NCSM Journal
of Mathematics Education Leadership

SPRING 2016 VOL. 17, NO. 1

National Council of Supervisors of Mathematics www.mathedleadership.org

Table of Contents

Exploring the Technological Pedagogical Content Knowledge (TPACK) of High School Mathematics Teachers: A Multiple Case Study

Jessica T. Ivy and Dana P. Franz, *Mississippi State University*

Abstract

The Technology Principle highlights the opportunities offered to enhance instruction through technology integration. With the advent and increased availability of new technologies, access has become less of an issue, yet widespread integration of instructional technologies in ways that support learning are not necessarily observed in classrooms. In this article, the barriers to technology integration are considered, with a particular emphasis on pedagogical content knowledge and its role in development of technological pedagogical content knowledge (TPACK). This interplay of beliefs about student learning and practices when teaching with technology is explored through the cases of two secondary mathematics teachers with common backgrounds but contrasting levels of TPACK.

Introduction

Instructional technologies introduce novel opportunities for student learning in secondary mathematics classrooms (National Council of Teachers of Mathematics [NCTM], 2000). The promise and vision for technologies is exemplified in the Technology Principle (NCTM, 2000), which states that technology has the potential to offer access to multiple representations and deepen mathematical understandings through exploring mathematical patterns, making conjectures, and testing those conjectures in ways which are only feasible with the technology. In this way, the quality use of technology does not suggest a replacement of paper-and-pencil calculations, but rather offers complimentary opportunities for students to make more generalizations, engage in symbolic transformations, and more accurately examine graphical representations (National Research Council, 2001). Most recently, NCTM (2014) affirmed their call for quality technology use in *Principles to Actions.* "An excellent mathematics program integrates the use of mathematical tools and technology as essential resources to help students learn and make sense of mathematical ideas, reason mathematically, and communicate their mathematical thinking" (p. 5).

The identified potential for enhancing student learning has led to widespread attention to instructional technology in the mathematics classroom (Cuban, Kirkpatrick, & Peck, 2001). The issue, however, is found in the ways in which technology tools are implemented in the classroom. Is the technology being used to take advantage of the opportunities described in the Technology Principle (NCTM, 2000) or by the National Research Council (2001)? Or, is technology a different tool used in traditional types of teaching? Research by Ertmer and Ottenbreit-Leftwich (2009) indicated that the latter might be the case. Although the availability of instructional technology is clearly essential to its implementation, availability does not guarantee implementation, much less quality implementation. Therefore, understanding teachers' knowledge and decisions regarding implementation of technology is essential. With this in mind, this study examined two juxtaposed case studies and provided insight for mathematics teacher leaders who aim to support teachers as they integrate technologies for the teaching and learning of mathematics.

Specifically, this research study examined teachers' beliefs and practices along with their implications on technology integration through the lens of teacher knowledge. Through the construct of technological pedagogical content knowledge (TPACK), the researcher explored the specialized knowledge that two high school mathematics teachers possessed, the evidence of this knowledge, and the implications for classroom practices. The following research questions were posed.

1. How do the two teachers studied perceive their use of instructional technologies?

2. How do these perceptions compare to indications from the analysis of other data gathered by the researcher? What is the role of second-order barriers to technology integration with regard to the two teachers' practices?

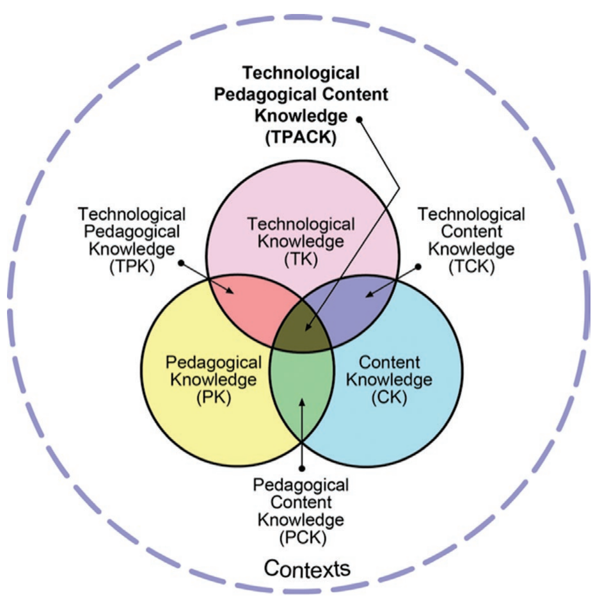
Background Literature

Technological Pedagogical and Content Knowledge

It is well established that mathematical content knowledge is required, but not sufficient, for being an effective mathematics teacher (Ball, Thames, & Phelps, 2008; Cuban, Kirkpatrick, & Peck, 2001; Hill, Rowan, & Ball, 2005; Shulman, 1986). Shulman (1986) described a special knowledge that must accompany teacher content knowledge to promote learning, referred to as pedagogical content knowledge (PCK). Many studies since Shulman's definition have confirmed the need for PCK (e.g., Ball et al, 2008; Grossman & Shulman, 1996; Shulman, 1987) indicating that teachers must understand appropriate pedagogical techniques specific to the subject matter content. Without PCK, teachers possess few tools for establishing an environment conducive to learning. Unfortunately, research studies have indicated that teachers rely on strategies they experienced as learners, utilize lecture-based strategies, or use repetitive examples during instruction (Darling-Hamond, 2006; Feiman-Memser, 1983; Lorti, 1975). With continued development of teachers' PCK, however, they become more successful in identifying the needs of their students, interpreting students' error patterns, engaging students in learning that leads to conceptual understandings, and possessing an awareness of the interconnected nature of mathematical concepts (NCTM, 2000, 2014; van Es, 2011).

With the overwhelming proliferation of instructional technologies, it has become apparent that possessing PCK and mathematical content knowledge is insufficient for ensuring effective mathematics instruction in this era of technology-enhanced classrooms (NCTM, 2014; Neiss, 2005; Pierson, 2001). Recognizing this deficiency, researchers defined a new type of PCK necessary for teaching mathematics with technology (Mishra & Koehler, 2006; Niess et al., 2009). Koehler and Mishra (2008) initially described this technology-driven knowledge. From their perspective, teachers needed to understand: technological content knowledge (TCK) or how to use the technology; technological pedagogical knowledge (TPK) or how to effectively teach the technology; and pedagogical content knowledge (PCK) or how to anticipate the learning needs of students to promote conceptual learning through the use of technology. Further discussions yielded a new construct: 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 and is represented by a Venn diagram to demonstrate this interplay (see Figure 1). Using

FIGURE 1.
The TPACK Model and its components. Reproduced with permission of the publisher © 2012 by tpack.org.



a progressive model, Niess and colleagues interpreted the TPACK construct specifically for the mathematics classroom (Niess et al., 2009). This model defines the development of mathematics teachers' TPACK, across four themes (i.e., curriculum and assessment, learning, teaching, and access) with five teacher use levels within each theme (i.e., recognizing, accepting, adapting, exploring, and advancing). The next section provides descriptions of these levels.

Levels of TPACK

Teachers' beliefs about the use of technology generally fall within one of five levels of the model defined by Neiss and colleagues (2009). At the ***recognizing*** level, teachers believe that technology is a distraction from learning. Teachers at this level limit the use of technology to checking computations or reinforcing previously taught concepts. When teachers begin to incorporate technology into lessons, they progress to the ***accepting*** level. These teachers tend to plan lessons that integrate technology as supplemental lessons, which are taught in a teacher-centered fashion with no opportunities for students to select their own strategies. As teachers begin to view technology as a learning tool they enter the ***adapting*** level. At this level, teachers continue to use technology to reinforce previously learned concepts in teacher-led lessons, but these teachers have a clear vision for integrating technology as a tool for student learning. The fourth level of TPACK is the ***exploring*** level. At this level, teachers integrate technology as a tool for student-led explorations of high-level thinking tasks that may be technology-dependent. These teachers use inductive and deductive strategies with technology by planning engaging questions for instruction. The highest TPACK level is the ***advancing*** level, in which technology is consistently used as a tool for the teaching and learning of mathematics. These teachers are often recognized by their colleagues for their specialized knowledge and pedagogy regarding instructional technology.

The TPACK Development Model differentiates teachers who integrate technology seamlessly into daily instruction from those who use technology as a supplement to traditional teaching (Pape et al., 2012). It should be noted that a teacher might be at different levels for different themes and for different technologies (Miller, 2011). The recognizing level is the lowest level, but it is assumed that teachers who meet the criteria for the recognizing level or fall below those criteria are classified at the recognizing level.

Teachers with available instructional technologies may experience a failure to progress through the levels of the TPACK Development Model due to a variety of barriers to technology integration (An & Reigeluth, 2011; Boling & Beatty, 2012). Barriers to integration will be examined in the following section.

Identified Barriers to Technology Integration

Although the availability of technology is essential to its implementation, availability alone does not guarantee implementation (An & Reigeluth, 2011; Ertmer, 1999). Ertmer stated, "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 Technology Principle (NCTM, 2000) and *Principles to Action* (NCTM, 2014), it is essential that teachers are afforded opportunities to gain the knowledge necessary to take advantage of instructional technology (Machado, Laverick, & Smith, 2011).

Researchers have sought to identify barriers to appropriate instructional technology integration in the mathematics classroom (e.g., Ertmer & 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 order barriers included 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. Second-order barriers included teachers' attitudes, beliefs, knowledge, skills, and practices. Understanding these barriers will help academic leaders understand how best to assist with quality technology integration and facilitate teachers' development of TPACK, which supports the significance of this study. Although first- and second-order barriers both existed, first-order barriers were outside of the participants' control. Thus, this research focused on second-order barriers to technology integration.

Methodology

Research Overview

The study from which this data was gathered was a qualitative study, consisting of data from seven secondary mathematics teachers in a southeastern state in the United States (Ivy, 2011). To identify potential participants, the researcher sent a Call for Participants to a list-serve of secondary mathematics teachers and selected a sample of seven teachers whose responses to the call indicated varied levels of instructional technology integration. Two of the seven teachers were selected for inclusion in this article because their similarities in setting and experience contrasted notably with their differences in instructional technology integration and pedagogical practices. Yin (2014) described the use of multiple case design through theoretical replication to consider cases with commonalities which can yield compelling and robust results. This methodology follows the replication, rather than sampling, techniques described by Yin for the purpose of introducing theoretical interest, extending beyond the similarities and differences of the cases.

To gain a vision of the level of instructional technology integration of each participant, the researcher conducted an initial interview, observed a classroom lesson that included the use of graphing calculators, conducted a follow-up interview, collected a sample lesson, and collected a completed TPACK Development Survey. The qualitative data were analyzed using deductive analysis to align data pieces (i.e., statements from participants, observations, sample lessons) to fit within the existing levels of the TPACK Developmental Model. Deductive analysis is described by Patton (2002) as the use of an existing framework to consider qualitative data. Brief descriptions of the instruments used in data collection are provided below.

Instruments

To gain insight into the beliefs and practices of the participants, the researcher in collaboration with a colleague created the TPACK Development Model Self-Report Survey and Interview Protocol. Each of these instruments along with information regarding classroom observations will be described in the paragraphs that follow.

TPACK Development Model Self-Report Survey. As the colleague's research interests also focused on in-service teachers' TPACK, the collaboration between the colleague and the researcher led to the development of the research instruments. The TPACK Development Model Self-Report Survey (see Appendix A)[1] included statements that pertained to the themes identified by the TPACK Development Model. For this study, responses to the items related to the Teaching and Learning themes and their subthemes were considered. Subthemes of the Learning theme include mathematics and conceptions of student thinking. Subthemes of the Teaching theme include mathematics learning, instruction, environment, and professional development. These subthemes originated in the work of Niess and colleagues (2009), who described the mathematics specific TPACK Development Model. These subthemes resulted in six 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.

Although this instrument was created in collaboration with the aforementioned colleague, the TPACK Development Model Self-Report Survey was also submitted to Margaret Niess, who is one of the foremost experts in the study of mathematics teachers' TPACK. The colleague and the researcher used feedback from Niess to further refine the survey prior to using it as an instrument in this study. Because the survey was a newly developed instrument, statements and details from the study were examined by colleagues in the field who provided insight and opportunities for further revision and ensured construct validity.

Prior to completing the survey, participants were provided with oral instructions. They were instructed to select one instructional technology (e.g., graphing calculator) that they used regularly and to check all statements that were true for them when considering their experiences with this self-selected type of technology. Statements provided by participants were examined to ensure alignment with appropriate levels of the TPACK Development Model.

Interview protocol. The Initial Interview Protocol included broad questions regarding technology integration to offer participants an opportunity to share information about instructional technology use in their classrooms. The Interview Protocol included eleven items. Three

[1] The first author would like to express gratitude for the collaborative contributions of Julie Riales in creating and refining the TPACK Development Model Self-Report Survey.

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 participant's levels within the TPACK Development Model. The focus of the Interview Protocol was on the Learning and Teaching themes. The follow-up interviews consisted of individual rather than standardized protocols. Questions asked during these discussions were written to seek clarification and additional details.

Field notes. An organizational tool was used to collect field notes during classroom observations. The primary purpose of the field notes was to gather insight into teachers' practices using a method that did not introduce the bias of the self-reported data. Observation field notes focused on teacher actions with particular attention given to actions described in the TPACK Development Model. Classroom observations were utilized to validate the assignment to the levels when conflicting evidence surfaced in interviews and surveys.

Researcher as an instrument. The first author served as the primary researcher, collecting and analyzing the qualitative data. Therefore, the researcher served as an instrument (Patton, 2002). In this capacity, the researcher collected field notes and other data while practicing reflexivity, that is keeping a conscious note of ideologies and biases which could influence findings, as recommended by Patton. Due to these practices, as well as professional experiences studying the use of technology in the classroom, working with teachers to increase technology integration, and teaching mathematics lessons with technology, the researcher effectively served as an instrument throughout the study.

Qualitative Analysis Considerations

To adhere to the constructs of qualitative inquiry, the researcher integrated assurances of credibility, transferability, dependability, and confirmability into the research design (Shenton, 2004). Miles, Huberman, and Saldana (2014) specifically noted three key recommendations for achieving internal validity, credibility, and authenticity, which were used by the researcher in the analysis of study data: triangulation between complementary data sources to reach converging conclusions combined with methods to reconcile the differences between conflicting conclusions; use of meaningful, context-rich descriptions; and linking of data to existing theories or constructs. In consideration of dependability concerns of qualitative research, the interviews were conducted using a guided conversation style. Audio recordings of the interviews were transcribed and transcriptions were analyzed by the primary researcher with final data analysis reviewed by a credible critic. Documentation of dependability was established through an audit trail kept through researcher notes and reflections constructed throughout the duration of the study. Confirmability was ensured through the aforementioned triangulation, as well as being reflexive in consciousness (Patton, 2002).

Results

Both participating teachers, Ms. Thomas and Ms. James (pseudonyms), taught at high schools in which approximately 60% of students qualified for free or reduced lunch and with a racial makeup of approximately two-thirds of the students were Caucasian and slightly less than one-third were African American. They both had been teaching approximately 25 years at the time of the study. In addition, both taught a variety of high school mathematics courses and had access to instructional technologies, notably graphing calculators and mathematical software. Despite these similarities, data collected from the two participants painted contrasting pictures of instructional technology integration and equally different pedagogical practices. Descriptions of each case and the relevant data collected are provided in the following paragraphs.

MS. THOMAS

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. Then the researcher analyzed Ms. Thomas' responses and noted responses that were relevant to her TPACK levels for the teaching and learning themes.

When asked to describe her feelings about technology, Ms. Thomas responded, "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." She provided an example of how she used the calculator to introduce parallel lines, through carefully controlled students' experiences, and maintained that paper-and-pencil procedures should precede explorations involving technology. "When they get 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 were several notable components to Ms. Thomas' statement. First, Ms. Thomas stated that students should learn concepts prior to using instructional technology especially noting the overdependence for simple calculations. This statement corresponded to the recognizing level for the Teaching theme. 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, indicating that she was at the recognizing level for the Learning theme. 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, suggesting she could have been moving toward the accepting level for the Teaching theme, which is demonstrated when teachers mimic aspects of professional development in their teaching (Niess et al., 2009).

When asked to describe the role technology played in her classroom on a daily basis, Ms. Thomas made a reference to using technology to introduce real-world concepts; however, she did not provide an example of this practice when asked to do so during a follow-up question. Based on this response, Ms. Thomas limited students' opportunities with instructional technologies to using the calculators for computations and occasional graphing, which was characteristic of the recognizing level for the Teaching theme. She also expressed that she limited the availability of technology during the formative phase of concept development, further indicating the recognizing level for the Teaching theme and advancing beyond the recognizing level for the Learning theme.

The analysis of the interview data revealed that Ms. Thomas was at the accepting level for the Teaching theme of TPACK (Niess et al., 2009). At this level, a teacher "merely mimics the simplest professional development mathematics curricular ideas for incorporating the technologies" (p. 22). The researcher made this classification despite Ms. Thomas' connections to the recognizing level for this theme. Ms. Thomas' occasional technology use for concept exploration, and her participation in technology-related professional development enabled her to be rated at the accepting level for the Teaching theme. For the Learning theme, interview data revealed that Ms. Thomas was at the recognizing level of TPACK (Niess et al., 2009). At this level, a teacher "views mathematics as being learned in specific ways and that technology often gets in the way of learning" (p. 21).

Observation. The researcher observed an Algebra I lesson in Ms. Thomas' classroom approximately two weeks after 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 entered the room, 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 participant 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 less than a minute 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, "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." Ms. Thomas concluded the lesson by informing 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 the point of intersection. Students did not use technology in ways that embodied the Technology Principle (NCTM, 2000). Specifically, students were not using technology to access mathematics that they would not otherwise have been able to access, nor did they explore new concepts with the technology. Calculator use was reserved for performing a series of procedures after the teacher determined the skill had been "mastered" by students using paper and pencil. Furthermore, this use of technology limited students' opportunities to develop conceptual understanding of the mathematics by focusing on memorized procedures rather than concepts and connections. Data from the observed lesson indicated that Ms. Thomas was at the recognizing level for both 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' practices and beliefs regarding instructional technology integration. During this interview, Ms. Thomas stated that she often used technology to allow students to make connections to the real world; however, she did not provide an example of tasks that she had used in this way. 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 could be performed quickly with the calculator, such as performing operations.

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. 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. Ms. Thomas' 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).

Self-report survey. Ms. Thomas' 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 her use of graphing calculators. 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. Six items from the survey aligned with the Teaching and Learning themes, with two items for the Learning theme and four items for the Teaching theme (see Appendix A). Ms. Thomas' responses are summarized in Table 1.

Table 1: Summary of Ms. Thomas' Survey Responses

Theme	Survey Statements*	Level alignment to TPACK Developmental Model
Learning	3	Adapting
	9	Exploring
	10	Advancing
Teaching	14	Exploring
	15	Advancing
	18	Adapting
	21	Recognizing
	24	Exploring
	27	Accepting

* Survey statement numbers correspond to the survey items found in Appendix A.

Summary. An initial interview analysis indicated accepting and recognizing levels for the Teaching and Learning themes, respectively. In contrast, self-report survey data indicated Ms. Thomas' TPACK for the Learning theme to be between the adapting, exploring, and advancing (highest) levels for the Learning theme and at all levels for the Teaching theme. Subsequent observation and follow-up interview data provided indications of the accepting levels for both themes. Self-report bias and the alignment of non-survey data led to the conclusion that Ms. Thomas' TPACK levels for both the Teaching and Learning themes of TPACK were within the recognizing and accepting (lowest) levels.

MS. JAMES

Initial interview. The researcher was particularly interested in Ms. James because she, along with a colleague, went to such efforts to acquire technological resources for her classroom. 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, "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." She elaborated, "I don't see how math makes sense without seeing a picture of it and using graphing calculators or technology. . . . Concepts were probably lost with kids that needed a visual to see why things work and how they're connected."

Ms. James' response indicated a vision of instructional technology use as a tool for teaching and learning. She related her feelings toward the learners' experiences. This statement connected to the conception of the 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' comment suggested that she used technology as a teaching tool in her classroom.

Ms. James had extensive teaching experience with technology. She was able to recall in detail her acquisition of instructional technologies. Her statements demonstrated a certain internal motivation to incorporate instructional technologies while teaching mathematics. The researcher asked Ms. James to recount how she learned to use the graphing calculators. Ms. James responded, "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." She described her current practices including visits to professional conferences. "I'll try to go in sessions and learn as much as I can. . . So whatever we do, we just figure out on our own." She also described learning from her 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."

Ms. James' statements 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 statements connected with the professional development descriptor at the exploring level for the Teaching theme of TPACK (Niess et al., 2009). During the interview, Ms. James expressed 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. The researcher noticed 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." She elaborated, "The kids are all engaged when you're using the Navigator system, but on the other hand, they may not stay on task. . . . when they realize that technology does so much, and they want to show off." She concluded with an example. "If I ask them to send equations that do a certain thing, then . . . And it may not be anything like we were looking for. . . You have to take the good with the bad."

There were two notable components to these statements. 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 had shaped her teaching and learning strategies. The second notable aspect to this response was the idea that when using technology you have "to take the good with the bad." This was notable because Ms. James viewed herself as a technology supporter, yet she still acknowledged misuse and challenges associated with technology integration.

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' responded with laughter and stated, "I don't ever think about not using it. It's an everyday thing." Technology had become an essential component to Ms. James' 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. 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).

Observation. The researcher observed a Pre-Calculus lesson in Ms. James' 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 (i.e., a circle and a line) and determine the intersections of their graphs. Ms. James led a discussion about graphing a circle on 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 was graphed in the calculator with the default window setting.

After reviewing the homework item, Ms. James distributed a task sheet. Ms. James introduced 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. Specifically, Ms. James anticipated that some students would initially not be able to view the data because they would be using the default window. She encouraged students to discuss these types of issues. Ms. James led the class through graphing the data in a scatter plot. Throughout the lesson, she 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. When Ms. James asked students to tell what they noticed about the data, they reported 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 would overtake the sale of CDs. Other questions were used to guide students' interpretations of the data. The lesson was teacher-led but solicited active participation from the students. 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. 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. Based on the observation data, Ms. James was at the exploring level for the Learning 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 were 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' continual desire to improve her teaching strategies. She also described how students used technology to engage in projects and decision-making tasks. 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. The follow-up interview data indicated that Ms. James was at the exploring level for the Teaching and Learning themes of TPACK (Niess et al., 2009). This analysis was based upon statements that indicated that Ms. James integrated instructional technology into all aspects of her teaching, took instructional risks with technology, and sought out professional development opportunities.

Self-report survey. Ms. James' 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. Self-report survey data suggested that Ms. James' perceptions of her Teaching and Learning TPACK levels were slightly higher than the levels suggested by other data the researcher obtained. 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 due primarily to the teacher-guided structure of her lessons and use of task sheets, which provided little opportunity for students to use technology in an exploratory way. Further, the researcher classified Ms. James as transitioning from the adapting level to the exploring level for the Teaching theme of TPACK due to her tendency to rely on one primary technology (graphing calculators) and the limited way in which calculators were used to explore new concepts (Niess et al., 2009). Ms. James' responses are summarized in Table 2.

Table 2: Summary of Ms. James' Survey Responses

Theme	Survey Statements*	Level alignment to TPACK Developmental Model
Learning	5	Advancing
	10	Advancing
	14	Exploring
Teaching	20	Advancing
	24	Exploring
	29	Advancing
	30	Exploring

* Survey statement numbers correspond to the survey items found in Appendix A.

Summary. An initial interview analysis indicated that Ms. James was at the exploring level for the Teaching and Learning themes. In contrast, self-report survey data indicated Ms. James' TPACK for the Teaching and Learning themes to be between the exploring and advancing (highest) levels. Further, subsequent observation and follow-up interview data provided indications of the exploring levels for both themes. Self-report bias and the alignment of non-survey data led to the conclusion that Ms. James' TPACK levels for both the Teaching and Learning themes of TPACK were at the exploring level.

Discussion

Based on interviews, it seemed that the participants had similar PCK based on consistent statements describing the use of technology to explore mathematics concept; however, classroom observations and additional data suggested otherwise. Ms. Thomas described fostering an environment conducive to developing mathematical understanding through exploration of concepts, but her classroom instruction was lecture-based and teacher-centered with few opportunities for students to make decisions about how to proceed or to problem solve. Alternatively, Ms. James was less structured in her approach to teaching, yet employed techniques that allowed students to control the flow of the lesson within reason. She used questions to guide students toward generalizations and encouraged participation through requiring students to lead the class. Ms. James' actions indicated that she viewed the role of the teacher as a facilitator.

The participants also held different views about the role of instructional technology in the classroom. Ms. Thomas used technology out of a fear of "being left behind," while Ms. James used technology because she believed it held promise for deepening mathematical understandings. Through the data collected from these two participants with similar years of teaching experience and teaching settings, it seemed that limited PCK may have been the single most important barrier to overcome with regard to instructional technology integration. This claim is based on the second order barrier that comes from a PCK deficiency. That is, a lack of understanding of how to teach well will certainly prevent an understanding of how to teach well *with technology*.

Despite the apparent differences in PCK, data from both participants demonstrated inconsistencies between their perceptions of their instructional practices and observed instructional practices. Although the researcher crafted and revised the instruments based on extensive feedback from peers and an expert in educational technology, there was evidence to indicate that the participating teachers did not consistently communicate in ways which aligned with their practices, perhaps even misinterpreting questions and survey items based on their misunderstandings of academic language. Ms. Thomas and Ms. James referenced engagement of students in NCTM's Process Standards; however, this was not consistently present during observed lessons, particularly in Ms. Thomas' class. Both participants frequently used educational jargon such as *conceptual understanding, problem solving*, and *connections*. These ideas were often referenced using vague phrases and without providing details to substantiate the claims. A misunderstanding of these terms links to the explanation for the lack of alignment among the themes identified, the results of the TPACK Development Model Self-Report Survey, and other data collected. Participants' misinterpretation of words used in the survey could have affected their responses. Regardless, it was clear from the data collected that Ms. Thomas and Ms. James both envisioned their technology integration to be exemplary.

Implications for Leaders

As stated previously, the TPACK Development Model consists of five levels for each theme. These levels, from lowest to highest, are recognizing, accepting, adapting, exploring, and advancing. As described in the literature, a lack of pedagogical content knowledge (PCK) will prevent progression through this model (Neiss et al., 2009; Pape et al., 2012). In particular, a teacher with low PCK may have difficulty progressing past the adapting level for the Teaching and Learning themes, though this may cause some teachers to not progress beyond the recognizing level. It is useful to consider the descriptors and examples from the TPACK Development Model in this explanation and to relate these ideas to the concept of PCK.

Pedagogical practices that indicate low PCK link to the unproductive beliefs toward the teaching and learning of mathematics found in *Principles to Actions* (NCTM, 2014). These unproductive beliefs include a focus on procedures and memorization over reasoning and conceptual understanding, mastering a set of basic skills prior to exploring and solving contextual problems, and a focus on step-by-step procedures to minimize classroom struggle. Further, *Principles to Actions* identifies unproductive beliefs about tools and technology, which align with lower TPACK levels. Unproductive beliefs include restricting technology use until a skill or procedure is mastered without the technology, viewing technology as solely an efficient way to get or confirm computational solutions, using technology with only certain groups of students, and limiting experiences with technology to individual activities or videos. The unproductive beliefs about teaching and learning certainly support unproductive beliefs about the use of tools and technology for teaching mathematics.

An awareness of the influence of low PCK and unproductive beliefs on teachers' TPACK has implications for mathematics education leaders, particularly in terms of planning for professional development and other areas of teacher support. Considering the Learning theme, a teacher at the accepting level "has concerns about students' attention being diverted from learning. . . mathematics to a focus on the technology" (Niess et al., 2009, p. 21), whereas at the adapting level a teacher "begins to explore, experiment and practice integrating technologies as mathematics learning tools" (p. 21). At the exploring level a teacher "uses technologies as tools to facilitate the learning of specific topics" (p. 21). Academic leaders can use this information to foster exploration of new instructional technologies with specific attention to the ways the technologies represent specific concepts, situated within the context of existing course structures. Professional development needs to be focused and as much as possible individualized, if teachers are going to implement technologies in ways that result in increasing student understanding and achievement.

In evaluating the descriptors of the Teaching theme, similar indications are observed. A teacher at the adapting level "uses technology to enhance or reinforce mathematics ideas that students have learned previously" (Niess et al., 2009, p. 21) as seen in Ms. Thomas' classroom, while a teacher at the exploring level "engages students in high-level thinking activities for learning mathematics using technology as a learning tool" (p. 23) as demonstrated in Ms. James' classroom. It is equally relevant to note that teachers with low levels of TPACK and unproductive beliefs about technology view instructional technology as a supplement to instruction, whereas teachers with higher levels of TPACK and productive beliefs about technology envision instructional technology as a valuable tool for enhancing learning opportunities for students (NCTM, 2014). This idea of using available resources to improve learning opportunities also ties to the concept of PCK by indicating that a teacher with higher levels of TPACK views mathematics teaching as a dynamic system in which tools can improve opportunities, and teachers with lower levels of TPACK envision mathematics teaching as unchanging and algorithmic.

Of further use to mathematics education leaders is the use and inadvertent misuse of educational jargon. The realization that mathematics teachers may inadvertently use common education terminology in ways that inaccurately represent their classroom practices highlights the need for mathematics teacher leaders to gain insight into classroom practice from a variety of sources. According to Davis and Simtt (2003), learning systems are complex to study due, in part, to the lack of consistency in language or jargon. It is essential, then, that within a school system leaders ensure teachers and teacher leaders clearly define the jargon used to ensure that the vision and interpretation is consistent and clear.

Through the examination of these two participants and the TPACK Development Model descriptors, it is suggested that significant PCK serves as an impetus to effective instructional technology integration. Likewise, a lack of PCK presents a second-order barrier to quality instructional technology integration. Although prior research has clearly identified barriers to instructional technology integration (Ertmer, 1999; Ertmer & Ottenbreit-Leftwich, 2009; Hew & Brush, 2007), the role of PCK has not been identified as is suggested in this study. Clearly PCK is an essential component of TPACK, yet the interplay of these two types of knowledge deems further exploration.

Conclusion

This research highlights opportunities for increased exploration of secondary mathematics teachers' perceptions of technology integration through the lens of the TPACK Development Framework. However, TPACK exploration and implementation introduces implications for policies, research on best practices for teaching with technology, and teaching professional development for implementing instructional technologies (Trouche, Drijvers, & Sacristan, 2013). With consideration of individual teachers' PCK, professional development should be built around the needs of teachers rather than limited to rapid introduction of new technologies or prepared lessons with technology. It seems that if meeting a teacher's needs for PCK improvement is expected, then a teacher's TPACK could progress and thus impact student learning with technology. In our current era of the integration of the Common Core State Standards for Mathematics (Common Core State Standards Initiative, 2010), we must recognize the imperative nature of engaging students in the Standards for Mathematical Practice. Notably, students should engage in a learning environment, which fosters the "use of appropriate tools strategically" (p. 7). Ms. Thomas' students used tools appropriate for the mathematics being studied, but were not given the opportunity to use these tools in a strategic fashion. In contrast, Ms. James required her students to develop strategies for solving problems, and her students used technology to carry out these strategies and explore concepts. Teachers' beliefs about how to effectively facilitate student learning directly impact their classroom practices, and this study demonstrated how instructional technology integration is not immune to this effect. In a brief conversation with these two participants, it would seem that they had similar beliefs about teaching and learning. Further analysis, however, highlighted stark differences in their beliefs and practices toward the use of technology. Though these findings provide insight into these cases, it is important to acknowledge that with such a small sample, large generalizations are not possible. While Ms. Thomas' beliefs about technology integration lacked depth and reinforced purely procedural uses of calculators, Ms. James' view of technology was much closer to achieving the vision set forth by the Technology Principle (NCTM, 2000). The phenomena that allowed Ms. James to overcome the second-order barriers that continued to plague Ms. Thomas necessitate further inquiry. ✪

References

An, Y. J., & Reigeluth, C. (2011). Creating technology-enhanced, learner-centered classrooms: K–12 teachers' beliefs, perceptions, barriers, and support needs. *Journal of Digital Learning in Teacher Education, 28*(2), 54-62.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*, 389–407.

Boling, E. C., & Beatty, J. (2012). Overcoming the tensions and challenges of technology integration: How can we best support our teachers. In R. C. Ronau & M. Niess (Eds.), *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 136–156). Hershey, PA: IGI Global.

Common Core State Standards Initiative. (2010). *Common core state standards for mathematics.* Washington, DC: National Governors Association Center for Best Practices and Council of Chief State School Officers. http://www.corestandards.org.

Cuban, L., Kirkpatrick, H., & Peck, C. (2001). High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *American Educational Research Journal, 38*, 813 – 834.

Darling-Hammond, L. (2006). Constructing 21st-century teacher education. *Journal of Teacher Education, 57*, 300-314.

Davis, B., & Simtt, E. (2003). Understanding learning systems: Mathematics education and complexity science. *Journal for Research in Mathematics Education, 34*, 127-167.

Dunham, P., & Hennessy, S. (2008). Equity and use of educational technology in mathematics. In M. K. Heid & G. Blume (Eds.), *Research on technology and the teaching and learning of mathematics* (Vol. 1, pp. 345 – 418). Charlotte, NC: Information Age Publishing.

Ertmer, P. A. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development, 47*(4), 47 – 61.

Ertmer, P., & Ottenbreit-Leftwich, A. (2009). Teacher technology change: How knowledge, beliefs and culture intersect. *American Educational Research Association.* Denver, CO. Retrieved on August 17, 2010 from http://www.edci.purdue.edu/ertmer/docs/AERA09_Ertmer_Leftwich.pdf

Feiman-Nemser, S. (1983). Learning to teach. In L. Shulman & G. Sykes (Eds.), *Handbook of teaching and policy* (pp. 150 – 170). New York, NY: Longman.

Grossman, P. L., & Shulman, L. S. (1996). Knowing, believing, and the teaching of English. In T. Shanahan (Ed.), *Teachers thinking, teachers knowing: Reflections on literacy and language education* (pp. 3–22). Urbana, IL: National Conference on Research in English and National Council of Teacher Educators.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology and Research Development, 55*, 223 – 252.

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal, 42*, 371-406.

Hokanson, B., & Hooper, S. (2004, October). *Integrating technology in classrooms: We have met the enemy and he is us.* Paper presented at the meeting of the Association for Educational Communication and Technology, Chicago, IL.

Honey, M., & Moeller, B. (1990). *Teachers' beliefs and technology integration: Different values, different understandings.* New York, NY: Center for Technology in Education.

Ivy, J. T. (2011). *Secondary mathematics teachers' perceptions of their integration of instructional technologies* (Doctoral dissertation). Retrieved from ProQuest. (10093)

Koehler, M. J., & Mishra, P. (2008). Introducing technological pedigogical content knowledge. In AACTE Committee on Innovation and Technology (Eds.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 3–29). New York, NY: Routledge.

Li, Q. (2007). Student and teacher views about technology: A tale of two cities? *Journal of Research on Technology in Education, 39*, 377–397.

Lortie, D. C. (1975). *School teacher: A sociological inquiry.* Chicago, IL: University of Chicago Press.

Machado, C., Laverick, D., & Smith, J. (2011). Influence of graduate coursework on teachers' technological, pedagogical, and content knowledge (TPACK) skill development: An exploratory study. In M. Koehler & P. Mishra (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 4402–4407). Chesapeake, VA: Association for the Advancement of Computing in Education.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). Fundamentals of qualitative data analysis. In M. B. Miles, A. M. Huberman, & J. Saldaña (Eds.), *Qualitative data analysis* (3rd ed.) (pp. 69–104). Thousand Oaks, CA: Sage.

Miller, T. K. (2011). A theoretical framework for implementing technology for mathematics learning. In R. N. Ronau, C. R. Rakes, & M. L. Neiss (Eds.), *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 251–270). Hershey, PA: IGI Global.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A new framework for teacher knowledge. *Teachers College Record, 108*, 1017–1054.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all.* Reston, VA: Author.

National Research Council. (2001). *Adding it up: Helping children learn mathematics.* J. Kilpatrick, J. Swafford, & B. Findell (Eds.). Mathematics Learning Study Committee, Center for Education Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education, 21*, 509 – 523.

Niess, M. L. (2008). Knowledge needed for teaching with technologies - Call it TPACK. *AMTE Connections, 17*(2), 9–10.

Niess, M. L., Ronau, R. N., Shafer, K. G., Driskell, S. O., Harper, S. R., Johnston, C., . . . Kersaint, G. (2009). Mathematics teacher TPACK standards and development model. *Contemporary Issues in Technology and Teacher Education, 9*(1), 4 – 24.

Norton, S., McRobbie, C. J., & Cooper, T. J. (2000). Exploring secondary mathematics teachers' reasons for not using computers in their teaching: Five case studies. *Journal of Research on Computing in Education, 33*, 87 – 109.

Pape, S. J., Irving, K. E., Bell, C. V., Shirley, M. L., Owens, D. T., Owens, S., . . . & Lee, S. C. (2011). Principles of effective pedagogy within the context of connected classroom technology: Implications for teacher knowledge. In R. N. Ronau, C. R. Rakes, & M. L. Neiss, (Eds.), *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 176–199). Hershey, PA: IGI Global.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Pierson, M. E. (2001). Technology integration practice as a function of pedagogical expertise. *Journal of Research on Computing in Education, 33*, 413–429.

Shenton, A. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information, 22*, 63-75.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*, 4 – 14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*, 1–23.

Swan, B., & Dixon, J. (2006). The effects of mentor-supported technology professional development on middle school mathematics teachers' attitudes and practice. *Contemporary Issues in Technology and Teacher Education* [Online serial], 6(2). Retrieved from http://www.citejournal.org/vol6/iss1/mathematics/article1.cfm

Trouche, L., Drijvers, P., Gueudet, G., & Sacristan, A. I. (2013). Technology-driven developments and policy implications for mathematics education. In A. J. Bishop, M. A. Clements, C. Keitel, J. Kilpatrick, & F. K. S. Leung (Eds.), *Third international handbook of mathematics education* (pp. 753–789). New York, NY: Springer.

van Es, E. A. (2011). A framework for learning to notice student thinking. In M. Sherin, V. Jacobs, & R. Philipp (Eds.), *Mathematics teacher noticing: Seeing through teachers' eyes* (pp. 134–151). New York, NY: Routledge.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: Sage Publications, Inc.

APPENDIX A.

TPACK Development Model Self-Report Survey

(Teaching and Learning Items only)

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 believe that if my students use this technology too often, they will not learn the math for themselves.
	2.	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.
	3.	I have allowed my students to explore a few topics using this technology even before the topics are discussed in class.
	4.	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.
	5.	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.		
	6.	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.
	7.	If my students use the technology to explore a new topic, they won't think about and develop the mathematical skills for themselves.
	8.	I try to use this technology to promote my students' thinking, but have not had a lot of success.
	9.	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.
	10.	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.		
	11.	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.
	12.	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.
	13.	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.
	14.	I use this technology as a learning tool to engage my students in high-level thinking activities (such as projects or problem-solving).

	15.	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.		
	16.	My students and I use this technology for procedural purposes only.
	17.	I have led my students through a few simple ideas of how to use this technology that I learned during professional development.
	18.	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.
	19.	When my students explore with this technology, I serve as a guide. I do not direct their every action with the technology.
	20.	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.		
	21.	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.
	22.	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.
	23.	I use some exploration activities with this technology, but I usually guide my students through the steps to save class time.
	24.	I have explored a variety of instructional methods with this technology, to allow my students to engage both inductively and deductively.
	25.	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.		
	26.	I would consider attending a workshop demonstrating the use of this technology, but only if it is local.
	27.	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.
	28.	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.
	29.	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.
	30.	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.		

This instrument was created by Julie Riales and Jessica Ivy.