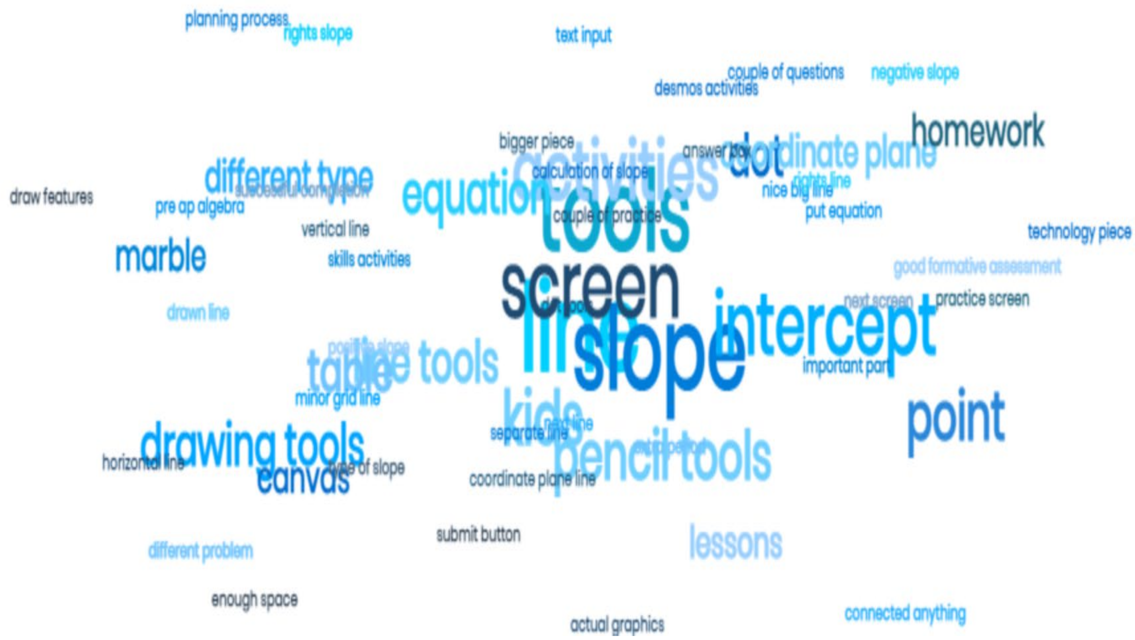
kristin rojas
"Manipulation of the tools and accuracy of plotting the points and drawing the line" using the pencil tool or line tool
Reply

kristin rojas
Couple of practice screens as we transition from one skill in the activity.
Reply

kristin rojas
Visually look at the screen and count it out or some may want to use the drawing tools. "So, I set up a screen for them to just focus on the drawing tool."
Reply

kristin rojas
Plotting and drawing lines then connecting the line
Reply

APPENDIX K: SAMPLE WORDLE



APPENDIX L: SAMPLE EXCEL CODING COMMENTS

Subject	CK (Content Knowledge) Mathematics	TK (Technology Knowledge)	PK (Pedagogical Knowledge)
Question	What are the learning standards within your lesson?	How are students using technology during instructions? (technology)	Why have you decided to use these instructional strategies within your lesson?
Comment	I want the student to be able to simplify multi-step order of operations, and multi-step evaluating expressions.	I wasn't going to. I figured, this first go-round, for them and me, just getting them to be able to use the graphing calculator, is going to be probably more important. As I get more comfortable with Desmos, and as the kids get more comfortable with the graphing calculator, then I think I can add in more of the explanation part.	Notes at the beginning and then do the desmos activity , line 276 it breaks up the activities for the kids. In other words, they're doing some note-taking, like they would in a classroom, and then we're taking out the calculators and we're practicing the skill, and they have their notes right next to them if they need them. So, I feel like, to replicate the classroom, it's better to do the note-taking, and then to switch over to using the calculator. And I could even have them copy those four problems down so that when we work them in the desmos they can put their answers in their notes.
Question	Why do students need to know this concept?	How are students using Desmos activities, Desmos Geometry, Desmos graphing utilities and/ or Desmos Scientific calculators during instructions	How will you access student performance during instruction?
Comment	Getting them use to graphing calculator along with the content of order of operations and evaluating expressions.	Desmos Activities with the Desmos Graphing Calculator	Monitoring responses in the Desmos Activity
Question	How will students demonstrate their thinking of mathematics?	How are students using the virtual manipulatives during instructions?	How will you adapt to different learners?
Comment	they should work it in their notebook, and then we'll switch over to Desmos, and then they can confirm their solutions, and then nobody has to know if they got it right or wrong. And then they can see the Desmos steps when they type it in .	Learning how to use the graphing caluclator to confirm solutions-Only . line 417 So, I felt like it was making this much more complicated, if I threw in the algebra tiles on top of the graphing calculator, which is probably newer to them, on top of reviewing the order of operations, but the evaluating may be newer to them, also.	line 394 Well, repeating the directions and problems orally as well as written. And then, when they get to the confirming part, answering their questions about the minus and the negative values in particular. and I've been making sure that I update my information to meet the newer standards. But also paring it down, so that I don't overwhelm the kids with too much at one time. line 458
Question	How will you know that they understood the concept?	How does the technologies enhance students' learning for a lesson?	How would you address common misconceptions?

Sub Support Dates | TPACK Template for Coding | S-subject 1 | A-Subject 1 | S-subject 2 | A-Subject 2 | A-subject 3 | A-subject 3 11-4

APPENDIX M: EMERGING THEMES LIST
Initial Findings Planning and Implementation

Follow-Up Support with Technology, Pedagogy, and Content for Secondary Mathematics:
Please respond to the following questions to identify what strategies and essential characteristics supported you during the planning and implementation of your lessons with the integration of technology.
What are the essential instructional characteristics of integrating technology, pedagogy, and content that occurred during the planning sessions? (Please select all that applies)

Statements	**Domain**
Planning the alignment of learning outcomes with technology.	TCK (Technological Content Knowledge)
Planning how to model mathematics using technology.	TCK (Technological Content Knowledge) CK (Content Knowledge) TK (Technological Knowledge)
Planning how to address misconceptions using technology.	PK (Pedagogical Knowledge) TPK (Technological Pedagogical Knowledge)
Planning how students will use the technology tools to demonstrate their understanding of mathematics.	TPK (Technological Pedagogical Knowledge) TK (Technological Knowledge) PK (Pedagogical Knowledge)
Planning how to pace the lesson with technology.	TPK (Technological Pedagogical Knowledge)
Planning how to monitor student progress with technology.	TPK (Technological Pedagogical Knowledge) TK (Technological Knowledge) PK (Pedagogical Knowledge)
Planning directions for virtual lessons.	PK (Pedagogical Knowledge)
Planning for feedback for students.	PK (Pedagogical Knowledge)
Planning for how students will demonstrate their understanding in multiple ways.	CK (Content Knowledge)
Planning how students will collaborate on the content using technology.	TPK (Technological Pedagogical Knowledge)
Planning which technology can be used to demonstrate an understanding of mathematics.	TCK (Technological Content Knowledge)
Planning which technology can be used to enhance student learning for a lesson.	TPK (Technological Pedagogical Knowledge)
Planning a lesson that appropriately combines mathematics, technologies, and teaching approaches.	TPACK (Technology Pedagogy and Content Knowledge)
Planning with the reports from the activity to determine the next steps for instructions.	PK (Pedagogical Knowledge)

Any additional comments on essential characteristics for planning with the integration of technology.

When planning for your lessons, what strategies supported you with the integration of technology? (Please select all that applies)

Statements
Modeling how to use the technology.
Modeling how to create lessons with technology.
Using content-related examples with technology to address current learning targets.
Discussion how students will demonstrate their understanding of content with technology.
Discussion of constraints with technology.
Discussion of misconceptions in content.
Discussion of prior knowledge needed for the content.
Discussion of how technology will provide feedback for students.
Roleplay with technology (in teacher and student views).
Reflection on pedagogy, technology, and content integration within a lesson.
Restating the focus of the lesson in using the technology.
Asking questions to guide the planning process.

Any additional comments on strategies to support your integration of technology.

APPENDIX N TPACK SURVEY AND INTERVIEW QUESTIONS WITH FINDINGS

Related Research & TPACK Survey Questions	Interview Questions	Key Findings
RR1 How does **technology** knowledge impact instructions that combine mathematics, technologies, and teaching approaches? **TPACK Questions (1-6) and (19-26)** (Appendix B)	How are students using technology during instructions? (during planning intervention) What instructional technology would you like to use with your classes? (pre-intervention question) What are the next steps to implement the technology and instructional task? (post-intervention question)	Planning how the students will use the technology tools to demonstrate their understanding (Students Perform), (Technology and Pedagogical**)**.
	Tell me how you will know that the students understood the concept?	Planning how to monitor students' progress with technology (Monitor Progress), (pedagogy and technology).
RR2 How does **content** knowledge impact instructions that combine mathematics, technologies, and teaching approaches? **TPACK Questions (7-9) and (18)** (Appendix B)	How are the learning standards being used within your lesson? (during planning intervention)	Planning how to model mathematics using the Technology (Teacher Models and Clear Expectations) (Technology and Content)
RR3 How does **pedagogical** knowledge impact instructions that combine mathematics, technologies, and teaching approaches? Related TPACK Questions (10-16) and (17) and (19-26) (Appendix B) **Aligns with Question 20**	How will you implement the instructional task? (during planning intervention) Why have you decided to use these instructional strategies within your lesson? (during planning intervention)	Planning which technology can be used to enhance student learning (Tools to Enhance Learning) (pedagogy and technology).
RR4 How do teaching experiences impact the integration of technology, pedagogy, and content? **TPACK Questions (28- 29)**	Describe some significant moments within your lesson and how technology was used for student learning. (follow-up after implementation)	Planning a lesson that appropriately combines mathematics, technologies, and teaching approaches (TPACK-Plan). **TPACK (Technology Pedagogy and Content Knowledge)**

APPENDIX O FINDING ALIGNMENT WITH QUALITATIVE AND QUANTITATIVE

The Key Findings from multiple data points from qualitative aligned with quantitative growth.

Domains	Key Findings from Multiple Data Points	Growth on TPACK Knowledge	Survey Questions Alignment
Technology knowledge (TK), Content Knowledge (CK), Technological Content Knowledge (TCK)	Planning how to model mathematics using the Technology (Teacher Models and Clear Expectations)	Teresa 1:00 TCK Teresa 1.16 TK Paulette 0.67 CK Paulette 0.17 TK Annie 2:00 TCK Annie 0.99 TK Catherine 1:00 CK Catherine 1:00 TCK Catherine 0.83 TK	1-6 TK 7-9 CK 18 TCK
Technology knowledge (TK) and Technology and Pedagogical (TPK)	Planning how the students will use the technology tools to demonstrate their understanding (Students Perform).	Teresa 1.16 TK Teresa 1.00 TPK Paulette 0.17 TK Paulette 0.57 PK Paulette 0.22TPK Annie 0.99 TK Annie 0.45 TPK Annie 0.14 PK Catherine 0.83 TK Catherine 0.57PK Catherine 0.67 TPK Karl 0.34 TPK	1-6 TK 19-26 TPK 10-16 PK
Technology knowledge (TK), Technology and Pedagogical knowledge (TPK), and Pedagogical knowledge (PK)	Planning how to monitor students' progress with technology (Monitor Progress),	Teresa 1.16 TK Teresa 1.00 TPK Paulette 0.17 TK Paulette 0.22TPK Paulette 0.57 PK Annie 0.99 TK Annie 0.45 TPK Annie 0.14PK Catherine 0.83 TK Catherine 0.67 TPK Catherine 0.57PK Karl 0.34 TPK Karl 0.28 PK	1-6 TK 19-26 TPK 10-16 PK
Technology knowledge Technology and Pedagogy (TPK)	Planning which technology can be used to enhance students learning (Tools to Enhance Learning)	Teresa 1.00 TPK Paulette 0.22TPK Annie 0.45 TPK Catherine 0.67 TPK Karl 0.34 TPK	20 TPK
TPACK (Technology Pedagogical and Content Knowledge)	Planning a lesson that appropriately combines mathematics, technologies, and teaching approaches	Catherine 1.00 TPACK Note Growth from Open-Ended Questions-All	28 TPACK Closed Question 29 TPACK Open-Ended

APPENDIX P CITI PROGRAM SOCIAL & BEHAVIORAL RESEACHER

CITI PROGRAM

Completion Date 21-Jul-2020
Expiration Date 21-Jul-2022
Record ID 36876885

This is to certify that:

Kristin McKitrick-Rojas

Has completed the following CITI Program course:

Not valid for renewal of certification through CME. Do not use for TransCelerate mutual recognition (see Completion Report).

Social & Behavioral Research - Basic/Refresher (Curriculum Group)
Social & Behavioral Research - Basic/Refresher (Course Learner Group)
2 - SBR 101 refresher (Stage)

Under requirements set by:

Old Dominion University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w87c260ef-8e49-4d5b-8e31-c461335fd589-36876885

VITA

Kristin Leigh McKitrick-Rojas
Doctor of Philosophy in Education: Occupational and Technical Studies
Old Dominion University

EDUCATION AND LICENSES

May 2017	Educational Specialist Degree in Education Leadership and Policy, Virginia Polytechnic Institute University
November 2011 to 2021	National Board-Certified Teacher, Early Adolescence/Mathematics
May 2004	Master of Education Degree, University of North Carolina at Wilmington
August 1994	Bachelors of Art Degree in Psychology and Minor in Science Clemson University
July 2020 to 2030	License Certification, State of Virginia**,** Administration Pre-K-12, Mathematics (7-12), Middle Education Science and Mathematics (grades 6-8), Math Specialist for Elementary & Middle Education

PUBLICATIONS

McKitrick-Rojas, K. (2020). A review of Desmos Geometry. *Virginia Mathematics Teacher*, *46*(2), 41-44.

McKitrick-Rojas, K. (2021). Book Review of Catalyzing Change in High School Mathematics: Initiating Critical Conversations. *Virginia Mathematics Teacher*, *46*(2), 52-55.

PRESENTATIONS & LEADERSHIP

2020-2021 Committees and Presenter for Workshops or Conferences

Virtual Connect Conference (Co-Chair Committee)- New Hired Educators.

Virtual Excellence and Equity in Education (EEE) Conference- (Co-Chair Committee).

Desmos Canvas Courses (Asynchronous and Synchronous)- Course designer and facilitator.

Virginia School Consortium for Learning (VaSCL) Virtual Workshops: Desmos Geometry.

Canvas Curriculum Co-Designer for Geometry and supported other mathematics courses.