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Secondary Mathematics' Teachers Perceptions of Their Integration of Instructional Technologies

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SECONDARY MATHEMATICS TEACHERS' PERCEPTIONS OF THEIR INTEGRATION OF INSTRUCTIONAL TECHNOLOGIES

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ABSTRACT

This qualitative research study explored the beliefs and practices regarding integrations of instructional technologies by seven secondary mathematics teachers. The researcher conducted an initial interview, a classroom observation, and a follow-up interview with each participant. Participants also submitted sample lessons and completed a TPACK Development Model Self-Report Survey. The interviews and observations were analyzed using deductive analysis, using the Technological Pedagogical Content Knowledge (TPACK) Development Model to assess technology-related practices.

Through responses to the TPACK Development Model Self-Report Survey, the participants revealed their perceptions of their practices and beliefs regarding technology integration. These perceptions were compared to the researcher's analysis of interviews, observations, and lesson samples. The researcher found that the participants perceived themselves to have much higher TPACK levels than indicated by other data collected. There was also a noted lack of pedagogical content knowledge (PCK) among participants with low TPACK, which indicated that their teaching practices limited technology integration. Pressures from standardized testing and interactions with colleagues were common factors noted to support technology integration. Pressures from standardized testing, however, tended to result in graphing calculator integration for computations and other rote uses.

The researcher also noted that participants were largely unable to differentiate between instructional technologies and non-instructional technologies. Participants erroneously reported presentation tools, such as LCD projectors, as instructional technology. Most participants lacked a vision for integrating technology as a tool for learning mathematics. Instead, many participants felt that technology posed a threat to the learning process. One participant, however, was a notable exception to these statements. Individual cases and the emergent themes are discussed.

DEDICATION

This work is dedicated to my husband, Kyle,

who has shared the sacrifices that made this journey possible;

to my young daughter Marion,

whose growing mind reminds me that this pursuit is worthwhile;

to my parents, Audrey and Randy,

who have always believed in me and encouraged me to do well in all things.

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CHAPTER I: INTRODUCTION

Introduction

Instructional technologies such as graphing calculators and computer programs offer invaluable opportunities for learning in mathematics classrooms. According to the National Council of Teachers of Mathematics (NCTM) Technology Principle, technology has the potential to offer access to multiple representations and deeper mathematics by allowing students to explore mathematical patterns, make conjectures, and test those conjectures in ways that would not be feasible without technology (NCTM, 2000). Although instructional technology is ever-changing, it is becoming more available in classrooms. Unfortunately, this increase in availability often does not translate to an increase in the actual use of instructional technology in the classroom (Dunham & Hennessy, 2008). Although the abundance of possibilities for enhancing student learning is promising, it is up to teachers to use technology in ways that most benefit students.

Technology, Pedagogy, and Content Knowledge (TPACK)

The knowledge needed to teach mathematics with technology is known as technology, pedagogy, and content knowledge (TPACK) (Niess et al., 2009). This construct grew out of an identification of the types of knowledge necessary for teaching. This special type of knowledge, known as TPACK, encompasses the intersection of content knowledge, pedagogical knowledge, and technological knowledge.

Niess et al. (2009) developed a model for defining the progression of a mathematics teachers' TPACK. This model includes four themes (curriculum and assessment, learning, teaching, and access) and five levels (recognizing, accepting, adapting, exploring, and advancing). Detailed descriptors included in the cited document allow identification of different levels for different themes based upon specific criteria. The TPACK Development Model differentiates teachers who integrate technology seamlessly into daily instruction from those who use technology as a supplement to traditional teaching.

The TPACK Development Model is a framework for identifying where a teacher's knowledge is within a defined spectrum. At the first level, *recognizing*, teachers have the ability to use the technology and align the technology with content but do not integrate the technology. Unfortunately many teachers have not yet gained the knowledge necessary to use the technology. For the purposes of this study, these teachers were classified as being at the recognizinglevel. The existence of teachers who technically fall below the recognizing level points to a problem that is outlined in the next section (Niess et al., 2009).

Statement of the Problem

Educational researchers have determined that integration of instructional technologies, such as graphing calculators and dynamic geometry software, in secondary mathematics classrooms has not increased with the rise in availability of these technologies (Cuban, Kirkpatrick, & Peck, 2001; Ertmer & Ottenbreit-Leftwich, 2009; Hew & Brush, 2007). Many barriers to instructional integration have been noted in research (Ertmer, 1999; Ertmer & Ottenbreit-Leftwich, 2009; Hew & Brush, 2007). Although these barriers give an indication of what prevents technology integration, little research is available that describes the types of supports perceived by in-service teachers to improve instructional technology integration in the secondary mathematics classroom.

The focus of this study was technology integration of in-service teachers; however, a larger body of research exists that examines the role of pre-service teacher programs in instructional technology integration. Research highlights pre-service teachers' attitudes and self-efficacy as keys to successful integration of instructional technologies (Clarke, Thomas, & Vidakovic, 2009; Groth, Spickler, Bergner, &Bardzell, 2009; Lee & Hollebrands, 2008; Swan & Dixon, 2006). From this research, one might assume that self-efficacy is also a key factor in technology integration for in-service teachers as well. Niess (2006) called for further research on how mathematics teachers develop a professional attitude toward instructional technologies. Knowing that self-efficacy is important is a first step toward technology integration, but gaining a deeper understanding of the teachers' perceptions of the development of knowledge that leads to self-efficacy is the next step.

Statement of Purpose

The purpose of this qualitative study was to explore secondary mathematics teachers' perceptions of their integration of instructional technologies, as described in the TPACK development model. Data, including teacher interviews, sample lessons, and classroom observations, were collected and analyzed for common themes.

Research Questions

The researcher sought to answer the following questions:

1. What are secondary mathematics teachers' perceptions of integration of instructional technologies in their classrooms as described in the teaching and learning themes of the TPACK Development Model?

2. How do secondary mathematics teachers' perceptions of integration of instructional technologies as described in the teaching and learning themes of the TPACK Development Model relate to the level of integration suggested by other data collected?
3. What factors motivate secondary mathematics teachers to incorporate instructional technologies?

Significance of the Study

Gaining a better understanding of what perceived supports enable and advance the integration of instructional technologies in the secondary mathematics classroom allows researchers, administrators, and professional development providers to make informed decisions. Educational researchers conducting studies that involve an instructional technology as a treatment can use findings from this study to support its implementation. Administrators and professional development providers can foster the growth of professional attitudes toward technology and work toward instructional technology integration in an informed manner when they have access to enablers of technology integration.

Definitions

For the purposes of this study, terms that will be used are defined in this section. *Instructional technologies* are defined as devices and software that have the capacity to extend the mathematics that is accessible to students, to allow students to engage in metacognitive activity that would otherwise not be possible, or to provide opportunity for students to reach a level of generality that would not be feasible without the technology (Heid & Blume, 2008).

Instructional technology use is defined as technology used to enhance student learning by fostering development of understanding of mathematical concepts (NCTM, 2000).

Barriers to technology integration are defined as any constructs, intrinsic or extrinsic to the teacher, which prevent integration of instructional technology.

Enablers are defined as constructs that allow teachers to integrate technology despite barriers that are present.

Summary

Technology offers opportunities for students to access mathematics in ways that are not otherwise available. It is essential then that teachers receive the necessary supports to gain the knowledge required to integrate the available instructional technologies effectively. This study identifies supports that allow teachers to progress through the TPACK development model, and, in essence, enrich the learning opportunities for their students. Chapter II will present related research and set the foundation for the study.

CHAPTER II: LITERATURE REVIEW

Introduction

According to the National Council of Teachers of Mathematics' (NCTM) Technology Principle (2000), technology is an essential component of mathematics education. When used appropriately, technology has the capability to enhance the teaching and learning of mathematics for all students. Additionally, the Technology Principle indicates that technology can be useful in allowing students to explore mathematical topics that may not be accessible otherwise. Technology can be incorporated into the classroom in one of two ways. That is, technology can be seen either as an integral part of daily instruction or as a supplemental resource used occasionally for certain topics (Cwikla, 2005).

This chapter will first examine research related to barriers to technology integration. Next, the chapter will consider research related to strategies for overcoming those barriers. Then, research findings related to instructional technology use in secondary mathematics classrooms will be discussed. Finally, a framework used to describe the knowledge necessary for integrating educational technology will be described along with research related to methods of assessing that knowledge.

Barriers to Technology Integration

Although the availability of technology is essential to its implementation, availability alone does not guarantee implementation (Ertmer, 1999). Ertmer suggested that "integration is better determined by observing the extent to which technology is used to facilitate teaching and learning" (p. 50). A synthesis of research by Dunham and Hennessy (2008) suggested that although availability of instructional technologies had increased dramatically, technology was still not adequately integrated into the teaching and learning of mathematics. Given the possibilities of enhancing student learning noted by Dunham and Hennessy, as well as in the NCTM Technology Principle (2000), it is essential that teachers are afforded opportunities to gain the knowledge necessary to take advantage of those opportunities.

Researchers have sought to identify barriers to appropriate instructional technology integration in the mathematics classroom (Ertner & Ottenbreit-Leftwich, 2009; Hew & Brush, 2007; Norton, McRobbie, & Cooper, 2000; Swan & Dixon, 2006). Ertmer (1999) classified barriers based upon their relationships to teachers. The researcher called barriers external to teachers "first-order barriers" and barriers internal to teachers "second-order barriers" .First- and second-order barriers will be described in detail in the paragraphs that follow.

First-order Barriers

First-order barriers are extrinsic barriers (Ertmer, 1999). In 1990, Honey and Moeller conducted a study that explored teachers' thinking on why they did or did not use technology in their classrooms. Interview data were collected from twenty teachers from urban and suburban school districts. After analyzing the data, Honey and Moeller identified obstacles, which they referred to as deterring factors. The identified deterring factors included teachers receiving inadequate training opportunities, experiencing problems with hardware, having small student-to-technology ratios, lacking time to work on planning and applications, and having problems making technology purchases due to district guidelines. Each of these deterring factors was external to the teacher and therefore represented first-order barriers.

Other first-order barriers to technology integration include lack of resources, e.g. technology, access, time, technical support, and institutional barriers, or lack of leadership and structure of the school day (Hew & Brush, 2007). Using a constant comparative method, Hew and Brush (2007) identified 123 barriers to instructional technology integration. Hew and Brush (2007) identified these factors based on a review of 48 empirical research studies related to barriers that affected the use of computing devices for instruction inK-12 classrooms and strategies for overcoming these barriers. These studies included 43 peer-reviewed articles, two reports, two conference presentations, and one book that included data from an empirical study.

Overcoming the aforementioned barriers is important, but not sufficient. Li conducted a study that examined the views of teachers and students related to instructional technology integration (2007). This project included the collection of data from fifteen mathematics and science teachers and 450 secondary students, using interviews and questionnaires. Li (2007) reported that the barriers identified by Honey and Moeller (1990), as well as teachers' difficulty integrating technology into existing curriculums, remained the most common teacher-perceived obstacles to instructional technology integration. Although technology is rapidly changing, the barriers to technology integration remain. None of the research studies revealed first-order barriers working alone. Second-order barriers were consistently present in classrooms with unsuccessful levels of instructional technology integration (Hew & Brush, 2007; Honey & Moeller, 1990; Li, 2007). As a result, second-order barriers will be addressed in the following section.

Second-order Barriers

Barriers which are intrinsic to teachers are known as second-order barriers (Ertmer, 1999). Second-order barriers include teachers' attitudes, beliefs, knowledge, skills, and practices.

In considering teachers' knowledge, Hokanson and Hooper (2004) identified five stages through which a teacher progresses as their knowledge gap related to their understanding of technology integration is narrowed. This model proposed that teachers must first take time to become familiar and comfortable with a technology, and then they progress to a level where they are able to use the technology. Next, the teacher becomes capable of integrating the technology into existing practices. Finally, the teacher begins to develop and implement tasks that are dependent on technology. Over time, and with success at each preceding stage, the teacher is able to teach using technology seamlessly to enhance student learning in the classroom. The greatest determination of success at each stage is an internal motivation, or overcoming the second-order barriers. These stages illustrate the complexity of the second-order barriers. Unlike first-order barriers, they are not material in nature, nor are they easily assessed or described.

The Interactions of Barriers

To demonstrate the interrelatedness of first- and second-order barriers, Hew and Brush (2007) created a model based on the 123 barriers identified from a review of literature. This model demonstrated the relationships among key barriers. These barriers included first-order barriers, such as subject culture, assessment, institution, and resources, as well as second-order barriers, such as teachers' attitudes, beliefs, knowledge, and skills. Subject culture included expectations and existing practices of a particular school or institution. Assessment was typically considered part of the subject culture and included high-stakes testing and other measures that seek to quantify student learning. Teacher attitudes and beliefs, which are both considered second-order barriers, were closely related to both subject culture and assessment, which are considered first-order barriers. Teacher attitudes and beliefs encompassed the expectations of the teachers about the role technology plays in the learning process. Knowledge and skills were reflective of attitudes and beliefs. These skills included the ability to use the technology correctly and the ability to integrate and adapt the technology to fit with pedagogical practices and classroom management. Institution included first-order barriers, specifically school leadership, mandating pacing guides, and other plans and policies. Institution was influenced by assessment. In turn, institution, a first-order barrier, influenced teacher's attitudes, beliefs, knowledge, and skills, which are second-order barriers. The institution influenced the resources that were available to support technology integration, including availability, access, time, and technical support. The description of these barriers indicated the interconnected nature of the obstacles faced by teachers and highlighted the interwoven nature of the barriers to technology integration.

Although first- and second-order barriers both exist, first-order barriers are often outside of the teachers' control. For that reason, this research will focus on second-order or intrinsic barriers to technology integration. Some teachers overcome these barriers quickly and are able to successfully integrate instructional technologies in their classrooms while others are slower at overcoming the obstacles. The next section will consider research related to overcoming these barriers.

Overcoming Barriers

Hew and Brush (2007) suggested several strategies for overcoming barriers, including development of a technology integration plan, sustained professional development, adjusting assessments, providing adequate resources, and changing teachers' attitudes and beliefs. These recommendations were based on a synthesis of literature related to instructional technology integration. Each of these recommendations will be described in the following paragraphs along with related research.

Development of a Technology Integration Plan

In overcoming barriers, research has demonstrated the potential of technology integration plans (Lim & Khine, 2006). In a study involving four schools, Lim and Khine (2006) reported that the development of a technology integration plan increased communication among teachers about technology and enabled teachers to identify clear goals of technology use. Research identified several essential components to the development of a technology integration plan. These components included the following: alignment of the technology with the curriculum and content; development of a shared vision that includes input from teachers and administrators; a detailed plan for integrating the technology plan; assurance of maintenance, upgrades, and access for technology; and a way to recognize instructional technology use and thus encourage others to use technology (Bowman, Newman, & Masterson, 2001; Eshet, Klemes, Henderson, & Jalali, 2000; Fishman & Pinkard, 2001; Gülbahar, 2007; O'Dwer, Russell, & Bebell, 2004). Rogers (2000) also noted that an instructional technology plan should go beyond technology issues and focus on teaching and learning with technology.

Sustained Professional Development

Although developing a technology integration plan is important, other areas essential to technology integration have been identified, including sustained professional development. Kastbert and Leatham (2005) conducted a survey of literature and identified three key factors related to teaching and learning mathematics with technology, namely access to technology, the place of the technology in the curriculum, and the connections between the technology and the pedagogical practice. These connections can be fostered through sustained professional development. Recognizing the importance of professional development, Hew and Brush (2007) reviewed literature and noted three effective professional development practices specific to instructional technologies: focus on content and pedagogical practices specific to the technology; allow teachers the opportunity to experience the technology “hands-on”; and design professional development practices specific to teachers’ needs. Also, Kastberg and Leatham (2005) indicated a need for in-service and pre-service teachers to be exposed to research about the effects of technology in their classrooms. Through sustained professional development, teachers can be offered support and education to overcome barriers to instructional technology integration.

Adjusting Assessments

Professional development may address the need to adjust assessments to be more appropriate for technology-rich classrooms. Technology may allow students to determine the direction of their learning, and this can cause issues with state assessments that focus on specific mathematical content. Dexter and Anderson (2002) recommended aligning assessments with state-mandated content standards. The purpose of this study was to examine existing improvement plans schools had in place that included instructional technology integration. The research examined the programs in each school and identified the elements that helped create successful technology integration plans. In this study of five schools, one school received a warning about low scores on a state assessment. The school had failed to align the technology with the state’s curriculum standards. The school adjusted the technology integration practices to include project-based assessments, which supported the state standards without taking away from the motivation and learning opportunities of the technology. This was accomplished by first identifying questions that students would answer. Then students were given opportunities to find these answers using technology without a defined method or course. These steps insured that students were provided opportunities to learn the content mandated by the state’s curriculum standards without taking away the benefits offered by the instructional technology.

Other research has identified successful measures for adapting assessments in classrooms that use instructional technologies. Bowman, Newman, and Materson (2001) found a teacher who formed contracts with the students to ensure that expectations and grading criteria for work with technology were clear. Criteria included requiring a certain number of PowerPoint slides or a detailed rubric for assignments. Another teacher required students to keep a portfolio that was evaluated throughout the year. Assessment strategies such as student-guided projects and establishing expectations provide insight on how teachers can adapt their assessment practices as they integrate instructional technology. These strategies also help focus student learning on the required content and therefore prepare students for state assessments.

Providing Adequate Resources

Research related to providing adequate resources has focused on computer availability and time. Strategies for overcoming a lack of technology availability include the use of laptop carts, which can be transported to various classrooms as needed (Grant, Ross, Wang, & Potter, 2005). Research has found that computers available in the classrooms are twice as likely to be used as computers located in central locations (Becker, 2000). This improves students' access to computers and allows students to work with technology in their daily environments.

With regard to the resource of time, research has focused on instructional time and planning time. Research has found that teachers with longer periods of class time, such as those with 90-minute lesson times or more, are more likely to integrate technology than teachers with traditional 50-minute lessons (Dexter & Anderson, 2000). Although research did not indicate a clear reason for this occurrence, it is possible that increased periods of class time correlate to increased periods of planning time, which is also limited for teachers. In addition to lengthening planning time, teachers can work together to plan and share lessons (Dexter & Anderson, 2000).

Strategies such as making technology available in the classroom, increasing instructional time, increasing planning time, and promoting collaborative lesson planning may help teachers overcome scarcity of resources such as available technologies, planning time, and instructional time.

Changing Teachers' Knowledge, Attitudes, and Beliefs

Arguably, it is more beneficial to understand what promotes than what prohibits instructional technology integration. Research consistently has found a positive relationship between teachers' beliefs in student-centered instruction and effective instructional technology integration (Ertmer & Ottenbreit-Leftwich, 2009; Ertmer, Ross & Gopalakrishnan, 2000). Other enablers of effective technology integration identified in research include providing teachers with the following: opportunities for teachers to share stories of effective technology use with each other, training in content knowledge, and access to research to support instructional technology use (Ertmer, Ottenbreit-Leftwich & York, 2007). Each of these enablers provides teachers with opportunities to confront and alter their knowledge, attitudes, and beliefs.

Ertmer (1999) reviewed existing research findings and suggested that teachers develop their knowledge, attitudes, and beliefs related to technology integration by first developing a vision through observing other teachers who integrate technology successfully, reflecting on their current practices, and collaborating with colleagues and experts. Furthermore, teachers need to identify opportunities to integrate the technology into the curriculum, thus increasing teacher knowledge. Specifically, Ertmer suggested that teachers need training related to classroom management with the technology as well as training related to existing resources and classroom activities. Finally, teachers must understand the role technology plays in student assessment (Ertmer, 1999).

The knowledge teachers need to improve technology use goes beyond knowing how to operate the equipment. Teachers need training in the specific pedagogical methods necessary for using technology to enhance teaching and learning. Ertmer and Ottenbreit-Leftwich (2009) identified the key variables of technology integration as self-efficacy, beliefs, and culture. For this reason, technology training must begin with teachers' existing knowledge to build the confidence and changes necessary to be effective and to view technology as more than a supplement.

Technology Lessons

As barriers to technology use are overcome, instructional practices with regard to technology integration in the mathematics classroom must be considered. Therefore, in this section, instructional technology practices in mathematics classrooms will be described first. Then, research related to different ways technology is used in mathematics lessons will be described. These lesson types will be discussed with consideration of time requirements, opportunities for learning, lesson quality, and classroom management.

Ertmer and Ottenbreit-Leftwich (2009) examined existing research to describe what technology integration looks like and gain insight into where efforts should focus to facilitate changes in instructional technology integration. Ertmer and Ottenbreit-Leftwich noted that although technology use was observed in mathematics classrooms, it was generally not being used to support student-centered instruction. According to these researchers, common uses of technology included typing assignments on the computer and completing drills or practice work. Although this research did identify technology use, these uses of technology were not taking advantage of the opportunities for learning and concept development that were described in the NCTM Technology Principle (NCTM, 2000).

Not all technology use is limited to typing assignments or completing drills. As teachers' knowledge about technology expands through training and other experiences, they begin integrating technology lessons into their classrooms. These technology lessons take various forms. McGraw and Grant (2005) identified two structures of technology-based lessons and explored how these types influenced students' opportunities for learning mathematics. The first type of lesson structure involved all students following a common procedure to reach a common outcome. In this type of lesson, the students did not decide which methods to use or how to proceed. Alternatively, the second type of lesson structure entailed students making decisions about how to proceed and devising their own conjectures. Students might have observed different situations than their peers but collaborated and shared conjectures after the investigations. The second type of lesson created opportunities for students to explore multiple strategies and representation, thus creating more opportunities to learn mathematics. Researchers noted that teachers using the first type of lesson structure tended to observe more classroom management problems. Although the second type of lesson structure required a longer time commitment due to the nature of the lessons, several of the first lesson types could be substituted for one of the second types. Although it is clear that the second lesson type is more beneficial to student learning, the second lesson type requires deeper teacher content knowledge and knowledge related to technology. The knowledge teachers have related to instructional technology implementation is known as technology, pedagogy, and content knowledge (TPACK) (Niess et al., 2009). This knowledge will be described in the next section.

Defining Technology, Pedagogy, and Content Knowledge (TPACK)

With the importance of instructional technologies in the mathematics classroom established (NCTM, 2000) and barriers to integration identified (Hew & Brush, 2007), it is imperative to consider the knowledge necessary for incorporating instructional technologies. Researchers agree that teachers must have knowledge beyond content knowledge to teach effectively (Shulman, 1986). Shulman identified the special knowledge needed to teach as pedagogical content knowledge (PCK), where the pedagogy component included knowledge of teaching and learning. As availability of instructional technologies increased, it became clear that knowledge of technology also played a role in knowledge needed for teaching. Educational researchers expanded the discussion of teacher knowledge to include the role of technology and coined the phrase technological, pedagogical, content knowledge (TPCK) (Margerum-Leys & Marx, 2002; Mishra& Koehler, 2006; Niess, 2005; Pierson, 2001). TPCK is the strict intersection of technological knowledge, pedagogical knowledge, and content knowledge. Koehler and Mishra (2008) recognized that TPCK was not accounting for technological content knowledge (TCK), technological pedagogical knowledge (TPK), or pedagogical content knowledge (PCK). Further discussions yielded a new construction: technology, pedagogy, and content knowledge (TPACK), which included these three realms of knowledge and the dynamic interactions among these realms (Niess, 2008). The TPACK construct takes into account the interplay of curricular decisions, assessment practices, teaching practices, and learning practices associated with student and teacher use of instructional technologies.

The curriculum and assessment theme examines the treatment of the content and how student learning is measured. The access theme considers how teachers address the aforementioned barriers, as well as technology usage and availability. The teaching and learning themes focus on the mathematical content knowledge of the teacher, the instructional strategies that are used when implementing technology, the understanding of how students develop understandings, and the teacher as a lifelong learner.

The TPACK Development Model includes five levels through which teachers may progress. Teachers progress through these levels for each of the themes described in the previous paragraph. These levels are recognizing, accepting, adapting, exploring, and advancing. The model is built on the assumption that first-order (extrinsic) barriers have been overcome. Following that assumption, teachers begin at the recognizing level for each new technology to which they are introduced. Second-order barriers teachers face impact the teachers' movements through the remaining four levels of the TPACK development model. Each of these levels will be described in the paragraphs that follow. Special attention to the teaching and learning themes will be noted for each level.

Recognizing Level

Teachers at the recognizing level believe that technology distracts from the learning process. Technology is used in their classrooms to reinforce concepts previously taught without the use of technology and for checking homework or computation (Niess et al., 2009).

A fictitious Algebra I teacher, Mr. Jones, will be used for illustration. Mr. Jones received a TI-Navigator system approximately one year ago. After experiencing some pressure from a colleague, he decided to begin using it. Each day as class began students logged into an application on their calculators and responded to a poll answering homework problems. Mr. Jones used this poll to decide which homework items to work on the board. Occasionally Mr. Jones set up a quiz for students to take at the end of the lesson to assess whether they remembered procedures from recent lessons. Mr. Jones was at the recognizing level for the TI-Navigator system based on the teaching and learning themes.

Accepting Level

Teachers at the accepting level may incorporate technology into a lesson, but focus the instruction on the technology rather than the mathematics. At the accepting level, teachers also tend to plan technology lessons as “extras” that are seen as an addition to the necessary mathematics instruction. These lessons are often teacher-centered with no opportunities for students to make decisions or select their own strategies (Niess et al., 2009).

Continuing the previous illustration, Mr. Jones realized that there were more opportunities for students to use technology to enhance learning, but he was not convinced that a technology lesson could replace one of his existing lessons. He was also not sure that students were “ready” to use the technology in other ways. After a unit on graphing linear equations, Mr. Jones had a day with no lesson planned. He decided to use this day for students to complete a technology-centered task that had students enter and share data using the TI-Navigator system. Following a step-by-step procedure, students graphed lines as a class. After displaying all students’ data, Mr. Jones provided a summary of the lesson and reviewed how to graph lines without the use of technology. Mr. Jones was at the accepting level for the TI-Navigator system, considering the teaching and learning themes.

Adapting Level

When teachers reach the adapting level, they begin to view technology as a tool for enhancing learning in the mathematics classroom. At this level, teachers may still use technology solely to reinforce previously learned concepts, and they are retaining their insistence that technology lessons should be teacher-led (Niess et al., 2009).

To continue the previous example, with increased student interest in the occasional technology lessons, Mr. Jones was planning technology lessons on a regular basis. Each Friday students completed a technology task that reinforced the topics discussed (without technology) throughout the week. Sometimes the technology allowed students to explore patterns that they were not able to explore previously, but it was never used to introduce a new topic. At the conclusion of each lesson, Mr. Jones provided the summary with little or no opportunities for students to discuss or explore. Mr. Jones was at the adapting level for the teaching and learning themes.

Exploring Level

At the exploring level, teachers use technology to facilitate the learning and exploration of mathematical concepts in the curriculum. This includes student engagement in high-level thinking tasks where technology use is essential. Teachers at the exploring level implement inductive and deductive strategies with technology through engaging questions (Niess et al., 2009).

As Mr. Jones became more comfortable with using technology on a regular basis, he began to integrate technology into daily lessons. He used technology to allow students to explore new concepts. Some of these concepts were not accessible to students prior to the introduction of the TI-Navigator system. During one lesson in which students collected and submitted data using the TI-Navigator system, students were given time to identify and describe patterns within their groups. Students shared a variety of patterns, which described the exponential pattern created when they examined the data submitted. Students used words, symbols, and pictures to describe what they saw. During the debriefing, students made connections between these patterns. The progress of the lesson was led by students' explorations and decisions. The following day, students were given descriptions of similar patterns and created situations and data sets to fit these patterns. They used the TI-Navigator system to explore and share these data sets.

When it was time for an exam, Mr. Jones used the technology to assess student understanding. Mr. Jones was excited about the opportunities his students had when they used technology, and he had taken a proactive role in sharing information with his colleagues. He was known within the school as a resource for technology lessons and technology integration ideas. Mr. Jones was at the exploring level for the TI-Navigator system with regard to teaching and learning themes.

Advancing Level

When teachers reach the advancing level, they consistently use technology as an integral tool for teaching and learning mathematics. At the advancing level, teachers plan, implement, and reflect on teaching and learning mathematics with technology. Often teachers at the advancing level are viewed by their colleagues as respected leaders with special knowledge of technology (Niess et al., 2009).

Mr. Jones used the TI-Navigator as an integral learning tool. He modified his teaching practices to focus on learning mathematics with technology. He planned technology lessons that allowed for ample exploration of mathematical concepts. After each lesson, he reflected on what happened, revised the lesson, and revised the following day's lesson appropriately. Mr. Jones sought out professional development opportunities and was eager to explore new technologies. Mr. Jones has now reached the advancing level for the TI-Navigator system with regard to teaching and learning themes.

As described in this example, a teacher's progression through the levels of the TPACK model is susceptible to their experiences, knowledge, beliefs, and attitudes. In this example, Mr. Jones used his positive experiences to explore instructional technology more deeply and progressed through each of the levels. Many teachers are unable to progress through the levels of

TPACK due to the aforementioned barriers associated with instructional technology integration. Researchers have begun to examine the experiences needed by teachers to advance through the levels of the model (Niess, 2005). This research will be presented in the paragraphs that follow, first for pre-service teachers and then for in-service teachers.

TPACK Research: Pre-service Teachers

Teacher training, specifically professional development, was previously identified as a way of overcoming barriers. Teacher training begins with teacher preparation; hence, this section will consider the role that teacher preparation programs play in instructional technology integration. Teacher preparation programs have a responsibility to prepare effective mathematics teachers who teach with technology and thus prepare the next generation of problem solvers. Researchers have begun examining the role of teacher preparation in advancing pre-service teachers' TPACK. These studies will be described in the following paragraphs.

Niess (2005) conducted a qualitative study that examined the technology pedagogical content knowledge (TPACK) of pre-service mathematics and science teachers in a program that incorporated technology instruction. Niess conducted five case studies that involved documenting and describing successes and difficulties of each pre-service teacher as their TPACK progressed. From the data, Niess (2005) recognized themes which called for teacher preparation programs to consider specific ways to expand their understanding of technology associated with the content and provide pre-service teachers with multiple opportunities to incorporate available technologies into their teaching using appropriate instructional strategies. Niess (2005) also noted that as a pre-service teacher advanced through the program, the focus of reflection changed from the candidate's teaching to the students' thinking and learning.

Other research has been conducted on teacher preparation programs and TPACK. Cavin (2007) conducted a study that examined the development of TPACK in pre-service teachers through lesson study. The pre-service teachers worked in small groups using the microteaching lesson study approach to refine lessons that incorporated technology. Instructional technologies used in the lessons included graphing calculators, Excel, Geometer's Sketchpad, TI-Interactive, and various online tools. Throughout the lesson study process, each group member taught the lesson at least once, allowing opportunities for discussion and lesson adjustments between lesson implementations. Cavin found that a teacher preparation program that included a technology focus helped foster the development of TPACK and that this progression was furthered by two key factors, namely experience having technologies modeled and a comfort level within the lesson study group. Cavin noted that the TPACK development of the pre-service teachers was also influenced by their beliefs and technology backgrounds.

In this section, supports for enhancing pre-service teacher knowledge have been identified. These supports include allowing opportunities for pre-service teachers to align technologies with their current schema of instructional strategies and fostering opportunities for pre-service teachers to reconcile their current content knowledge with the representations afforded by available technologies. Although these supports were identified with regard to pre-service teachers, in-service teachers need opportunities for similar knowledge growth.

Other research has considered teachers' perceptions of their progressions through the TPACK Development Model. McCrory (2010) conducted a study which explored teachers' TPACK using touch device technology. The participants included one in-service teacher and two pre-service teachers, but all of the participants were completing initial certification programs. During this study, participants were educated about TPACK and provided their opinions about their TPACK levels before and after the treatment of touch device technology accompanied by technology-related readings. Based upon McCrory's research, teachers tended to perceive themselves to be at higher levels than indicated by other data collected.

TPACK Research: In-service Teachers

The available research regarding TPACK development is limited primarily to pre-service teachers; however, some research is available to give insight into in-service teachers and their TPACK. Richardson (2009) studied twenty middle school teachers in six schools. These teachers participated in professional development that sought to increase their content knowledge and TPACK. Data were collected through journal entries, observations, and interactions during professional development activities. This study revealed a need for professional development to focus on connecting mathematical content to technology and pedagogy as well as focusing on the multiple representations technology offers. During exit interviews, teachers exhibited a positive disposition toward instructional technologies and also communicated that they perceived an increase in TPACK as they went through the professional development series.

Summary

Research related to instructional technology use in secondary mathematics classrooms has highlighted a problem with a lack of effective technology integration. Lack of technology availability is an obvious obstacle for technology integration; however, availability does not guarantee use of technology. Other barriers identified by research included obstacles beyond the control of teachers, such as a lack of training, a lack of release time, and a lack of product support. Other factors were intrinsic to teachers, such as their beliefs, knowledge, and self-efficacy. Opportunities for improving instructional practices through technology integration are possible with the growth of teachers' knowledge concerning the interplays of technology, pedagogy, and content, specifically TPACK. Research related to TPACK indicates that teachers tend to identify themselves to be at higher TPACK levels than indicated by other data. Other TPACK-related research noted that the development of this knowledge is strongly influenced by teachers' beliefs and backgrounds with technology. Chapter III will provide the methodology used to explore the problem.

CHATER III: METHODOLOGY

Introduction

Technology has the potential to enhance mathematics education (NCTM, 2000). To yield results, however, instructional technology should be used as more than a supplemental resource (Ertmer & Ottenbreit-Leftwich, 2009). The most obvious barrier to technology integration is lack of availability, but research has shown that overcoming this barrier does not guarantee implementation (Ertmer, 1999). There are many factors that contribute to whether or not a teacher implements instructional technologies into their mathematics classroom. These factors can be intrinsic or extrinsic to the teacher and include self-efficacy, beliefs, existing pedagogical practice, knowledge, or culture, as well as technology availability, technical support, and curricular alignment (Ertmer & Ottenbreit-Leftwich, 2009; Hew & Brush, 2007; Norton, McRobbie, & Cooper, 2000; Swan & Dixon, 2006). The knowledge teachers possess that influences if and how instructional technologies are used in the classroom is known as technology, pedagogy, and content knowledge (TPACK) (Niess et al., 2009). Having this established model for classifying teachers allows for exploration of their perceptions of technology integration in ways that aligns with current research.

The purpose of this study was to explore secondary mathematics teachers' perceptions of their integration of instructional technologies as described by the TPACK development model. This chapter first presents the research questions. Then, details regarding the design of the study are provided. Next, the population and the sample are described. Finally, an outline of the data collection and analysis procedures are shared.

Research Questions

This study sought to answer the following research questions.

1. What are secondary mathematics teachers' perceptions of integration of instructional technologies in their classrooms as described in the teaching and learning themes of the TPACK Development Model?
2. How do secondary mathematics teachers' perceptions of integration of instructional technologies as described in the teaching and learning themes of the TPACK Development Model relate to the level of integration suggested by other data collected?
3. What perceived supports are needed to assist secondary mathematics teachers in instructional technology integration?

Revising the Research Questions

Prior to beginning data collection, the researcher anticipated that participants would provide insight into what supports they perceived to assist their integration of instructional technologies. After data were collected and analyzed, however, the researcher found that participants did not directly identify these supports. Instead, the researcher was able to identify factors that motivated participants to incorporate instructional technologies.

Patton (2002) encouraged qualitative study design to be open and changing in ways that optimize opportunities for exploring the phenomenon. In accordance with this recommendation, the researcher revised the research questions as follows.

1. What are secondary mathematics teachers' perceptions of integration of instructional technologies in their classrooms as described in the teaching and learning themes of the TPACK Development Model?

2. How do secondary mathematics teachers' perceptions of integration of instructional technologies as described in the teaching and learning themes of the TPACK Development Model relate to the level of integration suggested by other data collected?
3. What factors motivate secondary mathematics teachers to incorporate instructional technologies?

Design

This study was qualitative in nature due to the type of research questions being addressed and the small number of participants. Qualitative design was appropriate because this study explored experiences of teachers (Patton, 2002). In addition, there was not enough known about the TPACK of in-service teachers for standardized instruments to be available. Qualitative data were collected using face-to-face interviews, classroom observations, self-report survey data, and lesson samples. These results are reported using a series of seven case studies. In each case study, the initial interview transcripts, classroom observation notes, follow-up interview transcripts, lesson sample, and self-report survey data are analyzed and information relevant to TPACK is shared.

Sample

The sample included seven secondary mathematics teachers in a southeastern state in the United States. The participants taught various mathematics subjects, including Algebra (varied levels), Geometry, and Calculus (varied levels). The sample included teachers with varying levels of technology integration during mathematics instruction. Due to the nature of high-stakes testing, virtually all secondary mathematics classrooms have access to some form of instructional technology, primarily graphing calculators.

To obtain the sample, a Call for Participants (see Appendix A) was sent through electronic mail using a list-serve of secondary mathematics teachers provided by the state's affiliate of NCTM. The Call for Participants was also sent to an additional list-serve of middle school and high school teachers who expressed interest in obtaining information about opportunities related to mathematics education. The Call for Participants gathered data about potential participants' technology use; however, responses to the Call for Participants were not analyzed statistically.

The researcher examined the returned Call for Participant forms and selected potential participants. There were nine responses to the Call for Participants, and three additional potential participants contacted the researcher via email to express interest. The researcher examined potential participants' information. Four participants who submitted Call for Participants forms were not selected because they were not located within a reasonable proximity of the researcher. The remaining five potential participants who submitted Call for Participants forms, as well as the additional three potential participants who expressed interest via email, were contacted to verify their acceptance to participate in the study. Of the eight selected participants, seven responded to emails and established agreeable times to conduct the initial interviews. Despite repeated attempts to contact the eighth participant, no response was received. After three attempts to make contact, the researcher decided not to include this participant in the sample.

The remaining sample included six high school teachers and one middle school teacher who all had access to instructional technologies, such as graphing calculators, non-graphing calculators, computer software, and the TI-Navigator System. The sample represented teachers from five schools and four districts. Three high school teachers taught in the same school with two of those teachers teaching the same subject. One high school teacher taught in the same district as the middle school teacher but taught a different subject. The sample formed a group that was heterogeneous with respect to reported types of available technology and reported frequency of technology use in the classroom.

Instruments

In an effort to answer the research questions, the researcher created the TPACK Development Model Self-Report Survey, Interview Protocol, and Observation Tool in collaboration with a colleague. This colleague was a doctoral candidate in education with an emphasis in secondary mathematics. The colleague had previously received a Master of Education degree in secondary mathematics education, a Master of Arts degree in mathematics, and a Bachelor of Science degree in Mathematics. The colleague had seventeen years of secondary level mathematics teaching experience. As the colleague's research interests also focused on in-service teachers' TPACK, the collaboration between the researcher and the colleague led to the development of the research instruments. Each of the instruments will be described in the paragraphs that follow.

TPACK Development Model Self-Report Survey

The TPACK Development Model Self-Report Survey (see Appendix B) included 55 statements that pertained to the four themes identified by the TPACK Development Model: curriculum and assessment, learning, teaching, and access. For the purposes of this survey, curriculum and assessment were considered separately. For each of the other themes, particular subthemes were considered. For example, to describe the learning theme, mathematics and conceptions of student thinking were considered separately. In the teaching theme, mathematics learning, instruction, environment, and professional development were each assessed. In assessing the access theme, usage, barriers, and availability were all considered. These created eleven separate categories with five statements per category. Each of the five statements corresponded to a particular development level. The order of the statements on the survey corresponded to their levels, with the lower levels provided first. Participants were provided with oral instructions prior to completing the survey. They were instructed to select one instructional technology that they used regularly and to check the statements that were true for them when considering their experiences with the selected technology.

Although this instrument was created in collaboration with the aforementioned colleague, the TPACK Development Model Self-Report Survey was submitted to Margaret Niess. The researcher and colleague used feedback from Niess to further refine the survey prior to using it as an instrument in this study.

Initial Interview Protocol

The Initial Interview Protocol (see Appendix C) was used to guide interview questions. This Initial Interview Protocol used broad questions about technology integration to offer participants an opportunity to share information about instructional technology use in their classrooms. The Interview Protocol included eleven items. Three of the items were administrative, seeking either background information or scheduling of observation time. The eight remaining items assessed multiple subthemes of the TPACK Development Model. The interview questions were designed to solicit information pertinent to each teacher's levels within the TPACK Development Model. The focus of the Interview Protocol was on the learning and teaching themes.

Observation Tool

The Observation Tool (see Appendix D) was used for classroom observations. The first two pages of the Observation Tool were used to record descriptions of the classrooms and detailed notes of the lessons observed, with timestamps occurring every five to ten minutes. The third page included specific items that should be noted related to each theme of the TPACK Development Model. The participant was the focus of the observation, not the students. Therefore, the observation tool and its accompanying field notes provided data relevant to the participant.

Role of the Researcher

The researcher was a doctoral candidate studying education with an emphasis in secondary mathematics. Previously, she served on a research project team as a professional development facilitator. Degrees earned include Master of Education and Bachelor of Arts degrees in secondary mathematics education. The researcher was previously employed as a high school mathematics teacher. She taught several subjects, including Pre-Algebra, Algebra I, Algebra II, Trigonometry, and Statistics. The researcher’s experiences, including teaching secondary mathematics education, exploring educational technologies, and participating in educational research, were evidences of the qualities necessary for conducting this research.

The researcher held biases and assumptions that had developed through working as a teacher and as a researcher. One bias was that the researcher felt that most secondary mathematics teachers did not use instructional technologies in ways that exemplified the vision described in the NCTM Technology Principle (NCTM, 2000). Instead, the researcher felt that technologies, specifically graphing calculators, were used in secondary mathematics classrooms for rote mathematics and applications that allowed students to use a program rather than refer to a formula or their own conceptual understanding when taking an exam. In the researcher’s experience, many teachers seemed unaware of the capabilities of technologies and failed to use them to bring new representations or new content into the mathematics classroom. The researcher was aware that some teachers fulfilled the vision of the NCTM Technology Principle; however, the researcher believed there were a relatively small number of these teachers. Additionally, the researcher believed that most secondary mathematics teachers were at the recognizing level for the teaching and learning themes (Niess et al., 2009). Although the model did not have a level below recognizing, the researcher believed that there were teachers who fell below the criteria described for the recognizing level in the model. Awareness of the biases and assumptions helped to ensure that they were controlled throughout data collection and analysis.

Data Collection Procedures

Prior to beginning data collection, the researcher sought approval from the dissertation committee. After successfully defending the prospectus, the researcher obtained approval from the Institutional Review Board. After these approvals, the researcher began the data collection process.

To identify a sample, a Call for Participants was sent using the list-serves previously described. Participants were selected from responses to the Call for Participants. The researcher intended to select five to ten participants purposefully from the responses to the Call for Participants; however, since there were so few responses, all seven respondents that were located within a reasonable distance were selected. Selected participants were contacted by email, and initial interviews were scheduled to occur within two weeks of establishing contact. The researcher also answered general questions at the time of the initial contact, but provided project details and gained consent at the beginning of the initial interview. After scheduling the initial interview, the researcher contacted the participant's principal to obtain written consent on school letterhead to conduct research in the school setting. One of the administrators requested an informational meeting, which was conducted prior to the principal providing consent. All letters of consent were acquired prior to the initial interview. After all letters of consent were collected from principals, the researcher submitted copies of these letters to the Institutional Review Board. The researcher scheduled the initial interviews to take place during a time that was convenient to each participant, occurring before school or during planning time.

The researcher sent reminder emails to participants within 24 hours of the initial interviews. Because the interviews were the first face-to-face interactions between the researcher and participants, the researcher began each interview by providing information relevant to the research being conducted and reminding each participant that participation was voluntary. Each participant was provided with a Participant Packet that included an information sheet (see Appendix E), a letter of gratitude for participation (see Appendix F), a summary of participant commitments to the study (see Appendix G), and the TPACK Development Model Self-Report Survey (see Appendix B). This packet was reviewed by the researcher with each participant prior to beginning the initial interview. All interviews were audio-recorded. To ensure trustworthiness, each participant was notified that information collected would not be linked to them in any way. The use of pseudonyms was discussed, and the researcher responded to any questions or concerns the participants had prior to beginning the interviews.

The focus of the initial interview included questions that allowed the researcher to identify the levels of TPACK for the teaching and learning themes for each participant. The initial interviews were guided by the Initial Interview Protocol, but included some deviation as deemed necessary by the researcher for the purposes of identifying the TPACK levels or obtaining and maintaining trustworthiness throughout the study. At the conclusion of each interview, a classroom observation and follow-up interview were scheduled, and participants were reminded to provide their completed TPACK Development Model Self-Report Survey and a sample lesson at their convenience, preferably at the time of the scheduled observation. Participants were reminded that these lessons should be tasks and lessons that they used in their classrooms and exemplify what they felt a technology lesson or task should look like.

The scheduled classroom observations took place during a lesson in which the teacher noted planned technology integration and within two weeks of the initial interview. Upon arriving at each classroom for the observation, the researcher requested the completed TPACK Development Model Self-Report Survey. Two participants did not have the TPACK Development Model Self-Report Survey completed at the time of the observation. The researcher reminded these participants about this obligation and provided additional copies of the survey when necessary. All participants returned a completed TPACK Development Model Self-Report Survey by the conclusion of the study.

The researcher used the Observation Tool to collect data during the scheduled observation. Observation notes were written and focused on the participants' actions and questioning. Minimal student data were collected in order to understand the interactions within the classroom. These data included general information about student responses to teacher questions and summaries of student statements that indicated normal classroom practices. No identifying information was collected, and the observations were not video-taped or audio-taped. At the conclusion of the observation, the researcher verified the follow-up interview appointments and reminded participants about remaining project commitments, when applicable. Prior to leaving the observation sites, the researcher reminded participants that participation in the study was voluntary. All participants chose to remain in the study.

One follow-up interview occurred for each participant. Six of the interviews were face-to-face interviews. One participant requested to submit responses to the interview questions via email because his schedule could not accommodate an additional interview. The follow-up interviews took place within two weeks of the observations and were less formal than the initial interviews. Follow-up interviews allowed the researcher to ask questions to clarify any areas that were unclear from previous data collected; therefore, the follow-up interview protocols were unique for different participants. Follow-up interviews occurred following the initial interviews and classroom observations and allowed the researcher time to reflect on missed opportunities for soliciting information during the initial interviews and focus the follow-up interview protocols on this missing information. The researcher transcribed each interview verbatim, noting pauses, laughter, and tones.

At the conclusion of the follow-up interviews, each participant received a small gift bag as a token of appreciation for their participation. Although two participants did not submit lesson samples, all participants were provided with a gift bag. All data collection took place between October 2010 and January 2011. After all data were collected, the researcher held a random drawing and awarded two TI-Nspire graphing calculators to two randomly selected study participants.

Data Analysis

Qualitative data analysis procedures were used to address each question. A description of how data were analyzed for each question is detailed below.

Question 1: *What are secondary mathematics teachers' perceptions of integration of instructional technologies in their classrooms as described in the teaching and learning themes of the TPACK Development Model?*

Responses to the TPACK Development Model Self-Report Survey allowed the researcher to identify at which level within the TPACK development model each participant perceived himself or herself to be by identifying statements correlated with the TPACK levels. During the planning phase of the study, the researcher anticipated that interview responses would provide insight into teachers' perceptions of their TPACK levels; however, after data collection, the researcher felt that interview data provided a clearer picture of participants' actual TPACK levels than their perceptions. After collecting the TPACK Development Model Self-Report Surveys from the participants, the researcher organized the responses into a table. The instructions for completing the survey allowed participants to indicate multiple responses for each category. These data were reported in the table and represented the statements that participants identified to represent their TPACK levels for a specific technology. Participants were instructed to select one type of instructional technology to use when completing the survey. Six of the participants selected the graphing calculator, and one participant selected an electronic whiteboard. Although the electronic whiteboard was not considered an instructional technology, the responses were still used to determine that participant's perception of TPACK because conversations indicated that responses specific to graphing calculator use would be similar. Each participant's perceived TPACK levels (specific to their selected technology) will be reported using case studies in Chapter IV.

Question 2: *How do secondary mathematics teachers' perceptions of integration of instructional technologies as described in the teaching and learning themes of the TPACK Development Model relate to the level of integration suggested by other data collected?*

Interview data and observations notes focused on aspects of instruction outlined in the TPACK development model. Using the data from observations and interview responses, the researcher assigned the appropriate levels for the teaching and learning themes as outlined within the TPACK model, as well as other themes when possible. This was accomplished by considering the alignment of statements made during the interviews and observation notes to the TPACK Development Model using deductive analysis (Patton, 2002). The researcher assigned a number to each descriptor from the TPACK Development Model and noted statements from the data collected that indicated levels and themes for the participants (Patton, 2002). For each data collection (i.e., interview, observation, or lesson sample) a justification of decisions was created by the researcher, which referenced the TPACK Development Model. The justification for the interview analyses included statements from the TPACK Development Model and interview responses that correlated to those statements. Justification for the observations and lesson samples was written in narrative form to provide an account of the observed class periods and planned lessons. The focus of the observations was on the teachers' actions with minimal notes about students' behaviors within the classroom.

Sample lessons collected during visits to participants were collected to allow the researcher to make determinations that might not have been possible based on observation and interview data alone. The lessons collected, however, included minimal details, and some lessons contained no mention of instructional technology despite written and verbal instructions from the researcher that the lesson portray how the participant felt "an ideal" technology task should look. The researcher then revisited the analyzed interview data and observation notes and compared these data to the survey data to determine if the participant and researcher agreed on the participants' TPACK levels, which indicated the level of instructional technology integration in the classrooms.

Question 3: *What factors motivate secondary mathematics teachers to incorporate instructional technologies?*

Interview data, observation data, and sample lesson data allowed for data triangulation that provided insight into the factors that influence instructional technology integration. All of the data were analyzed using deductive theory, based upon the existing TPACK Development Model. In the analysis of the interview data, phrases were used to justify classifications made by the researcher that linked the data to the TPACK Development Model. Observation notes were summarized for each participant and analyzed by connecting recorded events or statements from the observation with the TPACK descriptors. Content analysis was used to identify overarching themes from the data collected (Patton, 2002). Several themes emerged, and these themes were particularly evident in the interview transcripts; however, the researcher also observed common themes during the lessons. In this analysis, the method of bracketing was used to identify these themes (Patton, 2002). These themes were drawn from teacher insight as well as researcher insight based upon the data collected.

Credible Critic

After analyzing the data, the researcher contacted Dr. Margaret Niess, a noted researcher in the field of technology and mathematics education. The researcher requested that Dr. Niess review the analyses and provide constructive feedback to strengthen the findings and yield credibility to the study. After reviewing the analyses, Dr. Niess reported unanimous concurrence with the TPACK alignments based on evidence provided in Chapter IV (see Appendix H.)

Limitations

One limitation of this study was the fact that data were obtained by one researcher. In order to reduce the effects of bias, the colleague described in the Instruments section assisted in analyzing the data by reading through the researcher's analysis of interview transcripts and observation notes for situations where the researcher was concerned about bias or the TPACK level was questionable. In events when the colleague disputed the researcher's conclusions drawn from data analysis, the researcher and colleague met and used arguments based on the TPACK Development Model to come to a consensus. In an effort to minimize the effects, the researcher acknowledged these biases prior to beginning data collection. The researcher also used data saturation by collecting a large quantity of data, as each participant allowed, to provide maximal evidence for the analyses and results. Additionally, the researcher used content analysis and recorded a trail of all level assignments. This is viewable throughout the case studies, and the analyses were critiqued by a critic who substantiated the coding assignments.

An additional limitation involved the instruments themselves. The Interview Protocol, Observation Tool, and TPACK Development Model Self-Report Survey were based upon the TPACK framework and were unique to this and one other dissertation study. Additionally, interview data was self-reported by the teachers, which was limiting because teachers' perceptions were subject to their own biases.

The lessons learned through the study are transferable to similar settings. Additionally, these lessons offer insight for further research and exploration. Per the content analysis design of the study, the researcher viewed participants' technology integration through the lens of the TPACK Development Model. This narrowed focus is a limitation to the study in that the researcher may have not considered data relevant to participants' attitudes and beliefs regarding instructional technology integration in cases where the data werenot applicable to levels described in the TPACK Development Model. Finally, the purposeful selection of seven cases shed light on the integration of instructional technologies of these individuals. The concentration on these stories influenced the data collected, and the selection of other participants could have led to other valuable insights. The previously described processes worked to combat these limitations.

Summary

The interviews, observations, and sample lessons allowed the researcher to address the aforementioned research questions by analyzing data for themes and trends. By including participants at varying places on the TPACK development model, the researcher sought to provide information that will be useful to future research on the impact of technology in the classroom. The data collection procedures included an initial interview, an observation, collection of a sample lesson, a self-report survey, and a follow-up interview for each participant. These data allowed the researcher to determine at which level(s) of the TPACK Development Model for teaching and learning the participant perceived himself or herself to be, and the data allowed the researcher to determine at what level(s) for those themes the participant actually was. Data analysis was conducted using a deductive content analysis approach. From data gathered, the researcher was able to determine what factors influence instructional technology integration, thus providing insight and guidance for future research and decision-making. In Chapter IV the researcher will describe the results of the study, presented in seven case studies, and respond to the research questions.

CHAPTER IV: RESULTS

Introduction

According to the vision of the NCTM Technology Principle, instructional technologies have the potential to enhance learning opportunities in the mathematics classroom (NCTM, 2000). As access to instructional technology has increased, however, an increase in the use of these tools for teaching mathematics has not followed (Dunham & Hennessy, 2008). In an effort to address the research questions posed in Chapter III, this chapter will detail the analysis of data collected from seven secondary teachers. Data collected from these participants included interviews, self-report surveys, observations, and lesson samples. This chapter will first provide an overview of data analysis, then report data using a series of seven case studies. Then, responses to research questions and a summary of the chapter will be shared.

Analysis of Interview and Observation Data

Interview data were analyzed using deductive analysis to make connections between participant responses to interview questions and the descriptors in the teaching and learning themes of the TPACK Development Model (Niess et al., 2009). For the purposes of clarity and efficiency, codes will be used throughout this chapter to report the noted alignment of participant statements and observations to the descriptors from the TPACK Development Model (see Appendix I). Each code consists of three characters. The first character is an upper case letter that represents the theme, either teaching (T) or learning (L). The second character is a number representing the TPACK level, recognizing (1), accepting (2), adapting (3), exploring (4), or advancing (5). The third character is a lower case letter representing the descriptor, mathematics learning descriptor (m), conception of learning descriptor (c), instructional descriptor (i), environment descriptor (e), or professional development descriptor (p). Tables 1 and 2 detail the learning and teaching theme codes, respectively. These codes appear in case study analyses following quotations and other relevant data.

Table 1

Learning theme TPACK codes used for interview analyses

Level	Mathematics learning descriptor	Conception of student thinking descriptor
Recognizing	L1m	L1c
Accepting	L2m	L2c
Adapting	L3m	L3c
Exploring	L4m	L4c
Advancing	L5m	L5c

Table 2

Teaching theme TPACK codes used for interview analyses

Level	Mathematics learning descriptor	Instructional descriptor	Environment descriptor	Professional development descriptor
Recognizing	T1m	T1i	T1e	T1p
Accepting	T2m	T2i	T2e	T2p
Adapting	T3m	T3i	T3e	T3p
Exploring	T4m	T4i	T4e	T4p
Advancing	T5m	T5i	T5e	T5p

Case Studies

School data, background information, and data analyses of the seven participants will be shared in this section. The data for each participant will be described individually. Data reported will include the following analyses: initial interview, observation, follow-up interview, lesson sample, and survey. Pseudonyms will be used, and irrelevant details will be changed to ensure confidentiality of study participants. The case studies include the following participants: Ms. McKinnie, Mr. Witt, Mr. Statten, Ms. Spise, Ms. James, Ms. Thomas, and Ms. Bradley. These case studies will be reported in the order of their initiation to the study, marked by the occurrences of their initial interviews.

Ms. McKinnie (Participant 1)

Background. Ms. McKinnie taught at High School A, a rural school within a district where more than 70% of students qualified for free or reduced lunch the previous year. The racial makeup of this district was approximately 45% Black and 55% White. High School A had a five-year graduation rate of less than 60%, and per pupil expenditures were more than $1000 less than the state average.

Ms. McKinnie was the only Algebra I teacher at High School A. Her students were in grades eight through twelve. At the time of the study, Ms. McKinnie was in her fourth year as a teacher and her second year of teaching Algebra I. She had not received formal instructional technology training. Ms. McKinnie had TI-82 and TI-83 graphing calculators available in her classroom.

Initial Interview. During the initial interview, the researcher asked questions to gain an understanding of Ms. McKinnie's practices and beliefs with regard to instructional technology. Ms. McKinney's relevant responses to interview questions were connected to TPACK descriptor statements for the teaching and learning themes (Niess et al., 2009). Statements from the interview of notable relevance to technology integration will be shared in this section.

When asked how she felt about teaching with technology, Ms. McKinnie responded with the following statement.

> Honestly – I love it. I mean, I love it. I use my overhead daily. Wish I had [an electronic whiteboard] because I am tied to that overhead and I'm there nonstop. I would love to be able to walk around the room . . . I don't feel I can get enough one-on-one attention to see what they're doing. As far as calculators, I have that calculator that plugs into the overhead. I use that every time I have an opportunity to. So, I am all about technology. (L1c)

There are two notable aspects to her response. Prior to the beginning of the interview, the researcher discussed the difference in instructional technologies and non-instructional technologies. Ms. McKinnie did not differentiate instructional technology and non-instructional technology (electronic whiteboard) in this statement. With regard to TPACK, her statement about the use of the overhead calculator showed that she was "more apt to accept the technology as a teaching tool rather than a learning tool" (Niess et al., 2009, p. 21).

As the interview continued, Ms. McKinnie described calculator use on a test as "kind of cheating. . . . you know, basically you're not doing anything except plugging something in a calculator . . . [but] you're using the technology afforded to you." (L2m) She was specifically referring to using the graphing capabilities on graphing calculators to find the intersection of two lines. Although she consistently acknowledged this type of use of calculators during assessment, she expressed reservations about calculator use during instruction. Ms. McKinnie stated, "there are times when I don't allow them to use the calculator, so they will, you know, use their brain a little more." (L2m)

When asked to describe the role instructional technology played in her classroom on a daily basis, Ms. McKinnie responded, "we constantly use the calculator. . . . more so than I would like." (L1m) She continued by describing a specific topic that had recently been studied in her classroom.

> I introduced slope-intercept form last week. And they all know they can go to *y*-equals and put it in and figure out how to graph the line, but I wanted them to see how to do it without it by using the *y*-intercept and the slope. But, you know, when tests came it was like, "Please let us have the calculator back!"

After being questioned about what influenced her decision to allow students access to the calculators each day, Ms. McKinnie responded with the following.

> When I introduce something that I want them to learn before they turn into, "Oh, I can do this in the calculator." But for the most part – because, you know, after we've learned a

> concept, I do let them. But they've got to prove to me they can do it first without the shortcut because I tell them constantly, "you don't have a calculator at home." I think there's a thing going on in the state education about, you know, taking away the calculator for part of the Algebra I test. So, you know, they've got to know how to do it without the calculator also. But I do allow them to use it, especially when it's things that they've already learned. (T1e)

These two responses indicated that Ms. McKinnie "permits students to use technology 'only' after mastering certain concepts," which is the usage descriptor for the access theme of the TPACK model (Niess et al, 2009, p. 23). This suggested that she was at the recognizing level for this theme. The concern about changes in calculator use on the state-mandated high stakes testing is a theme that will be highlighted in the following chapter.

As the interview continued, Ms. McKinnie consistently expressed frustration and concern about technology use. She described a recent presentation to students who had been previously unsuccessful on the state Algebra I exam. The presentation demonstrated to these students how to use the graphing utility in the calculator to find the solution to a system of linear equations. Ms. McKinnie expressed her displeasure with this strategy. "They're memorizing how to put something in the calculator. And yes, it's helping our school get our scores up on our state test, but how is it really benefiting the students? And it's not." (T1m) The researcher noted that although Ms. McKinnie viewed such a task as being purely rote and void of opportunities to develop conceptual understanding, the benefit to the students lies in the implementation of such a task.

Ms. McKinnie made multiple references to technology misuse and concerns, and she expressed an interest in learning more about using instructional technologies. When the researcher asked her to describe improvements she would like to occur in her classroom, she responded as follows.

> I would definitely like to learn, do different. I guess I'm still learning so much. So I'm working on doing things different every day. I would definitely like to learn more because there are possibly things that I'm teaching that would be easier for them to do in the calculator where they still would have to use some math concepts because they got to that point where they used it in the calculator. . . . Where it's not just like this problem where they just stick it in the calculator and look for the point of intersection. Where they have to actually work through part of the problem instead of spending another fifteen minutes working on it.

Ms. McKinnie expressed in this statement a desire to learn more about technology and its capabilities to enhance student learning, but her knowledge gaps about the capabilities of the technology and the applications in the classroom restricted her view of the potential technology holds.

Although Ms. McKinnie did make a statement that suggested she was at the accepting level for the learning theme, the researcher examined the interview in its entirety and classified Ms. McKinnie as being at the recognizing level for both the learning and teaching themes of TPACK. She expressed the use of technology in her classroom, but this use primarily included procedures and calculations.

Observation. The researcher observed an Algebra I lesson in Ms. McKinnie's classroom approximately two weeks following the initial interview. Upon entering the classroom, the researcher noted that students' desks were arranged in rows and an overhead projector and stool were positioned at the front of the classroom.

As students entered the room, they each retrieved a calculator from a designated area. Then they placed the calculators on their desks and began working on a set of problems that were written on the whiteboard. As class began, Ms. McKinnie called on students to share their responses to the problems from the board. Next, Ms. McKinnie asked students to get out their homework assignments because they were going to “go over the tricky ones.” To conduct the homework review, Ms. McKinnie wrote problems on the board and worked the problems, narrating each step in finding the solution. Ms. McKinnie paused occasionally to remind students about sign rules for operations involving integers. She also reminded them to “remember 3 and *x* stay together like a couple” when considering the term 3*x*. She used the overhead projector to display solutions and work for the homework items.

Fifteen minutes after class began, she asked students to get out their notes from the previous day. She connected the new topic, perpendicular lines, with the prior topic, parallel lines. After a teacher-led lesson that included a series of questions and answers, she modeled several examples on the overhead projector. She occasionally called on students to share their solutions; however, the teacher led most of the lesson. Students were shown one way to work each problem. After the examples, the teacher reminded students to always check their answers and told them to use their calculators to check their work. (L1c) Then she assigned class work to be completed for homework. To summarize the lesson, Ms. McKinnie called on students to repeat the definitions of parallel and perpendicular lines and to describe the slopes of lines that are perpendicular or parallel.

Throughout the lesson the teacher referenced calculator use with regard to checking solutions. This lesson was technology-independent, and there was minimal calculator use by students. Students used calculators to check solutions and perform operations. (L1c) The lesson was teacher-centered, and the teacher asked questions that focused on memorized definitions and procedures. Technology was discussed by the teacher after the concept had been presented formally. (T1i)

Considering the observation of Ms. McKinnie in its entirety, the data further supported Ms. McKinnie's classification of being at the recognizing level for the teaching and learning themes. Considering the TPACK descriptors, the researcher noted that Ms. McKinnie did not use technology in ways that helped students develop understanding of mathematical concepts (T1e). In considering the other TPACK descriptors, the observation suggested that Ms. McKinnie did not fit the descriptors at the recognizing level for the teaching theme; however, as previously stated, participants who did not fit the criteria for the recognizing level were still classified as recognizing. Hence, the researcher classified her as recognizing level for the teaching theme due to barriers related to the functionality of the technology and its applications in the classroom.

Follow-up Interview. The follow-up interview with Ms. McKinnie occurred immediately following the observed lesson. In the follow-up interview, Ms. McKinnie stated that when she taught with calculators, the lesson was primarily teacher led "because if you don't keep a close eye on them when we're using the calculator, they're going to be drawing and figuring out other things they can do with it." (T1m) This statement exemplified management concerns. When questioned about the level of student engagement when calculators were available, Ms. McKinnie stated, "I think it makes them more engaged because they're interested in the calculators. They want to figure out an easy way to do something so they're going to pay attention to that."

During the follow-up interview, Ms. McKinnie also referenced the state Algebra I exam, saying that if she taught a different subject she would "have more opportunities to . . . figure out activities instead of just teaching the curriculum." (L1m) This statement indicated that Ms. McKinnie viewed technology tasks as separate from the curriculum and intended topics. She did not indicate a vision of technology being used to enhance the learning opportunities for students. She also continued to express concerns about calculator misuse, noting "adding fractions and multiplying fractions" as misuses of the calculator.

Data gathered during the follow-up interview supported previous data suggesting that Ms. McKinnie was at the recognizing level for the teaching and learning themes of TPACK (Niess et al., 2009).

Lesson Sample. The researcher repeatedly requested that Ms. McKinnie submit a sample lesson that exemplified her view of how technology should be used to teach mathematics. Ms. McKinnie did not submit the lesson sample.

Self-Report Survey. Ms. McKinnie's responses to the TPACK Development Model Self-Report survey indicated her perceptions about her TPACK levels to be mixed for the various themes when considering graphing calculators. A summary of her survey responses is provided in Figure 1. Shading indicates that the participant identified with the statement.

	Recognizing	Accepting	Adapting	Exploring	Advancing
Curriculum & Assessment (curriculum)			■		
Curriculum & Assessment (assessment)				■	
Learning (mathematics learning)	■	■			
Learning (conception of student thinking)			■		
Teaching (mathematics learning)			■		
Teaching (instruction)					■
Teaching (environment)		■			
Teaching (professional development)		■			
Access (usage)				■	
Access (barrier)				■	
Access (availability)		■			

Figure 1.Ms. McKinnie’s responses to the TPACK Development Model Self-Report Survey.

Ms. McKinnie's survey responses indicated that she generally believed that her TPACK levels were higher than the levels suggested by the interview and observation data; however, her responses to the survey on the teaching theme, mathematics learning descriptor, were in agreement with the other data collected by the researcher. Ms. McKinnie was noted by the researcher to be at the recognizing level for the teaching and learning themes of TPACK due to her limited view of the capabilities of technology and her lack of vision about how to improve.

Mr. Witt (Participant 2)

Background. Mr. Witt taught at High School B, a rural school located approximately thirty miles from High School A. High School B was located within a district where approximately 49% of students qualified for free or reduced lunch the previous year. The racial makeup of this district was approximately 4% Asian, 42% Black, 3% Hispanic, and 50% White. High School B had a five-year graduation rate of 87%, and per-pupil expenditures were more than $1000 above the state average.

Mr. Witt was in his sixth year of teaching at the time of the study. He taught AB Calculus, BC Calculus, and Algebra I. He identified himself as someone who grew up with an abundance of available technology. Mr. Witt had access to several presentation and instructional technologies in his classroom, including internet, computers, clickers, graphing calculators, and an electronic whiteboard.

Initial Interview. The researcher asked Mr. Witt the same questions asked of Ms. McKinnie. Responses relevant to the teaching and learning themes of TPACK will be discussed in this section (Niess et al., 2009).

While describing his experiences as a learner with instructional technology, Mr. Witt recounted and stated the following.

And [students] just amaze me sometimes – the little amount that we use these calculators – we don't know [graphing calculators] up to their capabilities. You know, one of the things that new ideas and newer things that I never saw until I was a student was using the CBR, the motion detector, you know, with the probe – the ranger probe. And that's what we use to teach slope. And I could very easily use it in calculus, if time permitted, to teach velocity and relate velocity and position and acceleration and derivatives and integral. So, you know, it's constantly changing. (T1m)

In this statement, Mr. Witt acknowledged an understanding that technology had the potential to be used in ways that make concepts more accessible to learners, but when he considered applying this potential to his calculus class, he was concerned that the time spent with technology tasks would take away from learning time. This concern suggested that he was at the recognizing level for the teaching theme and related to the mathematics learning descriptor for that level from the TPACK Development Model (Niess et al., 2009). It was also notable that Mr. Witt was not complacent in his teaching style. He acknowledged the need and desire to grow as a teacher and mentioned ways in which he sought out new tasks and ideas for his classroom. (T2p)

When asked to describe technology use on a daily basis in his classroom, Mr. Witt first described how students used the clickers for daily quizzes. He mentioned that this practice helped his calculus students prepare for the AP exam. Considering the use of graphing calculators, he said the following.

The calculators, my algebra kids use calculators every day. My calculus kids, most of the time, or a lot of the time, use calculators. Obviously we learn in calculus how to do it both with a calculator and without a calculator because that's the AP and College Board's push – to connect everything graphically and analytically. (T1e)

The researcher noted Mr. Witt's reference to NCTM Process Standards, specifically connections and representations. It is also notable that Mr. Witt described daily use of the calculators; however, throughout the interview he did not describe calculators as being used to explore new concepts. Calculator use was described in reference to using programs or performing computations that would be tedious without a calculator. (L1c)

Mr. Witt referenced his use of the internet for classroom instruction multiples times. At one point he described the following.

> If I find a good website, for instance, when we started spinning volumes of revolution, we'll do it in January in BC and we'll do it in March in AB. There's a great website that actually shows the 3D image of taking a graph, taking half of a parabola and revolving it around the *y*-axis. You know, anytime I can find a great illustration online, or a great problem online, or a good problem of the week or any of those things – you know, I'd be crazy not to take advantage of that. So anything that'll help supplement my teaching and supplement the resource materials we have – I try to take advantage of that… In algebra, we'll find an online website – especially when we talk about graphs – and I'll just pull up the graphs on the internet. And, you know, "guys tell me the story this graph is telling me. What do you notice?" They'll talk about slope. They'll talk about rate of change. They'll talk about *y*-intercept. So it definitely helps out as far as visual. (T1e)

This statement suggested that Mr. Witt used technology to bring in representations that would not have been possible without the technology; however, his description and our subsequent conversation suggested that his lessons were teacher-led and that he viewed such tasks as supplements to instruction. These statements aligned with the curriculum descriptor at the recognizing level for the curriculum and assessment theme of TPACK (Niess et al., 2009).

Many of Mr. Witt's responses during the initial interview suggested that he used technology as a "teaching tool" rather than fostering its use as a "learning tool," which connected to the conception of student thinking descriptor for the recognizing level of the learning theme of TPACK (Niess et al., 2009). As further evidence of this limited technology use, Mr. Witt described using the internet to "find a good explanation . . . to help explain why we write d*y*, d*x* when we take a derivative of *y*."

Mr. Witt perceived himself to be viewed by his colleagues as "advanced at using the technologies" because he used technology in ways that his colleagues did not. He also referenced situations where other teachers sought out his help and advice when preparing to use technology in their classrooms. Mr. Witt described how he continued to seek out ways to better his teaching and technology use: "I guess my biggest concern is, am I using this technology, am I using the internet, am I using this, am I using that as effectively as I should? You know, because you can always improve yourself." Although Mr. Witt did not mention areas of weakness in instructional technology integration, he saw himself as a life-long learner. Mr. Witt demonstrated the potential and the desire to improve his use of instructional technologies.

Mr. Witt's responses suggested that he was at the recognizing level for the learning and teaching themes of TPACK; however, his responses suggested he was moving toward the accepting level for the teaching theme because of his references to ways he has sought out professional development opportunities (Niess et al., 2009).

Observation. The researcher observed Mr. Witt's Calculus class the day following the initial interview. The students' desks were arranged in rows. Mr. Witt's desk was located in the front corner of the room, and an electronic whiteboard was located in the front center of the room. A student desk was located in the rear center of the room. During instructional time, Mr. Witt stood at this desk and led the class.

As students entered the classroom, they socialized until after the bell rang for class to begin. After gaining the students' attention, Mr. Witt displayed the following statement on the electronic whiteboard: "We sometimes need an efficient method to estimate area when we cannot find the antiderivative." Then Mr. Witt worked through a u-substitution problem from assigned homework. Next Mr. Witt asked students to recall the Trapezoidal Rule and warned students to not confuse it with Simpson's Rule. Then Mr. Witt asked questions about whether the Trapezoidal Rule gives an exact answer and under which conditions the answer would be an overestimate or underestimate. The responses were related to the concavity of the curve being considered. Mr. Witt used presentation slides on the electronic whiteboard to present an example.

After presenting the example and the steps for working the problem without a calculator, Mr. Witt provided instructions for using a program to solve the problem, "To use the calculator, go to *y*-equals, plug in *x*-squared – program – go to traprule – and put in the variables. What do you get? There you go! I saved you some time! Thank me later." (T1e) After instructing students to use the program, Mr. Witt compared the use of the Trapezoidal Rule with the Midpoint Rule and asked "how does the Trapezoidal Rule compare to the Midpoint Rule?" After a brief discussion, the class consensus was that these two algorithms were not the same. Furthermore, they deduced that one provided an overestimate, and one provided an underestimate. Next, Mr. Witt asked students to consider which one would provide the better approximation and then to share what they noticed about the errors of the two rules. The errors were displayed on a slide on the electronic whiteboard. Mr. Witt told the class that the Midpoint Rule error is always half the

Trapezoidal Rule error and in opposite directions. One student questioned whether this would always work, and Mr. Witt responded, “it works! I promise, it works!”

Then Mr. Witt told the class they would come up with Simpson’s Rule together. Mr. Witt displayed two graphs with the Midpoint Rule and Trapezoidal Rule graphs overlaid. Then he displayed a slide that demonstrated how Simpson’s Rule is the combination of the aforementioned algorithms. After this explanation, Mr. Witt described to the students how to use a calculator program to find a solution using Simpson’s Rule. Next, Mr. Witt displayed a formal definition for Simpson’s Rule. Mr. Witt also mentioned some real-world applications of Simpson’s Rule, including the interpretation of a scatter plot with data obtained from a radar gun and a chemistry laboratory task with a given rate but no function. Mr. Witt instructed students to look up the proof for Simpson’s Rule before administering a quiz. Students were not allowed to use calculators on the quiz.

The researcher analyzed data from the observation and concluded that Mr. Witt was at the recognizing level for the teaching theme of TPACK. No data relevant to Mr. Witt’s level for the learning theme was collected during the observation.

Follow-up Interview. The follow-up interview with Mr. Witt occurred four days after the observed lesson. During the follow-up interview, Mr. Witt mentioned that his students used online textbooks. When asked about whether he planned opportunities for students to make connections to other areas of mathematics or to everyday life using technology, he responded with the following.

> A lot of the time those opportunities just come up, just appear. And to be honest with you, it could happen with or without technology. It could happen as you’re on a whiteboard or a chalkboard or whatever. But, you know, having the capability to present,

> to post the internet on the board, to project it on the board – if something comes up. I know that last year in algebra, when we started talking about graphs, I sat down and I said, "okay." I searched graphing, Googled graphs. And "tell me what this graph is doing." So it just helps you to kind of delve a little deeper into those concepts, if those opportunities arise. (T1e)

Mr. Witt consistently reported using the internet as a source of finding representations and as a source of information for his classroom. He recounted, "if there's something I'm not sure of, you know, I can go over there and Google it, and – bam – here's us a different explanation. So that definitely helps."

The researcher also asked Mr. Witt whether he would describe his class as teacher- or student-centered when he teaches with technology. His response was as follows.

> I would say both. It depends on what we're doing that day. You know, in the algebra class I can definitely let it be more student-centered. Whereas in calculus, it's probably more teacher-centered, but it could be both. I mean, with the programs, obviously, I kind of have to show them the syntax to type it in. But once they know that, in calculus – bam – it's theirs. You know, I don't ever use it again. They use it a lot. . . . In calculus I'm a lot more old-fashioned than I am in algebra. In algebra the kids pretty much go and do. Whereas in calculus, [the students] kind of want me to do it. So, I would say both. I would say just depending on how you want to structure a lesson it could be both.

This response suggested that Mr. Witt viewed the needs of the learners to be different for the two subjects. The researcher followed up his responses by asking why he felt that it was different for the calculus and the algebra classes. Mr. Witt referred to "the higher level math" and said that "it seems like they're way more needy of me kind of helping them through the process and seeing where it comes from." (T2m) Mr. Witt also referenced the new symbolism that is introduced in calculus as a reason those lessons tend to be more teacher-led than algebra lessons.

After analyzing data from the follow-up interview lesson, the researcher identified Mr. Witt to be at the recognizing level for the teaching and learning themes of TPACK; however, as with other data, the follow-up-interview responses suggested that Mr. Witt was close to moving to the accepting level for the teaching theme.

Lesson Sample. At the initial interview, the researcher requested that the participants each submit a task or lesson they had used in their classrooms that they felt exemplified how technology should be used to teach mathematics. Mr. Witt submitted an outline of a task in which students explored the concept of slope using a motion detector and a computer program. According to the outline, students worked in groups of four. First, students observed a lesson on how to use the motion detectors. Then, students completed the exercise. Few details were provided about this task. Therefore, the researcher determined that there was not sufficient evidence to analyze this data and make conclusions regarding Mr. Witt's TPACK levels.

Self-Report Survey. Mr. Witt recorded the electronic whiteboard as the technology chosen to report on for the TPACK Development Model Self-Report survey; however, this technology is not considered instructional. Per a subsequent conversation with Mr. Witt, these responses would be similar if he had selected graphing calculators, which are considered instructional technology. Mr. Witt's responses to the TPACK Development Model Self-Report Survey indicated his perceptions about his TPACK levels to be at the exploring or advancing level for nine of the eleven descriptors. The remaining two descriptors were marked as being at the recognizing level (assessment descriptor) and the adapting level (access, availability descriptor). A summary of

Mr. Witt's responses is provided in Figure 2. Shading indicates that the participant identified with the statement.

	Recognizing	Accepting	Adapting	Exploring	Advancing
Curriculum & Assessment (curriculum)					■
Curriculum & Assessment (assessment)	■				
Learning (mathematics learning)					■
Learning (conception of student thinking)					■
Teaching (mathematics learning)					■
Teaching (instruction)					■
Teaching (environment)				■	
Teaching (professional development)				■	
Access (usage)				■	
Access (barrier)					■
Access (availability)			■		

*Figure 2.*Mr. Witt’s responses to the TPACK Development Model Self-Report Survey.

Mr. Witt's responses to the survey indicated that he perceived himself to have higher TPACK levels than suggested by other data the researcher collected. Based on interview and observation data, the researcher identified Mr. Witt to be at the recognizing level for the teaching and learning themes of TPACK. Mr. Witt has a clear view of how to improve his teaching with respect to integrating technology, and he was motivated and spoke with confidence in his own understandings of content and student learning.

Mr. Statten (Participant 3)

Background. Mr. Statten taught at High School C, a rural school district located approximately 50 miles from High School A and approximately 35 miles from High School B. High School C was located within a district where approximately 60% of students qualified for free or reduced lunch the previous year. The racial makeup of this district was approximately 1% Asian, 32% Black, 9% Hispanic, and 58% White. High School C had a five-year graduation rate of 81%, and per-pupil expenditures were approximately $300 less than the state average.

Mr. Statten was in his fifth year of teaching at the time of the study. He taught Geometry to students in grades nine through twelve. Mr. Statten had access to graphing calculators, a document camera, clickers, and an electronic writing tablet in his classroom.

Initial Interview. The researcher met with Mr. Statten prior to school one morning for the initial interview. After arriving at the school, Mr. Statten requested that the researcher limit the length of the interview. At his request, the researcher omitted some of the interview questions that were asked of other participants during the initial interviews. Questions that were not asked during the initial interview were submitted to Mr. Statten for the follow-up interview. Mr. Statten's responses to interview questions were connected to TPACK descriptors of the learning and teaching themes of TPACK (Niess et al., 2009).

When describing how he felt about teaching with technology, Mr. Statten responded with the following.

> I think students benefit the most from having technology because they're in a technology-based world…. So when they can actually use this technology in class, that seems to be more beneficial to them because they're getting to do something that they sort of know how to do already even if it's a brand new topic.

In this statement, Mr. Statten referenced his observation that students are comfortable with a variety of technologies from their everyday lives. He suggested further that this technology could be used to explore new concepts in the mathematics classroom; however, this suggestion was not substantiated by an account of how he had actually used technology to introduce a new concept.

As the interview continued, the researcher asked Mr. Statten to describe his experiences as a learner with educational technology. Mr. Statten mentioned that during his teacher preparation program he engaged in experiences with graphing calculators and with the TI-Navigator system; however, when the researcher asked about his use of instructional technologies as a teacher, he responded with the following statement.

> We actually have a TI-Navigator system, but nobody really knows how to use it. [We] haven't been trained on it – [we] don't know anything about it really. I sort of know a little bit about what can be done with it, but we have no training with it so we have a two- or three-thousand dollar system sitting in this closet right here that hasn't been used – or maybe been used once.

Despite acknowledging having had prior experiences with the TI-Navigator system, Mr. Statten expressed that he was not prepared to use the system in his classroom to teach mathematics. Furthermore, he expressed limited knowledge of the capabilities of the TI-Navigator system.

When asked to describe the role technology plays in his classroom on a daily basis, Mr. Statten responded with the following.

> Well a lot of times, especially in Geometry, there's not as much calculations that students have to do with [calculators]. I allow them to have it if they need to do computation. I do use it sometimes. We use Cabri Jr. a lot when we're starting to talk about perpendicular and angle bisectors. We used it a couple weeks ago when we talked about corresponding angles, same-side interior angles. . . . And some students really like it because, again, they're getting to play with it and draw their stuff and they really enjoy that. And then others are just kind of going through the motions. . . . But on a daily basis . . . they can use the calculator. . . . I guess the main way they use it is just for computation – the simple things like they don't have to have it for, but it just makes it easier for them. (L1c, T1e)

Mr. Statten's response indicated that he did use technology when introducing specific concepts in his classroom; however, the researcher asked him to elaborate on these lessons in order to understand the ways in which the technology was used.

> With Cabri Jr., instead of me sitting up there and doing it and talking about it, I prefer to let them – well, me, kind of walk them through the steps of how to get it set up and then them kind of discover what the topic is (T3e, L3m).

The researcher noted that this description indicated a procedural use of the technology, but also engaged students in exploration of certain topics. This aligned with the adapting level of the environment descriptor for the teaching theme and the adapting level mathematics learning descriptor for the learning theme of TPACK (Niess et al., 2009).

The researcher noted that this statement was the primary indication that Mr. Statten was at the adapting level for the teaching and learning themes of TPACK. Furthermore, the researcher noted that in order to confidently assign these levels to Mr. Statten, more evidence was necessary because this statement was vague and conflicting.

Observation. The researcher observed a lesson in Mr. Statten's classroom one week following the initial interview. The students' desks were arranged in rows. Mr. Statten's desk was located in the back of the room, and a podium with a document camera was located at the front of the room. During instructional time, Mr. Statten stood at or near the podium.

As students entered the classroom, Mr. Statten informed them that they would be using clickers to complete ACT practice problems. The students used ACT Practice Test booklets and worked quietly on the practice problems for ten minutes. As students finished items, they submitted their responses using the clickers. At the end of ten minutes, Mr. Statten listed the answers, and students graded their own work. Then, Mr. Statten told the students a number to indicate what their scores would have been on the mathematics section of the test based on the number of items they marked correctly.

Next, Mr. Statten asked students to get out their homework from the previous night. He quickly provided the answers to the homework items. Then Mr. Statten distributed a review sheet for an upcoming test and directed the students to divide into two large groups. The groups competed against each other, buzzing in using electronic buttons placed on their desks. When a group buzzed in, it provided a solution to a problem from the review sheet. When students repeatedly responded incorrectly to a problem, Mr. Statten responded, "you should know how to work this one, but I'll be impressed if somebody gets this next one." No students responded correctly to the next problem. Mr. Statten stopped the game and worked through the problems in a procedural manner and without noting the appropriate units in the solution. After working these problems, Mr. Statten reminded them to study for their test, and class was dismissed.

The researcher noticed that this lesson was technology-independent. Furthermore, no instructional technology was used. Also, Mr. Statten did not acknowledge students' understandings and misunderstandings in a way that guided instruction, and technology was not used in a way that aligned with the mathematical goals or offered students access to representations that would otherwise be inaccessible. Due to these limitations, the researcher was unable to use observation data in assigning TPACK levels for Mr. Statten.

Follow-up Interview. At Mr. Statten's request, the researcher emailed follow-up interview questions rather than conduct a face-to-face follow-up interview as was done with the other participants. In crafting the follow-up interview questions for Mr. Statten, the researcher aimed to gain a better understanding of the scope of instructional technology use in his classroom.

The researcher asked Mr. Statten to describe how he planned opportunities for students to make connections to other areas of mathematics or to everyday life using technology. Mr. Statten's response was as follows.

> I have always tried to use technology in my classroom to help students make connections. I often let students use technology to explore new concepts and try to develop or find more activities that can be used to teach the concepts to the students. (L3m)

The researcher found the wording of this response interesting because Mr. Statten described that he often "let" students use the technology. Although it does not portray a clear picture of the technology use, this statement indicates a level of technology independence. That is, students may have access to technology, but that technology was not required to complete the task. It was also notable that Mr. Statten made a second reference to using technology to introduce new concepts. (L3m)

The researcher also asked Mr. Statten to distinguish whether his lessons that included instructional technology are primarily teacher-centered or student-centered. Mr. Statten indicated that the lessons were teacher-centered because the students often lacked the familiarity with the technology necessary to conduct a student-centered lesson. This response was notable since he communicated in the initial interview that students' everyday uses of technology enhanced opportunities for its integration in the classroom.

The researcher also asked Mr. Statten to consider how student engagement changed when technology was used to teach mathematics. Mr. Statten responded with the following.

> I think that student engagement increases somewhat because the students are following my lead. When students have been asked to use technology without my lead, they are often much more engaged because they are working to find the solutions instead of just doing what I tell them to do. When students are allowed to work with something they feel comfortable with, they are going to be more engaged.

The researcher found this response to be difficult to interpret. The first sentence suggested that students were engaged because the teacher was leading them through a task; however, the remainder of the statement suggested that Mr. Statten saw open-ended tasks as more engaging because students worked to develop their own strategies. The researcher noted that Mr. Statten's statements beg for explanation; however, due to the nature of the follow-up interview, the researcher was unable to obtain further information. Subsequently, the researcher attempted to schedule an additional face-to-face interview but was unsuccessful.

Lesson Sample. The researcher repeatedly requested that Mr. Statten submit a sample lesson that exemplified his view of how technology should be used to teach mathematics. Mr. Statten did not submit the lesson sample.

Self-Report Survey. Mr. Statten's responses to the TPACK Development Model Self-Report survey indicated that he perceived himself to be at the exploring level for the learning theme and at the adapting or exploring level for the teaching theme. A summary of his survey responses is provided in Figure 3.

	Recognizing	Accepting	Adapting	Exploring	Advancing
Curriculum & Assessment (curriculum)					
Curriculum & Assessment (assessment)					
Learning (mathematics learning)					
Learning (conception of student thinking)					
Teaching (mathematics learning)					
Teaching (instruction)					
Teaching (environment)					
Teaching (professional development)					
Access (usage)					
Access (barrier)					
Access (availability)					

Figure 3.Mr. Statten's responses to the TPACK Development Model Self-Report Survey.

Most of the data collected indicated that Mr. Statten was at the adapting level for the teaching and learning themes of TPACK; however, survey data indicated that he perceived himself to be at the exploring level for most of the teaching and learning theme descriptors of TPACK (Niess et al., 2009).

Ms. Spise (Participant 4)

Background. Ms. Spise taught at High School D, a rural school located approximately seventy-five miles from High School A, sixty miles from High School B, and 30 miles from High School C. High School D was located within a district where approximately 60% of students qualified for free or reduced lunch the previous year. The racial makeup of this district was approximately 1% Asian, 29% Black, 1% Hispanic, and 69% White. High School D had a five-year graduation rate of 72%, and per-pupil expenditures were approximately $775 less than the state average. Two other participants in this study, Ms. James and Ms. Bradley, also worked at High School D.

Ms. Spise was in her tenth year of teaching at the time of the study. She taught Algebra I and Calculus. In her classroom, Ms. Spise had access to an electronic whiteboard, SmartView software, and graphing calculators. Although she had no formal technology training, Ms. Spise had a mentor, Ms. James, who was also part of the study. Through this relationship, Ms. Spise developed a curiosity and desire to explore further instructional technologies.

Initial Interview. During Ms. Spise's initial interview, the researcher asked questions to gain an understanding of Ms. Spise's practices and beliefs regarding instructional technology use in the classroom. Ms. Spise's responses that connected to the teaching and learning themes of TPACK descriptor statements will be discussed in this section. Other themes emerged from the interview and will be discussed in a subsequent chapter.

Ms. Spise expressed that technology was ingrained in the culture of her students. She stated that when she began her career she "wanted them to do more by hand . . . [and] have more knowledge in their head" but recalled that she "saw that after a couple of years that probably wasn't the best. So now I let them rely heavily on the calculator." When the researcher further questioned how the calculator was used in her classroom, Ms. Spise responded, "we use calculators on a daily basis, of course, for the state test. . . . We look at graphs and look at tables. . . . It really helps them connect." Ms. Spise expressed, however, that most of the use of calculators was to provide affirmation to students about their solutions. (L1c)

As the interview continued, the researcher asked Ms. Spise to describe what influenced her daily decision to use or not use instructional technology to teach mathematics. Ms. Spise responded, "My plans revolve around the state test. . . . So everything I do is pointed, you know, 'is this going to help them on the state test?'. . . . It dictates what I do on a daily basis."

Ms. Spise described herself as "not as savvy [with technology] as a couple of other teachers" and elaborated with the following statement.

> I do not feel comfortable using something that I don't feel like I have mastered. . . . Like the Navigators, I would love to learn, but until I had really mastered it, I would not use it. So I guess I'm not as gutsy as some of the others. I'm more safe. I like to be safe. . . . My personality is real structured, and so if it's something that's going to cause a lot of chaos, I really can't handle that, so I would definitely say I'm not as technology-savvy as some of the other ones.

During her interview, Ms. Spise identified Ms. James as a mentor and a resource. She described her admiration for Ms. James.

> She uses the Navigators, and she – she does it all. She goes to all these conferences and, you know, learns all this new stuff. So if I ever need anything or have questions about anything. . . . She's the one to go and ask. . . . So I don't feel uncomfortable asking for something. She doesn't make me feel like I'm not a good enough teacher. And so I feel real comfortable with her. I have gone to her class and observed.

The researcher asked Ms. Spise about specific improvements she would like as far as instructional technologies in her classroom. Ms. Spise responded with the following:

> I know there are all kinds of things out there. . . . I know that would be very beneficial, but . . . I don't really go to a lot of conferences anymore. . . . Really the only way I go is if [Ms. James] says, 'you want to come here with me? You want to do this with me?' And then I'll go with her. But I really don't know anything else that I would like to have besides a Navigator. Or [a document camera]. I'd really like to have [a document camera]. (T1p)

During the interview Ms. Spise expressed a concern that she did not have adequate time to engage her students in technology tasks due to constraints related to high-stakes testing (T1m). Ms. Spise did not express any understanding of uses of technology beyond calculations and reinforcing previously studied concepts (L1c, T1e).

The researcher analyzed data obtained during the initial interview and concluded that Ms. Spise was at the recognizing level for the teaching and learning themes of TPACK (Niess et al., 2009).

Observation. The researcher observed a lesson in Ms. Spise's classroom approximately three weeks following the initial interview. The class was an Algebra I class in which most of the students had previously taken Algebra I without receiving a passing grade. The students' desks were arranged in rows. As students entered the classroom, they retrieved a calculator from a designated area.

When class began, Ms. Spise instructed students to get out their homework assignments, and then she orally provided the solutions to the homework. Students occasionally asked Ms. Spise to work problems on the board, which she completed in a procedural manner. After the homework review, Ms. Spise distributed worksheets and assigned specific problems for students to work. As students worked, Ms. Spise walked around the room working problems at students' desks when they communicated needs for assistance. After ten minutes, Ms. Spise orally provided solutions to the assigned worksheet problems and instructed students to prepare to take notes.

Ms. Spise led a lesson on adding and subtracting radical expressions with like radicals, then with unlike radicals. She worked eight examples on the board before assigning three additional problems for students to work at their desks. After four minutes, Ms. Spise worked the three additional problems on the board. Ms. Spise instructed students to complete the other side of the worksheets during the remaining thirty minutes of the class period and to be prepared for a quiz the following day.

During the observed class period, no instructional technology was used; however, graphing calculators were available. Although most students retrieved calculators at the beginning of class, most of them returned the calculators prior to working the assigned problems. This is likely due to the nature of the problems, which required memorized procedures and single-digit addition. Instructional time ended thirty minutes prior to the end of class.

Due to the lack of integration of instructional technology, the researcher was unable to make any classifications related to Ms. Spise's TPACK levels from the observation data.

Follow-up Interview. The follow-up interview with Ms. Spise occurred immediately after the observed lesson. In the follow-up interview, Ms. Spise stated that her lessons were teacher-centered because “we have such a timeline and…. such a strict, you know, ‘you have to do this on this day and you have to do this the next day.’” Given the observed use of class time, this was a notable statement.

The researcher asked Ms. Spise to talk about how student engagement was different when students had access to instructional technology. Ms. Spise responded with the following statement.

> When they have that calculator on their desk, you know, they like it. They pick it up; they’re going to use it. If I took that calculator away, I think there would be a revolt . . . They just feel like it’s their security . . . Just like in my second period today, the guy that sat right here and didn’t know his multiplication tables in his head. So he uses his calculator for things as simple as 125 divided by 10. . . . And the kids just feel like it’s their safety net. You know, if they have that calculator then they can figure things out. But if I take that calculator away, then they feel like they’re done. (L1c)

In this statement, Ms. Spise expressed a limited view of the use of graphing calculators in a mathematics classroom. She viewed calculator use as limited to computations and checking solutions and this view was recognized in her students.

The researcher asked Ms. Spise if she engaged students in projects that required the use of instructional technologies. Ms. Spise responded that after her students completed high-stakes testing, she assigned projects; however, these projects were not technology-dependent.

Near the end of the interview Ms. Spise stated that she always let students use calculators because “some of [the students] can’t do some of your basic functions without the calculator . . .

because in seventh grade they just hand it to them and so from seventh grade they've had the calculator." Ms. Spise's rationale for allowing students constant access to the calculators was not focused on what students can learn using the technology but rather on compensating for what they have not learned. (T1i)

The researcher analyzed data gathered from the follow-up interview with Ms. Spise. This analysis suggested that Ms. Spise was at the recognizing level for the teaching and learning themes of TPACK (Niess et al., 2009).

Lesson Sample. The researcher obtained a lesson sample from Ms. Spise that Ms. Spise identified as exemplifying her vision of how instructional technology should be used to teach mathematics. Upon obtaining and analyzing the lesson sample, the researcher noted that the collected lesson sample did not include instructional technology integration. Furthermore, the lesson sample indicated that the observed lesson was indicative of Ms. Spise's daily routine in the classroom.

Because the lesson sample did not include the integration of instructional technologies, this data was not helpful in assessing Ms. Spice's TPACK levels for the teaching and learning themes.

Self-Report Survey. Ms. Spise's responses to the TPACK Development Model Self-Report survey indicated her perceptions about her TPACK levels to be mixed for the various themes. A summary of her responses is provided in Figure 4.

	Recognizing	Accepting	Adapting	Exploring	Advancing
Curriculum & Assessment (curriculum)					
Curriculum & Assessment (assessment)					
Learning (mathematics learning)					
Learning (conception of student thinking)					
Teaching (mathematics learning)					
Teaching (instruction)					
Teaching (environment)					
Teaching (professional development)					
Access (usage)					
Access (barrier)					
Access (availability)					

*Figure 4.*Ms. Spise's responses to the TPACK Development Model Self-Report Survey.

Ms. Spise's survey responses indicated perceived TPACK levels that were higher than the levels suggested by the interview and observation data. Ms. Spise was noted by the researcher to be at the recognizing level for the teaching and learning themes of TPACK (Niess et al., 2009).

Ms. James (Participant 5)

Background. Like Ms. Spise, Ms. James taught at High School D. She was in her twenty-eighth year of teaching. Ms. James taught Algebra II, Pre-Calculus, Advanced Algebra, and AP Calculus. Most of her students were in eleventh or twelfth grade. Ms. James had access to a document camera, graphing calculators, and a TI-Navigator system. Ms. James had attended numerous formal trainings that focused on instructional technology use. She had also sought out grants and other external funding to acquire technology for her classroom.

Initial Interview. During the initial interview, the researcher asked Ms. James a series of questions to gain an understanding of her beliefs and practices related to instructional technology integration. The researcher analyzed the interview data to make connections to the teaching and learning themes of TPACK (Niess et al., 2009). Interview data relevant to Ms. James's TPACK levels for the teaching and learning themes will be discussed in this section.

When asked to describe her feelings about teaching with technology, Ms. James responded as follows.

> I just think about how I taught before we got technology. And I just think about how it wouldn't have made sense to me. Math wouldn't have made sense to me if I were in those classes because now I don't see how math makes sense without seeing a picture of it and using graphing calculators or technology. So I think a lot of concepts were

probably lost with kids that needed a visual to see why things work and how they're connected. (L4c)

Ms. James's response indicated vision of instructional technology use as a tool for teaching and learning. She related her feeling toward the learners' experiences. This statement connected to the conception of student thinking descriptor at the exploring level for the learning theme of TPACK (Niess et al., 2009). Also, Ms. James made references to the NCTM Process Standards of connections and representations in this statement. Additionally, Ms. James's comment suggested that she used technology as a teaching tool in her classroom.

The researcher asked Ms. James to describe how her integration of instructional technologies had changed throughout her career. Ms. James referred to her years of teaching prior to having access to instructional technologies.

> I probably taught ten years before graphing calculators came out, and a colleague of mine and myself went to a math conference and we saw the very first…. graphing calculator there, and we said, "we've got to have those!" So we came back and went to businesses in the community and begged for money. I can't remember if we got enough money to purchase 15 calculators, but we had all those businesses come into our classroom and watch the kids use the calculators.

Ms. James had extensive teaching experience. She was able to recall in detail her acquisition of instructional technologies. Her statement demonstrated a certain internal motivation to incorporate instructional technologies while teaching mathematics. The researcher was particularly interested in Ms. James because she, along with a colleague, went to such efforts to acquire these resources for her classroom. The researcher asked Ms. James to recount how she learned to use the graphing calculators, and Ms. James responded with the following.

> This colleague of mine, she and I just taught each other how to use it, and that's the way we've done with everything. Whatever [the district] purchased for us, we've been able to get through participating in studies – we've just taught ourselves how to use it. Now if I go to conferences I'll try to go in sessions and learn as much as I can, but I don't get to go very many places. So whatever we do, we just figure out on our own. My students, they can teach me a lot. . . . Like with the [TI-89] graphing calculator. . . . They take one home, and they have one with them all the time. They come back, and they show me what it does. (T4p)

Ms. James's statement suggested that she actively sought out the knowledge necessary to integrate instructional technologies. She communicated that she used the resources that were available, including workshops, conferences, colleagues, and students. Her statement connected with the professional development descriptor at the exploring level for the teaching theme of TPACK (Niess et al., 2009).

Ms. James expressed during the interview that she was continuing to grow as a learner and a teacher. She spoke about plans to integrate dynamic geometry software into her calculus instruction.

> I have the [dynamic geometry software], but I haven't taught myself enough . . . I got it for my AP Calculus class. And I haven't gotten to the part of calculus that I know that I want to use it for. I haven't taken the time to sit down and learn it yet, but I do have it. I have in my mind what I want to do but; somebody told me there's already programs that you can download that have the motion and the change, the animations that I really wanted it for. . . . So I'm just going to have to research . . . During Christmas [break], I can get down to that and figure it all out. (T4p)

The researcher found it interesting that although Ms. James was a proficient user of multiple instructional technologies, she continued to seek out additional technologies and strategies for incorporating them in her classroom. Ms. James had a certain motivation that she made reference to during the interview. She described her experiences of becoming comfortable with using the TI-Navigator system in her classroom.

> You just have to dig your heels in and say, "I'm going to use it" because, you know, too much good comes out of it. For example, the kids are all engaged when you're using the Navigator system, but on the other hand, they may not stay on task. . . . It's hard to keep them on task when they realize that technology does so much, and they want to show off. If I ask them to send equations that do a certain thing, then . . . they're like "well who put that up there?" And it may not be anything like we were looking for. . . . You have to take the good with the bad.

There are two notable components to this statement. First, Ms. James expressed an internal motivation to succeed at implementing the Navigator technology. Based on data obtained during the interview, this motivation seemed to apply to other technologies as well and has shaped her teaching and learning strategies. The second notable aspect to this response is the idea that when using technology you've "got to take the good with the bad." This was a common notion that was expressed by multiple participants, and it will be discussed further in a subsequent chapter. The researcher chose to call this theme the *double-edged sword* view of technology.

During the interview, the researcher asked Ms. James to describe the factors that influenced her decision to incorporate instructional technologies into daily lessons. Ms. James's responded with laughter and stated that, "I don't ever think about not using it. It's an everyday thing." Technology had become an essential component to Ms. James's class, so much so that she referred to technology as "like your child or your husband" while emphasizing the role it played in her classroom.

As the interview continued, the researcher asked Ms. James to describe how she felt her colleagues perceived her use of instructional technologies. She laughed as she responded with the following.

> [My colleagues] probably think that I use it for everything and don't teach. . . . They know that I use it a lot, but I don't know that they know. . . . that we're doing explorations in here and we're not just using the calculators – and we're not just using the Navigator – to have fun.

Ms. James described professional development sessions she had planned and implemented that included instructional technologies; however, none of these sessions occurred within her district. She stated that, "there's nobody here that needs training. Everyone's trained." The researcher found this statement notable since Ms. Spise expressed a desire to learn more about instructional technologies.

Data gathered during the initial interview suggested Ms. James was at the exploring level for the teaching and learning themes of TPACK (Niess et al., 2009). The data further suggested that Ms. James was continuing to grow as a teacher and mentor. As stated previously, Ms. James was a mentor to Ms. Spise. Ms. James was an eager learner and educator whose successes were admired by her colleagues.

Observation. The researcher observed a Pre-Calculus lesson in Ms. James's room three weeks following the initial interview. At the beginning of class, Ms. James summarized the previous section in a few sentences and procedurally worked through an item from the homework assignment. This item required students to consider the graphs of two equations, a circle and a line, and determine the intersections of their graphs. Ms. James led a discussion about graphing a circle in the calculator, determining where the graphs intersected, and changing the graph so the top half of the circle was not visible. Ms. James also asked students to consider why the circle did not "look like a circle" when it is graphed in the calculator with the default window setting.

After reviewing the homework item, Ms. James distributed a task sheet. Ms. James described the instructions to the task by first asking students, "how many of you have iPods?" This conversation continued into a discussion of the history of recorded audio that related to the task. Ms. James asked one student to sit in her chair and operate the SmartView software so the students could confirm their steps as they worked through the task.

Using the data from the worksheet, students entered information into lists in the calculator. Ms. James anticipated technical difficulties with the technology that students would have, and she worked quickly to overcome these issues as they arose. Ms. James led the class through graphing the data into a scatter plot. Throughout the lesson, Ms. James often asked students to make predictions about what the graph would look like or how they would expect the data to look if the graph continued.

Ms. James challenged students to write an equation of a line that fit a specified set of data on the scatter plot. The class discussed whether it was reasonable to interpret this data linearly. Ms. James asked students to tell what they noticed about the data. Students noticed that, based on the data provided, the number of individual songs purchased increased while compact disc sales decreased.

A subsequent class discussion focused on how students would predict when the sale of digital albums to overtake the sale of compact discs. Other questions were used to guide students' interpretations of the data. The lesson was teacher-led but solicited active participation from the students. (T3e) Due to the prescribed nature of the task, students were offered few opportunities to make decisions about how to proceed. This lesson integrated multiple topics that the students had previously studied and did not introduce any new concepts. (T3m) This suggested that Ms. James was at the adapting level for the teaching theme of TPACK (Niess et al., 2009). The focus of the use of technology during the observed lesson was to enhance and assess student understanding of the concepts. (L4c)

Based on the observation data, Ms. James was at the exploring level for the learning theme and the adapting level for the teaching theme of TPACK (Niess et al., 2009).

Follow-up Interview. The follow-up interview with Ms. James occurred immediately after the observed lesson. In the follow-up interview, Ms. James stated that her lessons are usually teacher-led, although once or twice a week she implemented a student-led lesson. Ms. James acknowledged that the observed lesson was more teacher-led than she would have liked, but attributed this to having a visitor in the classroom. She discussed how she could adapt the lesson in the future: "I can see that activity being easily student-led or at least be done in small groups first and then do a whole group discussion on it. Then students lead that as presentations or carousels or something like that."

This response was indicative of Ms. James's continual desire to improve her teaching strategies. She also described how students used technology to engage in projects and decision-making tasks. (T4m) She described a challenge she had assigned that day based on a student's suggestion. Students were challenged to find piece-wise graphs that made a Christmas tree shape. This was a task that was not planned but rather an extension task used to further explore the concept from the daily lesson. (L4m) The researcher analyzed the follow-up interview data, which indicated that Ms. James was at the exploring level for the teaching and learning themes of TPACK (Niess et al., 2009).

Lesson Sample. At the request of the researcher, Ms. James submitted a sample technology lesson that she felt exemplified the way technology should be used to teach mathematics. The task required students to use given data to develop a model that could be used to make predictions. The task further required learners to justify their models and use them to predict and interpret the data. The task sheet indicated the keystrokes students needed to make on the calculator to display the data. Like the observed task, this task did not offer students opportunities to develop their own strategies or make decisions. (T3e) An analysis of the lesson sample suggested that Ms. James was at the adapting level for the teaching theme of TPACK (Niess et al., 2009). Without data related to students' prior knowledge and the timing of the implementation of the particular task, the researcher was unable to determine a level for the learning theme based on data from the lesson sample.

Self-Report Survey. Ms. James's responses to the TPACK Development Model Self-Report survey indicated her perceptions about her TPACK levels to be high for the various themes when considering graphing calculators. A summary of her survey responses is provided in Figure 5.

<table>
<tr><th></th><th>Recognizing</th><th>Accepting</th><th>Adapting</th><th>Exploring</th><th>Advancing</th></tr>
<tr><td>Curriculum & Assessment (curriculum)</td><td></td><td></td><td></td><td></td><td bgcolor="gray"></td></tr>
<tr><td>Curriculum & Assessment (assessment)</td><td></td><td></td><td></td><td bgcolor="gray"></td><td></td></tr>
<tr><td>Learning (mathematics learning)</td><td></td><td></td><td></td><td></td><td bgcolor="gray"></td></tr>
<tr><td>Learning (conception of student thinking)</td><td></td><td></td><td></td><td></td><td bgcolor="gray"></td></tr>
<tr><td>Teaching (mathematics learning)</td><td></td><td></td><td></td><td bgcolor="gray"></td><td></td></tr>
<tr><td>Teaching (instruction)</td><td></td><td></td><td></td><td></td><td bgcolor="gray"></td></tr>
<tr><td>Teaching (environment)</td><td></td><td></td><td></td><td bgcolor="gray"></td><td></td></tr>
<tr><td>Teaching (professional development)</td><td></td><td></td><td></td><td bgcolor="gray"></td><td bgcolor="gray"></td></tr>
<tr><td>Access (usage)</td><td></td><td></td><td></td><td></td><td bgcolor="gray"></td></tr>
<tr><td>Access (barrier)</td><td colspan="5">The participant did not indicate a response for this descriptor.</td></tr>
<tr><td>Access (availability)</td><td></td><td></td><td></td><td bgcolor="gray"></td><td></td></tr>
</table>

Figure 5.Ms. James's responses to the TPACK Development Model Self-Report Survey.

Self-report survey data suggested that Ms. James's perceptions of her teaching and learning TPACK levels were slightly higher than the levels suggested by other data obtained by the researcher. Ms. James classified herself to be primarily at the advancing and exploring levels for the teaching and learning themes, respectively. The researcher deduced, however, that Ms. James was at the exploring level for the learning theme and transitioning from the adapting level to the exploring level for the teaching theme of TPACK (Niess et al., 2009).

Ms. Thomas (Participant 6)

Background. Ms. Thomas taught at Middle School C, located in the same city as High School C. Ms. Thomas had been teaching for twenty-four years at the time of the study. She served as the Chair of the Mathematics Department at Middle School C, and she taught Algebra I, Transition to Algebra, and Pre-Algebra to eighth-grade students. In her classroom, Ms. Thomas had access to an electronic writing tablet, graphing calculators, and educational software used for test preparation.

Initial Interview. During the initial interview, the researcher asked Ms. Thomas a series of questions to gain an understanding of her practices and beliefs regarding instructional technologies. The researcher analyzed Ms. Thomas's responses, and responses that were relevant to her TPACK levels for the teaching and learning themes will be reported in this section.

When asked to describe her feelings about technology, Ms. Thomas responded with the following.

> I like to teach with technology. I think it's important. I think it's a great way for the kids to explore concepts and really use their critical thinking skills to take things that they know and translate it and use the calculator to do that. . . . I do think it's important for the kids to learn basic skills before they get loose on the calculator because they get really

> dependent on the calculator even just to do basic functions. And so the way I do it in my classroom is that I will teach a concept. Sometimes I use the calculator to introduce a concept and then we'll use pen and just work them out by hand. One example would be if you were writing an equation for a line that's parallel to another line and passes through a point. Well, if you took the calculator, you could show them how to graph first to introduce parallel lines – that they have the same slope. And they could explore by graphing those two lines on a calculator and seeing what they look like, then what's in common, what's different. . . . And then when they got through and they understand the concept that they have the same slope, then, they could take a problem and work it out. And then they could check it with the calculators and see that they're parallel.

There are several notable components to Ms. Thomas's statement. Although Ms. Thomas referred to students' engagement in critical thinking, she did not describe how this engagement could take place. Also, Ms. Thomas stated that students should learn concepts prior to using instructional technology. (T1e) Like other participants, Ms. Thomas expressed concerns that students would become dependent on technology. Ms. Thomas provided an example of how technology could be used to display a representation during the introduction of the concept of graphing parallel lines; however, the use she described was limited to using the technology as a teaching tool. (L1c) That is, she did not describe how students could explore the concept or make any decisions regarding the flow of the lesson.

During the interview, Ms. Thomas expressed that she incorporated technology into her lessons partly out of a fear of "getting left behind." She also stated that she had resisted integrating the technology into her teaching, but had recently "jumped on that idea that we have to use technology" because "I can get left behind or I can jump on and go."

Ms. Thomas described her participation in professional development opportunities related to instructional technology integration. She stated that she would occasionally structure her lessons to model things she had learned during these professional development sessions. (T2i)

When asked to describe the role technology played in her classroom on a daily basis, Ms. Thomas responded as follows.

> It's just been used for discovering ideas or concepts – kind of building a concept and I use it for basic – like a concept or objective that I'm teaching they can use the calculator on because that's not a tested objective in that area. Like an example – ratio and proportions – to use it to solve proportions on there. I'm not testing them on whether they can multiply or add or subtract or whatever. So I'll let them use it for that because that's not the concept I'm teaching. So I do that mostly until January or so, and then once they've learned some of the concepts that I want them to know, we use it in geometry the whole time…. I use it a lot in Algebra I and Transitions spring semester to do a lot of things – you know, systems of equations and things like that.

The researcher noticed that Ms. Thomas made another reference to using technology to introduce concepts, but, once again, her explanations did not substantiate her statement. Based on this response, Ms. Thomas limited students' opportunities with instructional technologies to using the calculators for computations and occasional graphing. (T1i) She also expressed that she limited the availability of technology during the formative phase of concept development. (T1m, L2m)

During the interview, the researcher asked Ms. Thomas to describe her concerns about integrating instructional technologies. Ms. Thomas described the following concern.

> The only concern I have is just to be sure that the students understand the concept and they're not just going to a program and pushing in numbers, you know, that they really understand what they're doing. And that they are comprehending the concept – not just pushing the buttons on a calculator. And that they understand and know how to do basic functions – that they don't rely on it to do all their basic functions.

This statement suggested that Ms. Thomas's primary concerns were that technology would interfere with learning of concepts and skills essential to students' success. (L1m) Although Ms. Thomas recognized that technology offered access to representations that would not otherwise be possible, she felt that technology threatened to interfere with the learning of mathematics. This was the *double-edged sword* theme that was noted for Ms. James and will be discussed in the following chapter.

The researcher analyzed the interview data and concluded that the data suggested that Ms. Thomas was at the accepting level for the teaching theme and the recognizing level for the learning theme of TPACK (Niess et al., 2009). The researcher made this classification despite Ms. Thomas's connections to the recognizing level for the teaching theme. Ms. Thomas's occasional technology use for concept exploration, and her participation in technology-related professional development, allowed her to be rated at the accepting level for the teaching theme.

Observation. The researcher observed an Algebra I lesson in Ms. Thomas's classroom approximately two weeks following the initial interview. When the researcher entered the classroom, it was noted that desks were arranged in rows. The teacher's desk was located near the front of the room, and an electronic whiteboard was located at the front of the room.

As students came in, Ms. Thomas instructed them to retrieve calculators from a designated area. When class began, Ms. Thomas distributed graded exams to students and read the solutions to the exam aloud. She instructed students to rework the problems they missed for homework.

Next, Ms. Thomas displayed an equation and asked students to graph the equation in their graphing calculators. Ms. Thomas used the SmartView program to display the graph on the electronic whiteboard. After noting the slope and *y*-intercept of the line, the teacher asked students to graph a second equation. The two lines were parallel to each other. Ms. Thomas asked, “What do you notice about their slopes? What do you notice about their *y*-intercepts? Why are they parallel?” Ms. Thomas allowed minimal time for discussion and quickly moved to a second example. In the second example, the two lines intersected but were not perpendicular to each other. She verbally provided the procedures necessary for using the calculator to find the point of intersection. The focus of the instruction was on the sequence of keys that students should push, without a discussion as to why this was appropriate.

As the lesson continued, Ms. Thomas provided six additional examples similar to the first two. The final example asked students to consider two equations. Students noticed that these two equations were equivalent. Ms. Thomas instructed students to write in their notes that “if they share the same line, they have infinitely many solutions. If they intersect, they have one solution, and if they’re parallel, they have no solutions.” Without answering additional questions, Ms. Thomas told the class they would return to this topic the following day.

The researcher noted that during the observed lesson, Ms. Thomas limited students’ use of instructional technology to graphing linear equations and using a calculator application to find intersection. (T1c) Students did not use technology to learn or access mathematics that they would not otherwise have been able to access nor did they explore new concepts with the technology. (T1i) Furthermore, this use of technology limited students’ opportunities to develop conceptual understanding of the mathematics. Data from the observed lesson indicated that Ms. Thomas was at the recognizing level for the teaching and learning themes of TPACK (Niess et al., 2009).

Follow-up Interview. The follow-up interview for Ms. Thomas occurred immediately after the observed lesson. Data analyzed from the initial interview and the observation provided conflicting levels for the teaching theme. During the follow-up interview, the researcher sought to gather data to better understand Ms. Thomas's practices and beliefs regarding instructional technology integration.

During the follow-up interview, Ms. Thomas stated that she often used technology to allow students to make connections to the real world; however, she was unable to provide any examples of tasks she had used. The researcher asked Ms. Thomas if she ever fostered discussions about explorations from the calculators. Ms. Thomas responded with a simple affirmative response, but declined to elaborate. Ms. Thomas also stated that her students' engagement increased when they had access to the graphing calculators because "they're more apt to try stuff on it than they would if they were just using pen and a [paper], I think." Her response suggested that her students' use of the graphing calculators was limited to tasks that can be performed more quickly with the calculator, such as performing operations. (L1c, T1i)

As the interview continued, the researcher asked Ms. Thomas whether she engaged students in projects with instructional technology. Ms. Thomas stated that she did not do this because of a lack of time. She specifically referenced time concerns due to high-stakes testing. (T1m) The researcher noted that her responses generally suggested that she did not view technology as a tool that was useful for exploring new mathematical topics. (L1m)

Ms. Thomas's responses during the follow-up interview suggested she was at the recognizing level for the teaching and learning themes of TPACK (Niess et al., 2009). The researcher also noted that Ms. Thomas provided multiple short affirmative responses to interview questions that were not substantiated by examples or observations.

Lesson Sample. The researcher requested that Ms. Thomas submit a sample lesson that she identified to exemplify how technology should be used to teach mathematics. Ms. Thomas submitted an overview of the lesson that was observed. Therefore, the analysis of the lesson sample was in agreement with the levels indicated by the observed lesson. The lesson sample suggested Ms. Thomas was at the recognizing level for the teaching and learning themes of TPACK (Niess et al., 2009).

Self-Report Survey. Ms. Thomas's responses to the TPACK Development Model Self-Report survey indicated her perceptions about her TPACK levels to be mixed for the various themes when considering graphing calculators. A summary of her survey response is provided in Figure 6.

	Recognizing	Accepting	Adapting	Exploring	Advancing
Curriculum & Assessment (curriculum)					
Curriculum & Assessment (assessment)					
Learning (mathematics learning)					
Learning (conception of student thinking)					
Teaching (mathematics learning)					
Teaching (instruction)					
Teaching (environment)					
Teaching (professional development)					
Access (usage)					
Access (barrier)					
Access (availability)					

*Figure 6.*Ms. Thomas's responses to the TPACK Development Model Self-Report Survey.

Responses to the self-report survey indicated that Ms. Thomas generally perceived herself to be at a higher TPACK level than that suggested by other data collected during the study. The environmental descriptor of the teaching theme was the only instance where the self-reported alignment agreed with the researcher's conclusion about her TPACK level.

Ms. Bradley (Participant 7)

Background. Ms. Bradley taught at High School D and was a colleague of Ms. Spise and Ms. James. She taught Algebra I and Advanced Algebra I to students in grades nine through twelve. In her classroom, Ms. Bradley had access to SmartView software and graphing calculators. Ms. Bradley was in her tenth year of teaching at the time of the study.

Initial Interview. During the initial interview, the researcher asked Ms. Bradley a series of questions to gain a better understanding of her practices and beliefs regarding instructional technology. Responses that were notable with regard to her levels of the teaching and learning themes of TPACK will be reported in this section (Niess et al., 2009).

When asked to describe how she felt about teaching with technology, Ms. Bradley replied as follows.

> It has its pros and cons. By that I'm specifically referring to the calculator because . . . they get a little dependent on them, a little addicted to their use. But there are, I think, more advantages than disadvantages, so I think it's good that we're able to provide technology and allow them to use it. . . during class and while they learn.

Ms. Thomas's response echoes the same *double-edged sword* concern that had been voiced by other participants.

The researcher asked Ms. Bradley to describe how her feelings about teaching with technology had changed throughout her career. Ms. Bradley had the following response.

> For a couple of years into my teaching, I just thought [graphing calculators] were unnecessary – and they are to a certain degree unnecessary because you can do math without them and learn well I think. But over time, I've learned to use them and see the benefits of them and gotten training. I do see how the main thing is that kids can make connections using a graphing calculator because they can see the line; they can see the change of the slope and immediately see that it's steeper. So there are a lot of things that they can do that quick.

Like some of the other participants, Ms. Bradley noted that she used technology to foster representations while teaching mathematics. It was also notable that Ms. Bradley did not view technology as an essential component of the mathematics classroom. Instead, her statement suggested that she viewed it as a supplement that offers some advantages. (T2m)

Ms. Bradley continued her explanation of her use of graphing calculators during instruction by stating the following.

> I hold back sometimes with the kids and don't show them everything. I don't want them to think that you can write a program and let the calculator do all the work for you. But I do teach them how to write a program. And I've had students in the past who think that's the most awesome thing ever, and they feel really smart, and so we have a little calculator programming day just so they know that it's capable of doing that. (T2m)

This statement suggested that Ms. Bradley limited everyday calculator use to operations and graphing with minimal opportunities for students to use calculators to explore new concepts. The statement further suggested, however, that Ms. Bradley occasionally used technology activities, but these were seen as supplemental to classroom instruction. This data suggested that Ms. Bradley was at the accepting level for the teaching theme of TPACK (Niess et al., 2009).

As the interview continued, Ms. Bradley described her participation in numerous professional development sessions.

> The benefit of being in a state-tested subject is that there are more perks. There's more training. I feel like if I had not been an Algebra I teacher – I mean, I taught downstairs for five years next to teachers who did not teach Algebra I, and they didn't use calculators much – no need to. Because they were in the same position that I was – they learned without it. . . . But I got the training that my school district did provide. Now I did some on my own because we had a teacher here that since she's retired has become a TI trainer, and she goes out and does workshops, and so she has helped me a lot. But other than that, it was professional development training.

Ms. Bradley's statement suggested that she engaged in professional development solely because she taught a state-tested subject and not necessarily because she possessed a desire to grow as an educator.

Ms. Bradley stated that her students used graphing calculators primarily for computation. (T1i) Ms. Bradley mentioned that she occasionally engaged students in a task where they used the technology to explore concepts.

> Recently, they had an investigation lab where they had to explore systems using their calculator, and so the activity required them to – "okay, now find your trace button" – and it walked them through some steps where they had to have that in their hand. But I would say maybe just occasionally lessons would really require that you have a graphing calculator. Other times it's just, you know, you can do computation in your head or on paper or using some other kind of calculator. (T2e)

Ms. Bradley's statement suggested that technology tasks were rarely used in her classroom, and these tasks were implemented in a procedural manner. This suggested that she was at the accepting level for the teaching theme of TPACK because she used technology only for supplemental lessons and in a step-by-step manner.

During the interview, Ms. Bradley expressed two chief concerns about technology integration. Her main concern about students was that they would become dependent on the technology. This statement suggested that her view of the capabilities of instructional technologies was limited primarily to computation. (L1c) Ms. Bradley's second concern was that without using technology, she would get behind as a teacher. This concern motivated her to continue to allow students to access technologies during mathematics instruction. This did not influence her, however, to take proactive steps toward increasing her knowledge regarding technology implementation. (T1p)

The researcher analyzed data from Ms. Bradley's interview and assessed her to be at the recognizing level for the learning theme and at the accepting level for the teaching theme of TPACK (Niess et al., 2009).

Observation. The researcher observed an Algebra I lesson in Ms. Bradley's classroom approximately two weeks following the initial interview. Upon entering the classroom, the researcher noted that students' desks were arranged in rows and an overhead projector and a podium were located at the front of the classroom.

As class began, Ms. Bradley distributed graded exams from the previous day and read solutions to the problems aloud. Ms. Bradley emphasized that students should use key words when considering a problem but did not allow for students to contribute to this aspect of the lesson.

After reviewing the exam, Ms. Bradley instructed students to turn to a page in their textbooks that contained practice standardized test items. As students retrieved their textbooks, Ms. Bradley distributed a playing card to each student. Ms. Bradley used a second deck of playing cards to randomly call on students to answer the questions from the textbook page. After a student provided a correct solution, Ms. Bradley asked questions pertinent to that item. The questions Ms. Bradley asked sparked short class discussions about topics such as reversing the questions and considering the reasonableness of the solutions.

The content of the questions included a variety of topics, including simplifying negative expressions with negative exponents, working with algebraic symbols, writing an equation to represent a given situation, solving inequalities, interpreting a table algebraically, equations of parallel lines, polynomial applications, and solving systems of equations. This lesson was intended to serve as a review of algebra topics.

After completing items from the textbook page, Ms. Bradley began the bonus round in which she used an overhead calculator to display the graphs of five lines. Students were challenged to write the equations of the graphed lines on notebook paper and submit it. Students had access to graphing calculators during this task. Ms. Bradley led a discussion of how three of the lines had the same slope and were thus parallel.

The researcher noted that the observed lesson was technology-independent. Students had access to technology but did not use it to explore new concepts during the observed lesson. Students were not engaged in the NCTM Process Standards during the observed lesson. Graphing calculators were used solely to create a representation that could have been created quickly without the technology. Based on observation data, the researcher noted that Ms. Bradley was at the recognizing level for the teaching and learning themes of TPACK.

Follow-up Interview. The follow-up interview with Ms. Bradley occurred immediately after the classroom observation. During the follow-up interview, the researcher sought to ask questions to gain a deeper understanding of Ms. Bradley's TPACK levels with regard to the teaching and learning themes of TPACK. Specifically, the researcher wanted to use the follow-up interview to reconcile the differences in the conclusions drawn from other data with regard to Ms. Bradley's level for the teaching theme.

During the observation, the researcher overheard students recalling a "Problem Solving Unit" from early in the semester. The researcher decided to ask Ms. Bradley to elaborate on this experience.

> The very first day of the year, for about three days, everything I do is related to problem solving, and it starts very small. Like, "Okay, I'm going to give you a task, and your task is to line yourselves up from tallest to shortest without talking." And then we talk about, "okay, what was the task and what were the things you could do and the things you couldn't do and what could you have done differently?" And they come up with their own things. . . . And so right off the bat when they come into my room, I emphasize problem solving as something they are in control of almost. Like, "you be creative and use the resources available and try to think of other strategies and things like that." But after those first few days then they know it's ongoing. It's not really like a unit, but we talk about some other ways to solve every problem they do if they exist and I know about them.

The researcher found this statement notable although it did not directly link to technology. This statement indicated an attempt by Ms. Bradley to engage her students in problem solving. Based on the observation, however, this was not supported throughout the school year.

The researcher asked Ms. Bradley whether she had engaged her students in projects that incorporated instructional technology. Ms. Bradley's response suggested that she occasionally used technology-based tasks that were supplemental to instruction but that she did not actively seek out tasks to integrate when planning a lesson. Like Ms. Thomas, Ms. Bradley expressed time concerns related to integrating technology-tasks. (T1m) These concerns were related particularly to pressures associated with high-stakes testing.

Based on data obtained from the follow-up interview, the researcher identified Ms. Bradley to be at the recognizing level for the teaching and learning themes of TPACK. The data further suggested that Ms. Bradley could be transitioning from the recognizing level to the accepting level for the teaching theme based on initial interview responses.

Lesson Sample. At the researcher's request, Ms. Bradley submitted a lesson sample that she felt exemplified how technology should be used to teach mathematics. The lesson objective was for students to draw conclusions and make predictions from scatter plots. During the lesson sample, students created a scatter plot and a trend line using step-by-step instructions. (T2e) After creating the scatter plot as a large group, students attempted several examples individually and then discussed the advantages and disadvantages of using a calculator versus using traditional methods for graphing scatter plots. (T1e)

The researcher analyzed the lesson and found that it suggested that Ms. Bradley was at the recognizing level for the teaching and learning themes of TPACK (Niess et al., 2009). The questions that guided instruction suggested that the focus of the lesson was on the usefulness of the technology rather than the mathematical topic, scatter plots.

Self-Report Survey. Ms. Bradley's response to the TPACK Development Model Self-Report survey indicated her perceptions about her TPACK level to be at the adapting, exploring, and advancing levels for the teaching and learning themes (Niess et al., 2009). A summary of her responses is provided in Figure 7.

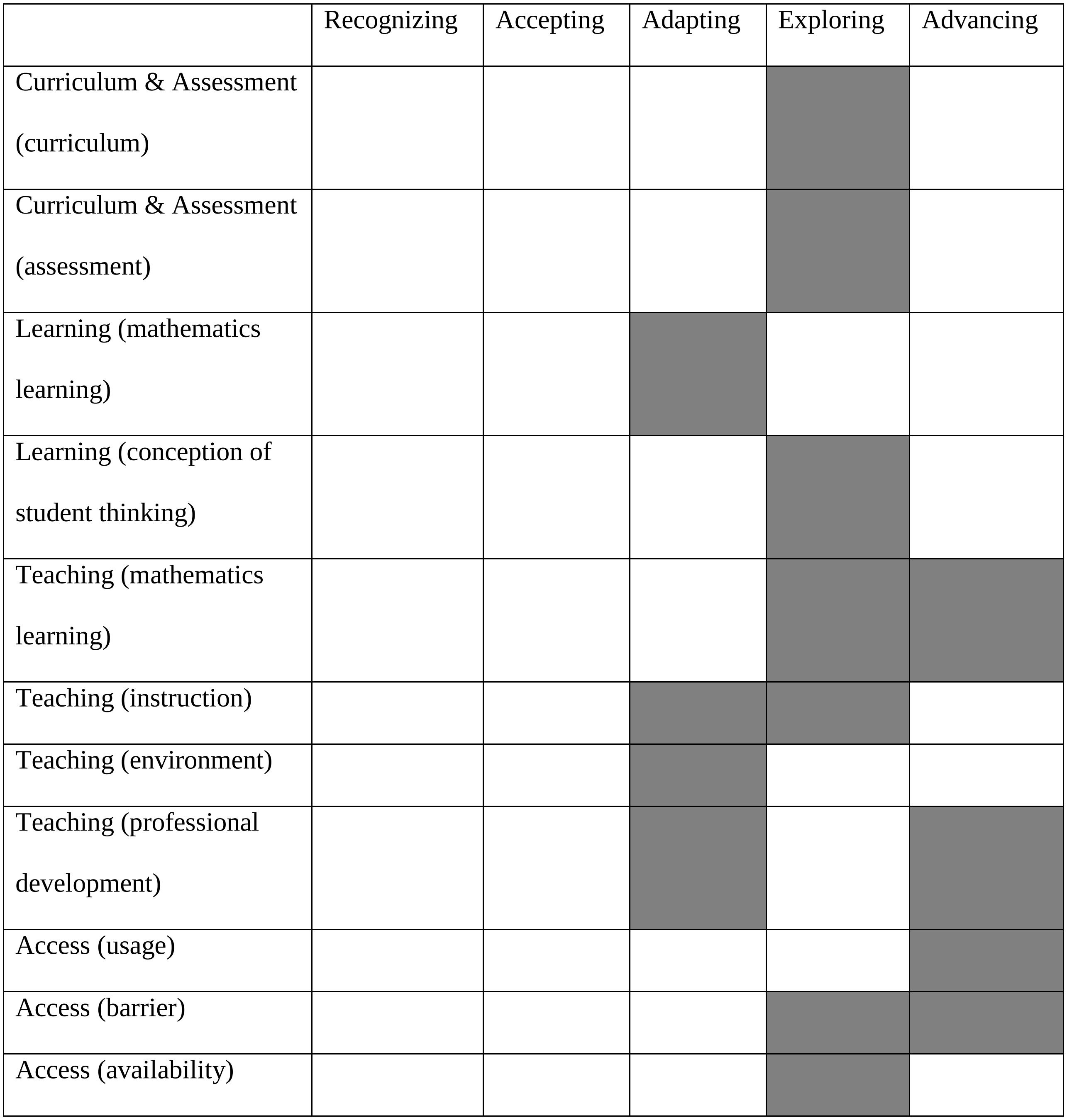

*Figure 7.*Ms. Bradley’s responses to the TPACK Development Model Self-Report Survey.

Self-reported survey data indicated that Ms. Bradley perceived herself to be at the adapting, exploring, and advancing levels for all TPACK themes. Other data obtained during the study, however, suggested Ms. Bradley was at the recognizing level for the teaching and learning themes of TPACK.

Response to Research Questions

This qualitative study was designed to address three research questions. Responses based on data analysis will be described in this section.

Question 1: What are secondary teachers' perceptions of integration of instructional technologies in their classrooms as described in the teaching and learning themes of the TPACK Development Model?

The researcher analyzed responses to the TPACK Development Model Self-Report Survey to gain insight into this question. Each participant completed the survey by indicating which statements corresponded to their practices and beliefs. Although the survey addressed all four themes of TPACK, only data from the thirty items that assessed perceptions of teaching and learning themes will be shared. Frequency of these responses is summarized in Figure 8. It is notable that participants often selected multiple responses within a given theme and descriptor.

	Recognizing	Accepting	Adapting	Exploring	Advancing	Descriptor totals
Learning (mathematics learning)	1	2	2	1	2	8
Learning (conception of student thinking)	0	0	1	3	4	8
Teaching (mathematics learning)	0	0	1	4	3	8
Teaching (instruction)	0	0	4	1	3	8
Teaching (environment)	1	2	1	4	0	8
Teaching (professional development)	0	2	3	2	2	9
Level totals	2	6	12	15	14	

Figure 8. TPACK Development Model Self-Report Survey – Teaching and Learning Themes.

Analysis of the data from the TPACK Development Model Self-Report Survey indicated that participants perceived themselves to be mostly at the adapting, exploring, and advancing levels of TPACK for the teaching and learning themes. Eight-four percent of the forty-nine responses indicated alignment to the upper three levels, and fifty-nine percent of responses connected to the exploring and advancing levels. Only two participants associated their practices and beliefs with descriptors at the accepting level. These two descriptors were the mathematics learning descriptor for the learning theme and the environment descriptor for the teaching theme.

Question 2: How do secondary teachers' perceptions of integration of instructional technologies as described in the teaching and learning themes of the TPACK Development Model relate to the level of integration suggested by other data collected?

During the study, the researcher collected data about participants' TPACK levels through interviews, observations, and lesson samples. Each piece of data was analyzed independently and the researcher made TPACK level classifications based on these analyses. Analyses of non-survey data were within one level of agreement, with the exception of Mr. Statten. Ms. James was also notable in that non-survey data suggested her TPACK levels for the teaching and learning themes to be at the adapting and exploring levels. Other participants' non-survey data suggested they were at the recognizing and adapting levels for the teaching and learning themes.

In comparison with TPACK Development Model Self-Report Survey data, non-survey data suggested lower TPACK levels. That is, participants' perceptions of their own integration of instructional technologies were higher than that suggested by other data collected. This was a trend also noted by McCrory (2010).

Question 3:What factors motivate secondary mathematics teachers to incorporate instructional technologies?

During interviews, the researcher asked questions to identify what factors motivated participants to integrate instructional technology. Participants who taught in high-stakes tested areas consistently referred to this as a pressure to integrate technology. Their descriptions of technology integration, however, did not match the vision of the Technology Principle (NCTM, 2000).

In order to gain insight into factors that facilitate achieving this vision, the researcher examined interview data from Ms. James because her responses indicated she was at the highest TPACK levels for the teaching and learning themes when compared with other participants. Ms. James described in her interview an internal motivation to seek out new technologies and find ways to use them to enhance student learning. During her interviews, Ms. James was eager and excited to discuss technology and describe her students' successes in mathematics class that involved technology.

Although many participants described experiences with instructional technologies that occurred in professional development settings, the experiences perceived by participants to be most influential on their teaching practices were experiences with colleagues and other mentors. Ms. James, Ms. Spise, and Ms. Bradley all attributed much of their successes with instructional technologies to collaboration with colleagues. Ms. McKinnie expressed that her lack of instructional technology integration was due in part to a lack of opportunities for such collaboration.

Upon reflecting over the data collected throughout the study, the researcher identified factors to instructional technology integration to include an internal desire to actively seek better learning opportunities for students and colleagues with a willingness to collaborate and pursue opportunities for enhancing technology integration. Participants who taught high-stakes tested subjects also suggested that pressures associated with their teaching assignments encouraged them to integrate technology, namely graphing calculators, in ways that could optimize test scores (computations and programs).

Summary

In this chapter, data from seven case studies that were used to address the research questions of this study was shared. For each case study, summaries and relevant data from initial interviews, classroom observations, follow-up interviews, lesson samples, and survey responses were analyzed and reported. This data was compiled, and responses to the research questions were shared. The researcher found that participants perceived their TPACK levels for the teaching and learning themes to be higher than the levels suggested by other data. Chapter V will include a summary of the study findings, identify themes that emerged, and describe recommendations for future research.

CHAPTER V: DISCUSSION

Introduction

Although instructional technology has become more available in secondary mathematics classrooms, the integration of such technologies has not increased (Dunham & Hennessy, 2008). Further, technology integration is often limited to performing computations and does not portray the vision of enhancing student learning as described in the NCTM Technology Principle (NCTM, 2000). This study sought to examine secondary mathematics teachers' perceptions of their technology integration, determine how these perceptions relate to the level of integration suggested by other data, and identify common factors that motivate such integration.

In this chapter, a summary of the findings related to the research questions is provided. Next, additional themes that emerged throughout the data analysis are described. Finally, recommendations for future research and practice are shared.

Summary of Findings

The researcher collected data relevant to the following research questions.

1. What are secondary mathematics teachers' perceptions of integration of instructional technologies in their classrooms as described in the teaching and learning themes of the TPACK Development Model?
2. How do secondary mathematics teachers' perceptions of integration of instructional technologies as described in the teaching and learning themes of the TPACK Development Model relate to the level of integration suggested by other data collected?

3. What factors motivate secondary mathematics teachers to incorporate instructional technologies?

Questions from the TPACK Development Model Self-Report Survey afforded participants the opportunity to express their perceptions of instructional technology integration. The researcher analyzed this data and noted most responses corresponded to the exploring and advancing levels of the teaching and learning themes of TPACK (Niess et al., 2009). Through analyses of interview transcripts, observation notes, and lesson samples, the researcher noted a distinct lack of agreement between the aforementioned perceptions of participants' TPACK levels and the TPACK levels suggested by other data collected. The researcher noted that most participants were at the recognizing or adapting levels for the teaching and learning themes, with one participant at the exploring level for the learning theme. Generally participants' perceptions of their technology integration were higher than that suggested by other data collected, which agreed with prior findings by McCrory (2010).

Data pertaining to participants' perceptions of their practices and beliefs with regard to technology integration was obtained through response to the TPACK Development Model Self-Report Survey. The researcher hypothesized that the lack of alignment between the self-report data and other data could be due in part to misinterpretation of survey items. It is also notable that survey items for each descriptor were placed in order from recognizing to advancing levels on the survey document. For this reason, participants may have indicated an alignment with higher-level statements because they felt satisfied with their practices regarding instructional technology.

Through the data collection process, some factors that were influential in instructional technology integration emerged. The strongest factor communicated during the study was communicated by Ms. James. Ms. James described having an internal motivating factor that allowed her to overcome the second-order barriers associated with technology integration (Ertmer, 1999). She was self-motivated to seek out technologies as they became available. Further, Ms. James collaborated with a like-minded colleague, forming a professional learning community. Ms. James described how she and her colleague had actively worked to obtain graphing calculators for their classrooms, become familiar with them, explored ways to integrate them into their existing practices, and implemented technology tasks. The last three steps were identified by Hokanson and Hooper (2004) as practices necessary in overcoming barriers to technology integration.

Ms. James's internal motivation allowed her to overcome her own second-order barriers and also influence her colleagues to integrate technology. Ms. James, Ms. Spise, and Ms. Bradley all attributed their successes with instructional technology integration in part to influences from colleagues. Interestingly, Ms. McKinnie noted this lack of collaboration as a reason for her lack of integration of instructional technology.

The researcher observed another motivating factor to instructional technology integration to include pressures associated with standardized testing. All study participants referenced this pressure. Participants who did not teach a state-tested area referred to the pressure they perceived on other teachers related to state testing and to other standardized tests, such as advanced placement examinations and college entrance examinations. It is notable, however, that this motivated the impacted teachers to integrate technology in ways that did not enhance student learning. Rather, technology was integrated for the purposes of applications of formulas and performing tedious operations.

Emerging Themes

The researcher noticed four primary themes that emerged during data collection. These themes were the view of technologies as a *double-edged sword*, concerns associated with standardized testing, an inability to differentiate between instructional- and non-instructional technologies, and misuses of educational jargon. Each of these themes will be discussed in the following paragraphs.

Double-edged sword

Multiple participants expressed a view of technology as a *double-edged sword*, meaning that technology offers advantages and disadvantages that must be carefully considered. Although this was a common theme, the concept differed slightly for different participants. Ms. James expressed her feelings about this theme as “you’ve got to take the good with the bad.” Her concerns focused on using technology to perform simple operations such as operations in the calculator. Ms. James described the positive aspects of technology in ways that indicated enhanced opportunities for student learning. Other participants’ concerns about technology integration, however, were focused on a fear that students would become “dependent on calculators.” Positive aspects of instructional technology integration focused on increased performance on high-stakes testing and students’ comfort levels with instructional technology. Multiple participants expressed concerns that students would become dependent on technology, particularly graphing calculators, if they were granted unlimited access. The attitudes and beliefs related to the *double-edged sword* theme related to the second order barriers described by Ertmer (1999). Furthermore, participants’ acknowledgement of weighing the advantages and disadvantages of technology followed by the decisions to incorporate it into practice indicates an overcoming of the knowledge gap described by Hokanson and Hooper (2004).

Standardized testing

Participants also frequently described pressures associated with high-stakes testing as limiting to instructional time and technology use. Ms. McKinnie, Ms. Spise, and Ms. Thomas expressed that they felt pressures associated with state-testing in Algebra I, and Mr. Witt and Ms. James described pressures associated with Advanced Placement exams. The researcher also noted that these pressures tended to encourage participants to use technology more for rote computations, programs, or to verify solutions rather than for exploration or learning tasks. Assessment was a key barrier identified in the review of literature by Hew and Brush (2007). Moreover, this barrier was noted to be connected to subject culture. That is, the prevalent culture of teacher expectations in secondary mathematics is tied closely to expectations associated with standardized testing.

Instructional versus non-instructional technologies

An additional theme that was prominent from all of the participants was a reluctance to differentiate non-instructional and instructional technologies. That is, participants did not view technologies used to teach mathematics, such as graphing calculators, as different from technologies used as presentation tools, such as LCD projectors. Furthermore, some participants were not able to accurately identify ways technology could be used to enhance student learning. Mr. Statten continually referenced the clickers as a learning tool; however, his lesson indicated that the clickers did not enhance opportunities for students to develop understandings of mathematics. Ertmer (1999) indicated that teachers develop their own visions of technology use by observing other teachers. The findings of this study agree with prior research on the need to foster the establishment of a learning community that helps teachers understand the role of instructional technologies in their classrooms.

Educational Jargon

Participants also referenced engagement of students in NCTM's Process Standards; however, this was generally not present during observed lessons. Participants frequently used educational jargon words such as "conceptual understandings," "problem solving," and "connections." These concepts were often referenced using vague phrases and without providing details to substantiate the claims. A misunderstanding of these terms links back to the explanation for the lack of alignment between the themes identified, TPACK Development Model Self-Report Survey and other data collected. Participants misinterpreting words used in the survey could have affected their responses.

Pedagogical Content Knowledge and TPACK

Niess et al. (2009) identified pedagogical content knowledge (PCK) as a component of TPACK. The construct of PCK was identified previously by Shulman (1986) as the knowledge necessary to teach in ways that make the content understandable to learners. With the exception of Ms. James, the study participants demonstrated low PCK. These participants did not engage students in learning mathematics with or without technologies. Rather, the researcher observed the practices of these participants to rely heavily on rote memorization without opportunities for exploration, discussions, justification, or active engagement in learning mathematics. The researcher noted this lack of PCK as a barrier to effective implementation of instructional technologies. Furthermore, this research suggests that without a growth in PCK, teachers' progressions through TPACK Development Model will be limited.

Recommendations for Future Research and Practice

Although this study contributes to the field of mathematics education through seven case studies of instructional technology integration, the study also paves the way for additional research into this complex situation. Future research aimed at further addressing the research questions is needed to produce generalized results. Additionally, future research should consider all of the TPACK themes, rather than concentrating on the teaching and learning themes of TPACK. Because the TPACK Development Model was developed recently, the quantity of studies is limited. Additional studies to better understand teachers' perceptions of other themes and the implications of these perceptions on practice are needed. Such studies would need to collect significantly more data over a larger amount of time.

The researcher also noticed that although many participants were classified at the recognizing level for the teaching and learning themes of TPACK, these participants were not all equal in their integration of instructional technologies. This observation suggested a need to further define the recognizing level of TPACK for the teaching and learning themes. One suggestion would be to identify a level of *pre-recognizing*, in which teachers who do not fit the criteria necessary for the recognizing level would be classified. Additionally, the researcher noted multiple situations in which data indicated participants were transitioning from one level to the next. Further research should explore and formalize such transitions.

This study showed limited implications due to the qualitative nature and small number of participants. The findings of the study, however, suggested some recommendations for practice. Namely, the researcher recommends that future researchers more intensely investigate exemplar teachers, like Ms. James, who possess internal motivation to integrate technologies in ways that enhance student learning. Through examining these success stories, researchers can further identify factors that help teachers fulfill the vision of technology integration described in the NCTM Technology Principle (NCTM, 2000).

Self-Reflection

As the researcher, I became interested in exploring instructional technology integration after observing secondary mathematics classrooms. Upon examining the problem and the surrounding literature, it became apparent that the best way to further investigate instructional technology integration in mathematics classrooms was through qualitative research. With my background in mathematics, I felt more comfortable conducting quantitative research; however, my obligation was to focus on the problem and make a contribution to the field of education rather than focus on my strengths. Further, pursuing a qualitative study helped me grow as an educational researcher. I was able to develop a better understanding of the importance of being aware of my biases.

The timeline for my dissertation study and my budding interest in instructional technologies followed closely behind the publication of the TPACK Development Model (Niess et al., 2009). It was natural to view technology integration through this new lens; however, using this emerging model included some challenges, which are highlighted in my aforementioned recommendations for further research. I have learned many lessons through this process that are fostering my growth as a researcher. These include developing an increased awareness of the effects of my work and subsequent publications on the beliefs and feelings of my participants. Further, I have learned to be purposeful in selecting appropriate qualitative terminology to describe my findings.

Reflecting over the dissertation process, I am grateful for the opportunity to explore instructional technology integration using a qualitative approach. I look forward to sharing this work with other educational stakeholders and continuing to explore and expand the ideas and themes that emerged from this endeavor.

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LIST OF APPENDICES

Appendix A

Technology Study: Call for Participants

This form is a call for participants. Completion of this form does not indicate that you will participate in the study. If you are selected as a potential participant, you will be contacted with more details and given the option to participate.
Your name: ___________________________
What grade level(s) do you teach? (Select all that apply.)

- ☐ Elementary
- ☐ Middle
- ☐ High

At what school do you currently teach?
____
What type(s) of technology do you have access to for your classroom? (Select all that apply.)

- ☐ Graphing calculators
- ☐ Non-graphing calculators
- ☐ Computer software
- ☐ TI Navigator
- ☐ Other ___________________________

What type(s) of technology do students use in your classroom? (Select all that apply.)

- ☐ Graphing calculators
- ☐ Non-graphing calculators
- ☐ Computer software
- ☐ TI Navigator
- ☐ Other ___________________________

How often do your students use technology as a tool for learning mathematics?

- ☐ Never
- ☐ Once or twice a semester
- ☐ Once or twice a unit
- ☐ Multiple times per week
- ☐ Every day

If selected, would you be interested in participating in a research project that examines instructional technology integration in the classroom? (Selected participants will be contacted by email or phone based on preference. At that time, more information will be provided to determine if you are interested in participating.)

- ☐ Yes
- ☐ No

If you answered yes to the above question, please provide your email address or telephone number. __________________

Thank you for taking time to complete this form.

Appendix B

TPACK Development Model Self-Report Survey

Specific to ________________________ (technology)

Please place a check in the box to the left of each statement that describes your beliefs and/or integration of technology in your classroom. You may give additional information in the spaces provided to clarify your selections or if none of the statements describe your beliefs/integration.

	1. I can see how this technology might be useful with some of the topics in my curriculum, but I am not convinced its use will make much of a difference for my students' learning.
	2. I believe this technology would make a difference in my students' learning and would like to use this technology with my students, but I'm not really sure how to integrate its use with the topics in my curriculum.
	3. I believe this technology is beneficial to students' learning. I have allowed my students to use this technology for investigation of a few topics.
	4. I believe this technology facilitates students' learning. I have allowed my students to use this technology for investigation of several topics. I have changed some of my lessons to integrate the technology and am searching for more ways to integrate the technology into the curriculum.
	5. I am convinced that this technology is essential to promote learning for my students. My students use this technology on a regular basis. I extend the objectives in my curriculum by allowing my students the opportunities to develop deeper mathematical thinking through the technology use.
Use this space for any additional information related to the statements above.	
	6. I don't like to allow my students to use this technology on tests because I want to know what they know about mathematics, not what the technology can do.
	7. I allow my students to use this technology only on certain parts of tests or only on certain tests.
	8. If I allow my students to use this technology on tests, I make sure that the test questions measure what my students understand (concepts) along with what they know how to do (procedures).
	9. I allow my students to use this technology on tests. I make my tests to involve a variety of questions (some that require the technology, some that they could use the technology but it is not required, and some in which the technology use has no impact).
	10. I design my assessments so that the students must demonstrate the understanding of the mathematics through the technology use.
Use this space for any additional information related to the statements above.	

	11. I believe that if my students use this technology too often, they will not learn the math for themselves.
	12. I am afraid that if I try to introduce a new topic with this technology, that my students will be too distracted by the technology use to really learn the mathematics. I want them to learn how to do it on paper first, and then they can use the technology.
	13. I have allowed my students to explore a few topics using this technology even before the topics are discussed in class.
	14. My students explore several topics for themselves using this technology to help them develop a deeper understanding. Sometimes the students' thinking guides their explorations in directions other than what I had planned.
	15. I design my own technology lessons. When I plan my lessons, I really think about how to integrate the technology to help the students better understand the mathematics. After the lesson, I reflect on the lesson and how it could be changed to increase student understanding using this and/or other technologies.
Use this space for any additional information related to the statements above.	
	16. I might show my students how this technology relates to the topic, and I don't mind if my students use this technology outside of class, but I do not plan to allow class time for the students to use this technology.
	17. If my students use the technology to explore a new topic, they won't think about and develop the mathematical skills for themselves.
	18. I try to use this technology to promote my students' thinking, but have not had a lot of success.
	19. I often use pre-made technology activities to engage my students in their learning. I reflect on my students' thinking, communication and ideas during the technology use to make decisions about any changes that need to be made in the design of the lesson.
	20. I cannot imagine my classes without this technology! Using this technology is a vital piece of facilitating my students' learning and helps promote their thinking to more advanced levels.
Use this space for any additional information related to the statements above.	

	21. This technology might be useful, but before I could use this technology, I would have to teach my students about the technology and how it works. I have too many objectives to cover to do that.
	22. I use this technology occasionally, such as between units or at the end of the term. The technology use doesn't necessarily tie with the mathematical goals of the class.
	23. I use this technology to reinforce concepts that I have taught earlier or that my students should have learned in a previous class. I do not use it regularly when teaching new topics.
	24. I use this technology as a learning tool to engage my students in high-level thinking activities (such as projects or problem-solving).
	25. I use this technology to present mathematical concepts and processes in ways that are understandable to my students. I actively accept and promote use of this technology for learning mathematics. Other teachers come to me as a resource for ideas of how to help their students use the technology to promote understanding.
Use this space for any additional information related to the statements above.	
	26. My students and I use this technology for procedural purposes only.
	27. I have led my students through a few simple ideas of how to use this technology that I learned during professional development.
	28. I have led my students through uses of this technology that I learned during professional development, but I changed the activities to meet the needs of my students.
	29. When my students explore with this technology, I serve as a guide. I do not direct their every action with the technology.
	30. On a regular basis, I use a wide variety of instructional methods with this technology. I present tasks for my students to engage in both deductive and inductive strategies with the technology to investigate and think about mathematics to deepen their understanding.
Use this space for any additional information related to the statements above.	
	31. In my class, the focus is on the mathematics first. I can imagine that perhaps this technology might be used to reinforce those mathematical ideas only after the students have shown they can perform the skills on paper.
	32. I allow my students to use this technology to assist them with their skills. I direct my students step-by-step to use this technology.
	33. I use some exploration activities with this technology, but I usually guide my students through the steps to save class time.
	34. I have explored a variety of instructional methods with this technology, to allow my students to engage both inductively and deductively.
	35. I use this technology in a student-led environment, where the students explore with the technology both individually and in groups. When working in groups, all members of the group are actively involved.
Use this space for any additional information related to the statements above.	

	36. I would consider attending a workshop demonstrating the use of this technology, but only if it is local.
	37. I am interested and would be likely to attend workshops or professional developments to learn more about how to use this technology to further mathematics education.
	38. I am likely to attend professional developments related to technology use in mathematics education and to share those ideas with other teachers in my building, but I am likely to focus on learning one type of technology integration at a time.
	39. I have made contact with others who are using this technology and plan to meet and work with them throughout the year to integrate this and other technologies appropriately into our mathematics curriculum.
	40. I believe it is time to transform our mathematics curriculum to one that utilizes 21st century technologies! I have found organizations and workshops that I can attend to learn more about how to integrate this and other technologies into my math curriculum. I plan to share what I learn with others in my district.
Use this space for any additional information related to the statements above.	
	41. My students can use this technology only after they have mastered the pencil-and-paper skills.
	42. I allow my students to use this technology on a regular basis, usually just for skill purposes and under tightly controlled circumstances.
	43. I have a few units in which I allow students to explore new topics with this technology.
	44. I encourage my students to use this technology during most class meetings. They often explore new topics using this technology.
	45. I allow my students to use this technology in every aspect of the class and encourage the technology use to challenge the boundaries of what they can learn and understand.
Use this space for any additional information related to the statements above.	
	46. Mathematics has not changed just because we have more technologies available. Students still need to know how to do everything they've always been taught. For example, my students can use the calculator to take square roots after they prove to me that they know how to do the algorithm to find square roots.
	47. It takes too much time and hassle to allow the use of this technology everyday. I will let my students use it from time to time, maybe when we aren't so rushed to cover objectives.
	48. Using this technology will present some management issues, but I plan to integrate this technology as a tool to enhance some, but not all, of my lessons and help my students take a new approach to learning mathematics in some units.
	49. I know that using this technology presents some new management issues, but I actively look for ways to minimize those challenges so that my students can use this technology on a regular basis.
	50. Using this technology presented some issues, but through extra planning and preparation, I have overcome those challenges and maximize the use of this technology resource.
Use this space for any additional information related to the statements above.	

	51. I see the use of this technology tool for simplifying some "messy math" problems (problems with "unfriendly" real-life numbers for example). I make this technology available on the rare occasion that we encounter those type problems (maybe for extra credit).
	52. Using this technology allows me to demonstrate more examples.
	53. I take a different approach to teaching using this technology. Through its use, my students not only explore and apply key concepts using multiple representations, but they are also able to examine more complex mathematics topics making mathematical connections than they would be able to without the technology use.
	54. Using this technology allows my students access to explore and apply key concepts using multiple representations (such as symbols, graphs, tables, and/or data lists) and making important connections among representations and concepts.
	55. My students regularly explore and apply key concepts of more complex mathematical topics than normally outlined for this class using multiple representations and connections.
Use this space for any additional information related to the statements above.	

Appendix C

Initial Interview Protocol

Please state your name, the grades and subjects you teach, and the school that you teach in.
During this interview, please do not refer to any student or teachers using their names. If you need to reference a student, teacher or other person, please use other identifiers. You can choose not to answer a particular question or to end this interview at any point. Do you understand that participation in this study is voluntary?
How do you feel about teaching with technology? How have these feelings changed throughout your career?
Please describe your experiences as a learner and as a teacher using instructional technologies, such as graphing calculators, TI-Navigator systems, and educational software.
Please describe the role that technology plays in your classroom. How do your students use instructional technologies to learn mathematics in your classroom?
What factors most influence your decisions to use or not use available instructional technologies?
What role does instructional technology play in your lesson planning? Will the progress of today's lesson influence tomorrow's lesson?
How do you think other teachers in your school would describe your use of instructional technologies? Why do you think that is?
Please describe any concerns you have about using instructional technologies in your classroom.
Describe any specific or general improvements you would like to occur in the implementation of instructional technologies in your classroom.
Thank you for your participation today. Before I leave I'd like to schedule a time to observe a technology lesson.

Appendix D

TPACK Observation Tool
Date ___________________
Teacher _______________________________________
School _________________________

Classroom description (including demographics, seating arrangements, available technologies, etc.)

Time	General notes	Notes specific to technology and TPACK

Time	General notes	Notes specific to technology and TPACK

Theme	Indicators
Curriculum & Assessment	• Technology-dependent or independent lesson • Formal or informal assessments • Alignment to framework
Learning	• Student use of technology • Awareness of students’ prior understandings and misunderstandings • Student engagement in Process Standards (NCTM, 2000)
Teaching	• Role of the teacher and instructional methods • Questions posed during lesson • Relating technology to mathematical goals
Access	• Technologies available and context of use • Student and teacher familiarity with technology • Access to representations

Appendix E

INFORMATION FORM

Title: Secondary Mathematics Teachers' Perceptions of their Progression through the TPACK Development Model

Investigator
Jessica Ivy, M.Ed.
Center for Mathematics and Science Education
[redacted]
The University of Mississippi
[redacted]

Dissertation Chair
Angela Barlow, Ph.D.
Center for Mathematics and Science Education
[redacted]
The University of Mississippi
[redacted]

Description

I will explore secondary mathematics teachers' perceptions about instructional technology integration. You will engage in two face-to-face interviews, be observed once during a lesson, and provide one sample lesson. In addition, you will complete a survey that collects data about your technological, pedagogical, and content knowledge (TPACK). This data will be used to determine what your perceptions are about your own TPACK, to compare your perceptions to other data collected, and identify supports you perceive to assist with instructional technology integration.

Risks and Benefits

You may feel uncomfortable reflecting on your teaching practices with technology, particularly if you are unhappy with your current integration of instructional technologies. Also, you may not be comfortable being observed during your teaching. I do not think that there are any other risks. Some teachers find it helpful to engage in these reflections that occur during the interviews.

Cost and Payments

Each of the two interviews will last approximately 20 minutes. The survey will take approximately 20 minutes to complete. The classroom observation will last approximately 50 minutes. There are no other costs for participating in this study. You will receive assorted school supplies for being part of this project. In addition, participants who participate fully in the project will be entered into a raffle to receive one of two TI-Nspire graphing calculators.

Confidentiality

I will only use your name to match the data that is collected. Before analyzing the data, each participant will be given a pseudonym that will be used for the duration of the study and for any subsequent publications. Other identifying information, including school, district, and city will be kept confidential. Original documents that contain identifying information will be kept in a locked cabinet. After data is matched, identifying information will be removed from these documents. Interviews will be audio-recorded and transcribed. Identifying information will be removed during the transcription process. I believe this will ensure confidentiality.

Right to Withdraw

You do not have to take part in this study. If you start the study and decide that you do not want to finish, all you have to do is to tell Jessica Ivy in person, by letter, or by telephone at the Center for Mathematics and Science Education, 101 OWMB, The University of Mississippi, University MS 38677, or 915-6621. Whether or not you choose to participate or to withdraw will not affect your standing with the Center for Mathematics and Science Education, or with the University, and it will not cause you to lose any benefits to which you are entitled.
The researchers may terminate your participation in the study without regard to your consent and for any reason, such as protecting your safety and protecting the integrity of the research data.

IRB Approval

This study has been reviewed by The University of Mississippi's Institutional Review Board (IRB). The IRB has determined that this study fulfills the human research subject protections obligations required by state and federal law and University policies. If you have any questions, concerns, or reports regarding your rights as a participant of research, please contact the IRB at (662) 915-7482.

Appendix F

Letter of Gratitude

Dear Participant,

Thank you for your participation in this study. The data gathered will be used to gain insight into the use of instructional technologies in high school classrooms.
Enclosed you will find an Information Sheet, a Self-Report Survey, and a Summary of Data Collection.

Please be aware that your data will be kept confidential. For data analysis and reporting purposes, pseudonyms will be used, and identifying information will be removed. Because this study focuses on teachers, no information about students will be collected.

As a thank you for your participation, you will receive a bag of school supplies at the conclusion of the study. You will also be entered into a raffle for one of two TI-Nspire graphing calculators. Full participation in the study is necessary to receive these incentives.

Please contact me at any point during the study with questions or concerns.

Thank you,

Jessica Ivy
[redacted]

Appendix G

Summary of Participant Commitments

- Initial Interview
  - Please provide a lesson plan, with associated handouts, that incorporates instructional technology.
  - You will receive the Self-Report Survey to complete before the observation.
- Classroom Observation
  - This lesson does not have to be the same as the lesson plan you submitted during the Initial Interview.
  - Please provide the completed Self-Report Survey.
- Follow-Up Interview
  - You will receive your Goody Bag of school supplies.

(The drawing for the TI-Nspire graphing calculators will take place after all data is collected. This will occur on or before January 15, 2011.)

Appendix H

Response from Credible Critic

OSU
Oregon State
UNIVERSITY

[redacted]

March 6, 2011

To: Jessica Ivy

From: Margaret L. Niess
Professor Emeritus Mathematics Education
Science and Mathematics Education
Oregon State University
[redacted]

Margaret L. Niess

RE: Review of Chapter IV of Dissertation

It has been my pleasure to review your Chapter IV of the dissertation that you conducted. As I reviewed this chapter I found sufficient detail about the participants to concur with your descriptions of their TPACK levels based on my research. I appreciated the opportunity to read this in advance. If I can be of further assistance, please let me know.

Appendix I

Descriptors of TPACK Development Model (Niess et al., 2009)

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Mathematics Teacher TPACK Development Model: Themes X **Levels** X **Descriptors** X **Examples**

CURRICULUM & ASSESSMENT

C: Curriculum descriptor A: Assessment descriptor Ex: Mathematics Example

Recognizing

C: Acknowledges that mathematical ideas displayed with the technologies can be useful for making sense of topics addressed in the curriculum.

Ex: Creates graphs of multiple linear functions using graphing calculators to provide a visual representation for varying slopes. Considers these visuals as making sense of the idea of slope but is unsure of how this might help students learn the basic concept.

A: Resists idea of technology use in assessment indicating that technology interferes with determining students' understanding of mathematics.

Ex: Does not allow calculator use when assessing students' understanding of solving linear equations.

Accepting

C: Expresses desire but demonstrates difficulty in identifying topics in own curriculum for including technology as a tool for learning.

Ex: Attends and participates in mathematics dynamic geometry system workshop to identify curricular ideas for incorporating the technologies as learning tools. Mimics the incorporation of a dynamic geometry system idea from the workshop to display measuring the sum of the angles of a triangle that upon multiple changes of the triangle suggests that the sum of the angles of any triangle is 180 degrees.

A: Acknowledges that it might be appropriate to allow technology use as part of assessment but has a limited view of its use (i.e., use of technology on a section of an exam).

Ex: Attends and participates in a mathematics assessment professional development to consider ideas for assessing students' understanding of solving systems of linear functions using the calculator as a tool. Mimics the assessment idea to explain the use of the calculator for solving systems of linear functions by using the trace function to identify the intersection. Often retests technology questions with paper and pencil questions to be sure that the concept was learned the 'right' way.

Adapting

C: Understands some benefits of incorporating appropriate technologies as tools for teaching and learning the mathematics curriculum.

Ex: Targets key topics students investigate with technology. Develops lessons to demonstrate mathematics concepts with technology and activities for students to use technology to verify or reinforce those concepts. After students have learned to create graphs of specific linear functions, students are challenged to use the spreadsheet to verify the graphical representation of the ordered pairs.

A: Understands that if technology is allowed during assessments that different questions/items must be posed (i.e., conceptual vs. procedural understandings).

Ex: Allows use of calculator in an assessment but designs the assessment to focus on gathering students' conceptual understanding of solving systems of linear functions in addition to their procedural understanding.

Exploring

C: Investigates the use of topics in own curriculum for including technology as a tool for learning; seeks ideas and strategies for implementing technology in a more integral role for the development of the mathematics that students are learning.

Ex: Adapts own previous mathematics lesson to include technology.
Ex: Develops own ideas about using technology to enhance current curriculum; thus, begins altering preexisting activities or creating new activities for current curriculum.

A: Actively investigates use of different types of technology-based assessment items and questions (e.g., technology active, inactive, neutral or passive).
Ex: Designs assessments where students are expected to show their understanding of mathematical ideas using an appropriate technology that extends beyond paper and pencil type questions.

Advancing

C: Understands that sustained innovation in modifying own curriculum to efficiently and effectively incorporate technology as a teaching and learning tool is essential.
Ex: Develops innovative ways to use technology to develop mathematical thinking in students such as using virtual algebra tiles to extend ideas of handheld manipulatives to focus on variables in algebraic expressions.
Ex: Modifies and advances curriculum to take advantage of technology as a tool for teaching and learning such as using CAS to explore more complex algebraic expressions.

A: Reflects on and adapts assessment practices that examine students' conceptual understandings of the subject matter in ways that demand full use of technology.
Ex: Develops innovative assessments to capture students' understandings of the mathematics embedded in the particular technology.

LEARNING

M: Mathematics learning descriptor C: Conception of student thinking descriptor
Ex: Mathematics example

Recognizing

M: Views mathematics as being learned in specific ways and that technology often gets in the way of learning.
Ex: Mathematical exploration with technology rarely seen.

C: More apt to accept the technology as a teaching tool rather than a learning tool.
Ex: Technology is used only outside of normal classroom activities, such as checking homework, calculating large numbers, etc.

Accepting

M: Has concerns about students' attention being diverted from learning of appropriate mathematics to a focus on the technology in the activities.
Ex: Limits student technology use, particularly during the introduction and development of key topics.

C: Is concerned that students do not develop appropriate mathematical thinking skills when the technology is used as a verification tool for exploring the mathematics.
Ex: Activities that use technology are almost always redone without technology to be certain students really learned the particular concept.

Adapting

M: Begins to explore, experiment and practice integrating technologies as mathematics learning tools.
Ex: Students explore some mathematics topics using technology.

C: Begins developing appropriate mathematical thinking skills when technology is used as a tool for learning.
Ex: Although students use technology for most topics, assessing student thinking remains mostly technology free.

Exploring

M: Uses technologies as tools to facilitate the learning of specific topics in the mathematics curriculum.
Ex: Students explore numerous topics using technology, sometimes ranging outside the topic at hand.

C: Plans, implements, and reflects on teaching and learning with concern for guiding students in understanding.

Ex: Technology activities are implemented and evaluated with respect to student learning of mathematics and student attitudes toward mathematics.

Ex: Manages technology-enhanced activities towards directing student engagement and self-direction in learning mathematics.

Advancing

M: Plans, implements, and reflects on teaching and learning with concern and personal conviction for student thinking and understanding of the mathematics to be enhanced through integration of the various technologies.

Ex: Students explore mathematics topics, integrating various technologies in attempts to better understand mathematical concepts.

C: Technology-integration is integral (rather than in addition) to development of the mathematics students are learning.

Ex: Engages students in high-level thinking activities (such as project-based and problem solving and decision making activities) for learning mathematics using the technology as a learning tool.

Ex: Technology is used to develop advanced levels of understanding of mathematical concepts.

TEACHING

M: Mathematics learning descriptor I: Instructional descriptor E: Environment descriptor
PD: Professional development descriptor Ex: Mathematics example

Recognizing

M: Concerned that the need to teach about the technology will take away time from teaching mathematics.

Ex: Students use technology on their own and little or no instruction with technology is present.

I: Does not use technology to develop mathematical concepts.

Ex: Technology, if used in class, is used for menial or rote activities.

E: Uses technology to reinforce concepts taught without technology.

Ex: Focus on linear functions where students practice creating graphs by hand to explore different functions. After students have demonstrated competence with linear functions, summarize the knowledge, with a spreadsheet example or a graphing calculator example.

PD: Considers attending local professional development to learn more about technologies.

Ex: Attends local workshops that focus on gaining skills with the technology; context of the learning activities is mathematics.

Accepting

M: Uses technology activities at the end of units, for “days off,” or for activities peripheral to classroom instruction.

Ex: Technology-enhanced activities are not used for topics that require more advanced technology skills.

I: Merely mimics the simplest professional development mathematics curricular ideas for incorporating the technologies.

Ex: Introduces the Pythagorean Theorem algorithmically; teacher use of dynamic geometry to verify the Pythagorean Theorem; students find solutions to example problems using paper and pencil.

E: Tightly manages and orchestrates instruction using technology.

Ex: Technology is directed, in a tightly sequenced, step-by-step process. Skill-based, non-exploratory technology use.

PD: Recognizes the need to participate in technology related PD.

Ex: Seeks out technology-related professional development, workshops that are directed at developing the technology in the learning of mathematics.

Adapting

M: Uses technology to enhance or reinforce mathematics ideas that students have learned previously.

Ex: Students use technology to reinforce previously teacher-taught concepts.

I: Mimics the simplest professional development activities with the technologies but attempts to adapt lessons for his/her mathematics classes.
Ex: Technology-based lessons are incorporated that are tailored to students' needs.
E: Instructional strategies with technologies are primarily deductive, teacher-directed in order to maintain control of the how the activity progresses.
Ex: Begins to adapt instructional approaches that allow students opportunities to explore with technology for part of lessons.
PD: Continues to learn and explore ideas for teaching and learning mathematics using only one type of technology (such as spreadsheets).
Ex: Shares ideas from professional development with other mathematics teachers in the building.

Exploring

M: Engages students in high-level thinking activities (such as project-based and problem solving and decision making activities) for learning mathematics using the technology as a learning tool.
Ex: Teachers share classroom-tested, technology-based lessons, ideas, and successes with peers.
I: Engages students in explorations of mathematics with technology where the teacher is in role of guide rather than director of the exploration.
Ex: Students use technology to explore new concepts as the teacher serves mostly as a guide.
E: Explores various instructional strategies (including both deductive and inductive strategies) with technologies to engage students in thinking about the mathematics.
Ex: The teacher incorporates a variety of technologies for numerous topics.
PD: Seeks out and works with others who are engaged in incorporating technology in mathematics.
Ex: Organizes teachers of similar mathematics and grade level in investigating the mathematics curriculum to integrate appropriate technologies.

Advancing

M: Active, consistent acceptance of technologies as tools for learning and teaching mathematics in ways that accurately translate mathematical concepts and processes into forms understandable by students.
Ex: Teacher is seen as a resource as novel ideas for helping students learn mathematics with technology.
I: Adapts from a breadth of instructional strategies (including both deductive and inductive strategies) with technologies to engage students in thinking about the mathematics.
Ex: The teacher helps students move fluently from one tool to another while demonstrating a focus on and a joy of deeply understanding mathematical topics.
E: Manages technology-enhanced activities in ways that maintains student engagement and self-direction in learning the mathematics.
Ex: The teacher forms and reforms learning groups where individual and group learning is valued and encouraged.
PD: Seeks ongoing PD to continue to learn to incorporate emerging technologies. Continues to learn and explore ideas for teaching and learning mathematics with multiple technologies to enhance access to mathematics.
Ex: Engages teachers in the district in evaluating and revising the mathematics curriculum to more seamlessly integrate technology throughout the grades, adjusting the curriculum for a 21st century mathematics curriculum with appropriate technologies.

ACCESS

U: Usage descriptor B: Barrier descriptor A: Availability descriptor Ex: Mathematics example

Recognizing

U: Permits students to use technology 'only' after mastering certain concepts.
Ex: Mathematical exploration with technology tools is challenged by beliefs about how students need to learn mathematics.

B: Resists consideration of changes in content taught although it becomes accessible to more students through technology.
Ex: Student access to technology is limited to 'after' they have learned the given concepts using paper and pencil procedures and only for rote activities.
A: Notices that authentic problems are more likely to involve 'unfriendly numbers' and may be more easily solved if students had calculators.
Ex: Assigns some mathematics problems using school and community data but saves then for "extra credit" work if students have calculators.

Accepting

U: Students use technology in limited ways during regular instructional periods.
Ex: Student activities with technology are limited to brief tightly controlled situations.
B: Worries about access and management issues with respect to incorporating technology in the classroom.
Ex: Students can only use technology in isolated situations or non-important learning situations.
A: Calculators permit greater number of examples to be explored by students.
Ex: Student use calculators to investigate patterns and functions.

Adapting

U: Permits students to use technology in specifically designed units.
Ex: Access to and use of technology is available for exploration of new topics, usually with the teacher's demonstration.
B: Uses technology as a tool to enhance mathematics lessons in order to provide students a new way to approach mathematics.
Ex: Concepts learned with technology are not assessed with technology.
A: Concepts are taught differently since technology provides access to connections formerly out of reach.
Ex: Students use dynamic geometry software to investigate and make connections between trigonometry functions.

Exploring

U: Permits students to use technology for exploring specific mathematical topics.
Ex: Access to and use of technology is available and encouraged for mathematics exploration during most class times.
B: Recognizes challenges for teaching mathematics with technologies, but explores strategies and ideas to minimize the impact of those challenges.
Ex: Technology is used extensively in assessments. Seeks out ways to obtain technology for classroom use and begins creating methods for technology management issues.
A: Through the use of technology, key topics are explored, applied, and assessed incorporating multiple representations of the concepts and their connections.
Ex: Simultaneous equations are developed from an authentic situation, solved, and interpreted using graphs, tables, symbols and data.

Advancing

U: Permit students to use technology in every aspect of mathematics class.
Ex: Technology is seen as an opportunity to challenge notions of what mathematics students can master.
B: Recognizes challenges in teaching with technology and resolves the challenges through extended planning and preparation for maximizing the use of available resources and tools.
Ex: Technology is used to expand the mathematics concepts that can be accessed by students.
A: Students are taught and permitted to explore more complex mathematics topics or mathematical connections as part of their normal learning experience.
Ex: Using the Internet to find interesting mathematical problems, students investigate the role that technologies can play in finding solutions to the problems.

VITA

Jessica Taylor (Doss) Ivy was born in Memphis, TN, and was the only child of Randy and Audrey Doss. She grew up in Southaven, MS, but moved to Columbus, MS, to attend the Mississippi School for Mathematics and Science in 2000. Jessica graduated from the Mississippi School for Mathematics and Science in 2002, and moved to Oxford, MS, to pursue a higher education. Jessica married Justin (Kyle) Ivy in December of 2005. In 2006, Jessica graduated from The University of Mississippi with a Bachelor of Arts degree in education. In May 2006, Jessica received the Robert W. Plants Student Teacher Award for secondary education, the Phi Delta Kappa Outstanding Secondary Preservice Teacher award, and the Elaine Deas Mullins Outstanding Mathematics Educator award.

During the 2006 – 2007 school year, Jessica worked as a mathematics teacher at Booneville High School. Jessica began graduate studies, which were funded by the Center for Mathematics and Science Education, in 2007 and received a Master of Education degree in 2008. In 2009, Jessica and Kyle welcomed their first child, Marion Taylor Ivy. Jessica continued graduate studies at The University of Mississippi in pursuit of a doctoral degree in education. During her graduate studies, Jessica presented at numerous national, state, and local conferences. Additionally, she was awarded the 2011 Outstanding Doctoral Student in Secondary Education Award.