International Journal of Technology in Education

www.ijte.net

Understanding Secondary School Teachers' TPACK and Technology Implementation in Mathematics Classrooms

Julia Eden Hill, Lida Uribe-Florez
[1]Boise State University
[2]Boise State University

To cite this article:

Hill, J.E. & Uribe-Florez, L. (2020). Understanding secondary school teachers' TPACK and technology implementation in mathematics classrooms. *International Journal of Technology in Education (IJTE), 3*(1), 1-13.

IJTE
International Journal of Technology in Education
Volume 3, Issue 1, Spring 2020

Understanding Secondary School Teachers' TPACK and Technology Implementation in Mathematics Classrooms

Julia Eden Hill, Lida Uribe-Florez

Article Info

Article History

Received:
30 July 2019

Accepted:
9 November 2019

Keywords

TPACK
Technology integration
Mathematics education
Mixed-methods
Secondary education

Abstract

The technological, pedagogical, and content knowledge (TPACK) framework provides an understanding of a teacher's knowledge in the three areas and how it is used to effectively teach with technology (Koehler, Mishra, & Cain, 2013). This study explores the TPACK of middle and high school math and special education teachers and how teachers integrate technology in their mathematics classrooms. Teachers in a rural public school district in the Mid-Atlantic region of the U.S were surveyed. In the concurrent mixed-method design, data were collected using a survey with 22 close-ended questions from Zelkowski, Gleason, Cox, & Bismark (2013) to measure teachers' TPACK (Likert scale of 1 to 5) and 7 open-ended questions regarding technology integration. Descriptive statistics were used to analyze the quantitative data while a two-cycle coding process, using holistic and pattern coding (Saldana, 2013), was used to analyze and identify themes of the qualitative data. The quantitative data showed that teachers were most confident in their pedagogical knowledge and least confident in their technical knowledge. The themes that emerged for technology integration reflected conceptual understanding, teaching strategies, time and student engagement. The high confidence in pedagogical knowledge is reflected in how teachers integrate technology, which was pedagogical in nature.

Introduction

The availability of technology in the K-12 classrooms across the United States has increased in recent years. Teachers are working to learn how to use technology to improve student learning and increase academic achievement. While the increase in the integration of technology in classrooms has been researched, there is a need for more with a focus on the middle and high school mathematics classroom (Minshew & Anderson, 2015). Technology provides unique challenges and benefits to the teaching and learning of mathematics. To greater understand how to support math teachers in their implementation of technology, their knowledge of technology, pedagogy, and math content must be understood, as well as their methods of and perceived barriers to technology integration. The goal of this study was to explore the relationship between teachers' knowledge and how they integrate technology in their mathematics classrooms.

TPACK Framework

The TPACK framework developed and published by Mishra and Koehler (2006) expands on the pedagogical content knowledge framework of Shulman (1986). This framework, shown in Figure 1, was created through a series of theory-based design experiments focused on understanding teachers' development toward using technology in the classroom. Through viewing the experiments collectively, the conceptual framework emerged. The framework provided a new way of viewing teachers' knowledge of technology for informed decision making (Mishra & Koehler, 2006; Sahin, 2011). This framework provides an understanding of a teacher's flexible knowledge in the three areas and how that knowledge can be used to effectively teach with technology (Celik, Sahin, Kiray, & Simsek, 2015; Koehler, Mishra, & Cain, 2013).

According to Koehler et al. (2013), technological knowledge (TK) is the teacher's knowledge of information technology for the purposes of communication, information processing, and problem-solving. Pedagogical knowledge (PK) is the teacher's knowledge about the methods, practices, and processes for teaching and learning. Content knowledge (CK) is the teacher's knowledge about the subject matter to be taught. Technological pedagogical knowledge (TPK) is the teacher's knowledge about the methods, practices, and processes for teaching and learning with technology. Technological content knowledge (TCK) is the teacher's knowledge about technology that is specific to the subject matter to be taught. Pedagogical content knowledge

(PCK) is the teacher's knowledge about pedagogy as it relates to the specific subject matter to be taught. Technological pedagogical and content knowledge (TPACK) is the teacher's knowledge about how all three components interact with one another. Figure 1 shows a Venn diagram depicting the three core components of TPACK as circles and the sections that overlap to create new categories of knowledge.

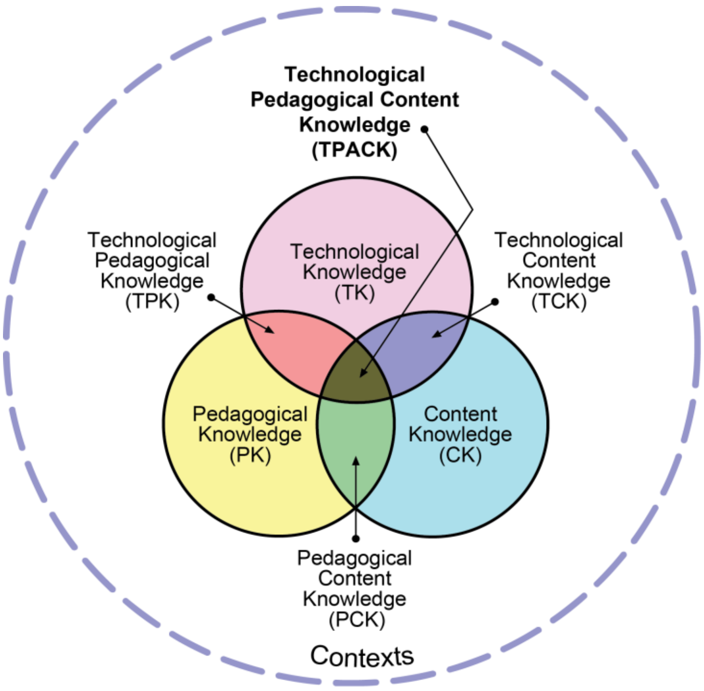

Figure 1. The TPACK Framework (Reproduced by permission of the publisher, © 2012 by tpack.org)

TPACK of Math Teachers

The TPACK framework addresses the knowledge of the teacher in the areas of technology, pedagogy, and content. The TPACK of the teacher influences the technology integration in the classroom at various levels and with a focus in different aspects of the classroom (Celik, Antonenko, Kiray, & Sahin, 2016; Koehler & Mishra, 2009). Much of the research of TPACK and math education is focused on pre-service teachers with few studies including in-service teachers. Through research involving pre-service math and science teachers, Niess (2005) suggests four components to TPACK professional development for math teachers. These components are: (a) an overarching conception of teaching mathematics with technology, (b) instructional strategies and representations for teaching mathematics with technologies, (c) students' understandings, thinking, and learning in mathematics with technology, and (d) mathematics curriculum and curricular materials. Although these components came from research regarding pre-service teachers, in-service teachers may benefit from these insights, as well.

Patahuddin, Lowrie, and Dalgarno's (2016) study of a middle school math classroom suggested that "examining critical events of authentic teaching can be a powerful tool in developing pre-service and in-service teachers' TPACK" (p. 871) and found limitations in the participant's TPK, TCK, and PCK, which impact the teacher's TPACK. In the study, authors indicated that the combination of the selection of the technology and the pedagogical views of the teacher influence the observability of all of the TPACK constructs. This means that the observation of TPACK will depend on the technology being used in the classroom and how it is being used. One observation may not be indicative of the teacher's TPACK in general. Kirikcilar and Yildiz (2018) studied three middle school math teachers' TPACK and found that while all three types of knowledge were used to create learning activities for students, teachers struggled most with integrating pedagogy and technology. Teachers need to grow in their understanding of how the knowledge of learning mathematics and the knowledge of technology interact. This includes understanding when and how technology will enhance the learning of mathematical concepts. As the teacher's TPACK is developed, the practices in the classroom will more likely reflect the knowledge of the teacher. While both pedagogy and technology training are necessary, the focus should be on the pedagogy (Celik, Sahin, & Akturk, 2014; Diaz & Bontenbal, 2000). This will keep the focus on learning mathematics effectively rather than the tools being used for learning.

Technology Integration in the Mathematics Classroom

The Common Core State Standards (CCSS) include content standards and Standard for Mathematical Practice (SMP). The content standards address what mathematical concepts should be taught in each grade level or course (Common Core Standards Initiative, 2018). The SMPs address how students are engaged with the mathematics and demonstrate the learning taking place (Common Core Standards Initiative, 2018). The SMPs balance procedure and understanding. Students must demonstrate fluency with mathematical procedures and also demonstrate an understanding of concepts through application and making connections (Common Core Standards Initiative, 2018, p. 6-8). Technology can assist in learning with the SMPs. It allows students to be more precise with mathematics, model mathematical concepts, and find patterns.

As technology has become more prevalent in education, it is important for educators to evaluate its use in the classroom within the context of the content area. In an effort to support and guide mathematics teachers, the National Council for Teachers of Mathematics (NCTM) has addressed technology integration in the mathematics classroom. In 2015, NCTM issued the following statement:

> Strategic use of technology in the teaching and learning of mathematics is the use of digital and physical tools by students and teachers in thoughtfully designed ways and at carefully determined times so that the capabilities of the technology enhance how students and educators learn, experience, communicate, and do mathematics. Technology must be used in this way in all classrooms to support all students' learning of mathematical concepts and procedures, including those that students eventually employ without the aid of technology. Strategic uses support effective teaching practices and are consistent with research in teaching and learning. (p. 1)

As mathematics teachers learn to strategically use technology in their classrooms there are factors that may influence their actions. One such factor is the teacher's own attitudes and beliefs towards technology. Pierce and Ball (2009) studied perceptions of secondary mathematics teachers that may affect their intention to use technology in the classroom. They found that most teachers believed that using technology would make mathematics more enjoyable for students and assist students in gaining a deeper understanding of mathematics and solving real-world problems. However, only a little over half of the teachers in the study believed it would result in the increased motivation of students to learn mathematics. While student motivation is important to learning, the contribution of technology to learning and understanding mathematics is equally valuable. Almost one-quarter of the participants of the study believed that students need to do math by hand in order to understand it. Ball and Stacey's (2005) study of one teacher supports the idea that students learn new concepts and procedures without technology and then progress to using technology to deepen understanding or provide a more efficient method of solving a problem. The use of technology should be carefully planned based on the learning processes required.

Another factor that influences technology integration is the teacher's self-confidence level with regard to using technology. Hennessy, Ruthven, and Brindley, (2007) found that "teachers felt that the real benefits of ICT [information and communication technology] will only be felt when confidence is increased" (p. 170). When teachers are more confident in their ability to use technology and help students learn to use technology in the classroom, the actual benefits will increase. While the value of ICT in the teaching and learning of mathematics, especially for understanding difficult concepts and relationships, was found, there was still a perception that using technology is not always the best method for teaching mathematical basics. The visualization of concepts and the reduction of tedious calculations was appreciated as long as students understood the basic calculations before using the technology for the task.

Research Questions

With the goal to understand mathematics teachers TPACK and how they integrate technology in their classrooms, we designed a mixed methods study which focuses on classroom technology use and the technological, pedagogical, and content knowledge (TPACK) of middle and high school mathematics teachers and special education teachers who work in mathematics classrooms in a rural public school system in the Mid-Atlantic region of the United States. The overarching research question is:

- Is the technological, pedagogical, and content knowledge of teachers reflected by the strategies used to integrate technology in the classroom?

The research question is divided into two parts. The first question, which is quantitative, focuses on the TPACK of mathematics teachers. The second question, which is qualitative, focuses on the integration of technology in mathematics classrooms. Therefore, the subquestions are:

1. What is the TPACK of the middle and high school math and special education teachers in a rural public school system in the Mid-Atlantic region of the United States?
2. How are the middle and high school mathematics and special education teachers in a rural public school system in the Mid-Atlantic region of the United States integrating technology in their classrooms?

Method

This study used a convergent parallel design of a mixed methods study (Creswell & Clark, 2011). In this method, the quantitative and qualitative data are collected concurrently. Both strands are equally important to the study and analyzed independently. The mixing of the data occurs in the final stage of the interpretation of the data. The method is appropriate to this study because the first research question addresses the TPACK of teachers through a series of quantitative survey questions. The second research questions address how the teachers integrate technology through several quantitative survey questions. The two sets of data are analyzed and discussed independently. In the final discussion, the overarching research question is addressed through merging of the two sets of data.

Context

The school system being studied, which adopted the CCSS as the foundation for its math curriculum, began the implementation of a 1:1 digital conversion in the 2015-2016 school year. All ninth-grade students in the district received a laptop. Each year thereafter, the incoming freshmen received a laptop such that by the 2018-2019 school year, every high school student had a laptop to use at school and at home during the school year. Each high school also received mobile hotspots to lend to students who did not have access to the internet at home so they could complete assignments for school. During the first year of the implementation, the middle schools in the district began purchasing carts of Chromebooks for students to use in the classrooms. Each year more carts were purchased. By the 2018-2019 school year, the student to Chromebook ratio was almost 1:1. With the implementation of devices in the classroom beginning in 2015, online resources were purchased to support the initiative and the mathematics curriculum. Engrade was the online resource delivery system used by the district. Teachers had access to provide instruction, assignments, assessments, and links to resources for students on the platform. Professional development on Engrade was provided for teachers through school-based learning sessions, which varied in length, frequency, and focus depending on location. The district provided a three-day workshop during the summer of 2017 in which teachers learned various features of Engrade and were given time to develop resources for their classes on the platform.

For both middle and high school, the Discovery Education Techbook was adopted in 2014 as the primary resource to provide lessons, activities, performance tasks, and practice exercises for 7th and 8th grade, Algebra 1, Geometry, and Algebra 2. Teachers of these courses were provided with approximately three full days of professional development in the four years prior to this study. Other online programs such as MyLabsPlus and WebAssign were used as supplements to the textbook for specific high school math courses. These programs provided practice exercises and assessments. One half-day training was provided for each of these two programs prior to the 2018-2019 school year. In addition to these primary resources, supplemental digital resources such as Desmos, Geogebra, and Geometer's Sketchpad were used as tools for graphing and modeling mathematics. These resources were mentioned and briefly discussed in various professional development sessions. However, they were not the focus of any sessions since 2010. In the fall of 2018, Open Up resources were implemented in the 7th and 8th-grade math classes. This open education resource provides a full course curriculum that may be used in place of the Discovery Education Techbook. The 7th and 8th-grade math teachers had three days of training during the summer of 2018.

Participants

Approximately sixty mathematics and special education teachers of grades 6-12 in a rural public school system in the Mid-Atlantic region of the United States in the fall of 2018 were invited to participate in the study. There were 31 teachers who accepted the invitation , thirteen who teach middle school and 18 who teach high school.

Twenty-four of the participants have taught for at least eleven years, while 5 have taught between five and ten years and 2 have taught for less than five years.

In the state in which the study was conducted, there are five different certifications that such teachers can hold. The elementary education certification allows teachers to teach grades 1-6. Fourteen of the participants hold this certification. The middle school mathematics certification allows teachers to teach math for grades 4-9. Fifteen teachers indicated holding this certification. Most teachers who hold this certification have bachelor's degrees in either elementary education or mathematics. The secondary mathematics certification allows teachers to teach math for grades 7-12. Fifteen teachers stated that they have this certification. Most teachers who hold this certification have bachelor's degrees in mathematics. The elementary/middle school special education certification allows teachers to work with students in grades 1-8, while the secondary/adult special education certification allows teachers to work with students in grades 6-adult. There were seven respondents who hold a special education certification. However, there was no indication as to which of these certifications were held.

Instrument

Twenty-nine middle and high school math teachers and special education teacher who work primarily in math classrooms in the school district completed a survey (see Appendix) that is a combination of a TPACK survey developed by Zelkowski, Gleason, Cox, & Bismark (2013) and open-ended questions that address the integration of technology in the classroom, which were designed by the two researchers of this study. This survey can be found in the Appendix. It also included items about demographic information such as years of experience, grade level, and certification level. The survey included 22 items related to the TPACK categories. These items used a 5-point Likert scale response. The response selections are SD = "strongly disagree," D = "disagree," N = "neither agree nor disagree," A = "agree," SA = "strongly agree." There were seven open-ended questions related to the teachers' integration of technology in their math classrooms. The questions were:

- How has technology changed the way you teach math? Please include an example.
- How has technology changed the way your students learn math? Please include an example.
- How has technology changed or broadened the "curricular knowledge" to be gained, learned, or applied? Please include an example.
- Do you currently feel that you are effectively integrating technology into your math classroom and why?
- What are some barriers that prevent you from more effectively integrating technology into your math lessons?

The teachers were provided with a link to the anonymous online survey to complete.

Data Collection

The research was approved by the institutional review board (IRB) at the university, the school system, and the administration of each participating school in July and August 2018. The invitation to participate was sent through email to all eligible participants in the school district in mid-September 2018. A reminder was sent through email at the beginning of October. After this reminder there were 19 participants. A third reminder was sent in mid-October and generated the remaining 12 respondents.

Data Analysis

The survey items were used to analyze the self-assessment of the teachers' TPACK. Each category, which included technology, pedagogy, mathematical content, and the intersection of all three, contained 5-6 questions. The responses for each category were grouped together and the mean scores for each statement and category were calculated. The way in which teachers integrate technology in the classroom was analyzed using the qualitative items on the survey. The first coding cycle used a holistic coding approach (Saldana, 2013). Codes for each of the two groups were created based on the ideas presented in the responses to the questions. Pattern coding was used for the second cycle to identify emerging themes from the first cycle (Saldana, 2013). Three of the questions focused on the teachers' perceptions of the effects of technology integration in their classrooms. These questions were analyzed as a group. Each sentence of each response was read to identify a general idea or theme. Some responses contained more than one theme. The total number of sentences or phrases in which a theme was identified was counted for a total of 68. In addition, the number of times each theme arose was counted. For some questions, there was no response or no theme arose. Two of the questions focused on the teachers' attitudes towards and perceived barriers to technology integration. Again, these two questions were analyzed together. Themes were identified by reading each sentence of each response. In some cases, more than one theme emerged from a response. The total number of sentences or phrases in which a theme was identified was counted for a total of 53. Again, the number of times each theme arose was also counted. The remaining two questions gathered a list of devices and programs used for technology integration. These two questions provided information that may be used to explain the results of the data analysis.

Results and Discussion

This section is organized by research questions, as indicated before, we answer the subquestions first, and then use the information from both analyses to answer the overarching question.

Subquestion 1: What is the TPACK of the middle and high school math and special education teachers in a rural public school system in the Mid-Atlantic region of the United States?

The quantitative data collected indicated that teachers reported having the lowest average score for knowledge of technology and higher average scores for knowledge of pedagogy and mathematical content, as shown in Table 1. The mean response for all of the technology items was 3.70 with a standard deviation of 1.02. Of the technology items, the lowest average scores were found for knowledge of different technologies, which had an average response rating of 3.28, and keeping up with important new technologies, which had an average response rating of 3.55. In the area of technology, they reported an average score of 4.03 for knowledge in learning technology easily.

Teachers displayed an average score of 4.46 with a standard deviation of 0.69 for knowledge of mathematical content. While the highest rating in this category was an average of 4.66 for having sufficient knowledge of mathematics, the lowest average was for content knowledge in the area of a deep and wide understanding of geometry, which had an average response rating of 4.10. Pedagogical knowledge had the highest average rating from the teachers with a score of 4.49 with the smallest standard deviation of 0.62. Teachers reported an average score of 4.32 for pedagogical knowledge in the area of adapting their teaching style to different learners and an average score of 4.61 for pedagogical knowledge in the area of adapting their teaching based on what students currently do or do not understand.

Table 1. Descriptive Results by the TPACK Components

TPACK Components	N	Mean	Standard Deviation
TK	28	3.70	1.02
knowledge of different technologies	28	3.28	1.06
keeping up with important new technologies	28	3.55	0.96
learning technology easily	28	4.03	0.96
CK	28	4.46	0.69
deep and wide understanding of geometry	28	4.10	0.82
deep and wide understanding of algebra	28	4.36	0.87
having sufficient knowledge of mathematics	28	4.66	0.48
PK	28	4.49	0.62
adapting their teaching style to different learners	28	4.32	0.72
adapting their teaching based on what students currently do or do not understand	28	4.61	0.57
TPACK	28	3.91	0.87
teaching lessons that appropriately combine algebra, technologies, and teaching approaches	28	3.68	0.98
teaching lessons that appropriated combine geometry, technologies, and teaching approaches	28	3.71	0.90
using strategies that combine mathematics, technologies, and teaching approaches in the classroom	28	4.21	0.63

Overall, the average rating for TPACK, which combines all three categories, was 3.91. Teachers expressed the lowest knowledge in teaching lessons that appropriately combine algebra, technologies, and teaching approaches, which had an average score of 3.68. Knowledge of teaching lessons that appropriated combine geometry, technologies, and teaching approaches was close with an average score of 3.71. The highest score for the category, with an average of 4.21, was using strategies that combine mathematics, technologies, and teaching approaches in the classroom. The data indicate that the teachers surveyed have the most knowledge of pedagogy with the knowledge of mathematical content close behind. The combined mean TPACK score was a little higher with a smaller standard deviation than the knowledge of technology alone.

In summary, the overall TPACK of the middle and high school math and special education teachers in a rural public school system in the Mid-Atlantic region of the United States is between neutral and agree, with an average score of 3.91 on a scale of 1 to 5. This is higher than the average score, 3.62, of TPACK for in-service math teachers from a study by Saltan and Arslan (2017). Of the three categories, teachers scored the lowest in their knowledge of technology, with an average score of 3.7. This is also higher than the average score, 3.58, of TK for the in-service math teachers from the study by Saltan and Arslan (2017).

Subquestion 2: How are the middle and high school mathematics and special education teachers in a rural public school system in the Mid-Atlantic region of the United States integrating technology in their classrooms?

Of the 68 responses from three questions regarding how technology is integrated into the classroom, 33 reflected on the conceptual understanding of mathematics (see Table 2). Teachers expressed that the use of visual representations and virtual manipulatives through technology provided students with the opportunity to learn mathematical concepts with a deeper understanding. Seventeen responses related teaching strategies, indicating that technology assists teachers in differentiating instruction and personalizing learning for students. The final two categories, time and student engagement, had nine responses each. Teachers suggested that technology provides students with more real-life applications, more opportunities for exploration of concepts, and ownership of learning. They also indicate that technology saves time during lessons, provides students with more immediate feedback, and provides teachers with useful data about student learning.

Table 2. Themes for Technology Integration

Theme	Definition	Example
Conceptual Understanding	An integrated and functional understanding of mathematics	"It has helped students understand concepts better and make connections between different topics." Participant 8 "...technology...has broadened the need for students to understand mathematics, instead of just to memorize formulas." Participant 18
Teaching Strategies	Methods used to help students learn course content	"I can now differentiate easier and reach more students when I have 25 in a class." Participant 4 "With numerous resources, we have multiple ways to teach and enhance lessons." Participant 25
Time	Time refers to the amount and quality of time spent with students in the classroom and time spent using data to drive learning	"Students no longer have to wait for direct teaching to learn." Participant 3 "Saves times so you can delve deeper into the problem." Participant 22
Student Engagement	The attention, interest, and persistence of students in their work	"They take ownership of their learning." Participant 24 "Technology enables me to give tasks about real-life problems." Participant 6

Most of the teachers surveyed stated that they either are effectively integrating technology or expressed a desire to learn how to improve (see Table 3). According to the responses from two questions, 26 out of 53, the most prevalent barrier to integrating technology in the classroom focuses on resources. Teachers stated a lack of devices for students, internet access, and technical support as reasons for not implementing technology effectively. They also mention that there are too many technological resources available and not enough time to determine which are best for their students. This leads to the second barrier, time, which received 20 responses. Teachers indicated a lack of time for learning new technology, planning for it in their lessons, and implementing the use in the classroom. The remaining two categories are teacher knowledge of and teacher attitudes towards technology with 5 and 2 responses, respectively. Teachers indicated that their own lack of knowledge of how to use technology in the classroom hindered their effectiveness in integration. One teacher showed a dislike for technology, in general.

Table 3. Themes for Barriers to Technology Integration

Theme	Definition	Example
Resources	Resources involves access to and the quality of devices, internet access, digital programs, tech support, and funding	"Sometimes there are so many options it is hard to get proficient with just one." Participant 7 "Availability of reliable devices for all students, money for licenses" Participant 3
Time	Time refers to time spent with students in the classroom, teachers' planning time, and time spent in professional development	"It takes so much time to learn a new program." Participant 6 "Time to apply in class, time to research during planning." Participant 18
Teacher Knowledge	Teachers' understanding of the purpose and methods for technology use in the classroom	"I do not know of enough mathematics programs I can incorporate in my curriculum." Participant 18 "Not knowing other technologies to use in math that is effective." Participant 21
Teacher Attitudes	Teachers' beliefs and perceptions of technology	"I don't like technology nor do I want to use it in my room." Participant 19 "We can always do better." Participant 30

Discussion

The results of the quantitative data suggest that these middle and high school teachers in the mathematics classroom are most confident in the area of pedagogy with their confidence in their content knowledge almost as high. Since only four of the participants do not have any math-specific certification, these results are not surprising. The teachers' lower confidence in their knowledge of geometry than algebra is consistent with the district-wide standardized test results in which students score lower, on average, in geometry standards than those of algebra at the middle and high school levels. However, it is interesting to note that the TPACK regarding geometry was higher than that of algebra. It appears that, while teachers felt less confident, on average, in their knowledge of geometry, they felt more confident in teaching lessons that combine geometry technologies, and teaching approaches than lessons that involve algebra.

The study shows that the PK of the teachers was higher than the CK, which may not coincide with the implications of Cox (2008), who suggests that secondary teachers tend to have a higher TCK than TPK. Further studies that include TCK and TPK would provide evidence to support any such claims. The PK and CK also had a smaller spread in the data, while the teachers' confidence in their TK had the smallest mean and the largest spread. This indicates a wider variety in the individual teacher's confidence in their own TK. The teachers indicated that they are least confident in their knowledge of technology but their confidence in their TPACK is just a little higher. This supports the findings of Harris and Hofer (2011) that teachers use the content and pedagogical methods related to the content to determine if a technology tool or resource should be used instructionally. When teachers have a specific learning goal in mind, they may be more confident in their knowledge for selecting technology to meet that goal rather than a general knowledge of technology.

Howard (2013) states that teachers with higher self-confidence and technological competency are more likely to integrate technology into their teaching. The teachers in the study indicated that their confidence in their ability to learn technology easily is higher than that of their knowledge of different technologies or keeping up with new technologies. Teachers may be more confident with a variety of technologies if given the opportunity to learn them and, thus, will be more likely to integrate those technologies in the classroom. It is possible that they may be willing to learn them given the proper exposure and time to practice. According to Hsu (2016), the best predictor of the way teachers will integrate technology into their classrooms is their beliefs about pedagogy, self-efficacy, and perceived value to student learning of the technology. It is not surprising that the qualitative data in this study indicate that teachers use technology in the classroom for pedagogical purposes, primarily for visualizing concepts, using virtual manipulatives, and differentiating instruction. This is contradictory to the findings of Howard and Mato (2011), which demonstrate that mathematics teachers use technology for skill-based activities rather than discovery learning activities.

Teacher belief is a critical factor in the decision to integrate technology, according to Inan and Lowther (2010). This study supports that claim as it also shows that the majority of teachers have a positive attitude toward technology integration and a willingness to learn and grow. This attitude of the teachers is also consistent with the findings of John and LaVelle (2004), which show that mathematics teachers tend to be more open to technology integration than some of the other content areas, especially the humanities-focused areas. Further studies comparing teachers of various content areas in the same school district would help determine if this is a valid claim. Leggett and Persichitte (1998) identified five obstacles that prevent the integration of technology into classrooms: time, expertise, access, resources, and support.

Teachers in this study mentioned three of these obstacles, access, resources and time, as the main barriers to using technology in the classroom. Although the middle school student to device ratio was almost 1:1 at the time of the data collection, the middle school teachers could have been referring to a lack of access to devices at home for their students because only the high school students take their devices home. It could also be that teachers felt they didn't have access to the kind of devices they wanted to use with their students. Also, many teachers may expect students to be able to complete work online at home and some students may not have internet access. Teachers may also feel that they do not have the time to learn new technologies because there have been many changes to middle and high school math courses and curriculum over the past several years.

Conclusion

Overarching Research Question

The data suggest that the technological, pedagogical, and content knowledge of teachers is reflected by the strategies used to integrate technology in the classroom. The high confidence in pedagogical knowledge is reflected in the ways teachers recorded integrating technology as 50 of the 68 responses to how they integrate technology were pedagogical in nature. The main barriers, resources and time, are closely related as time could be considered a resource. The lack of time and resources could be a reason teachers were less confident in their knowledge of technology, specifically in the variety of technologies and newer technologies. They might simply not have the time to spend learning how to use resources that are available to them since they indicated that they learn technology easily.

Connection with Previous Literature

As the research indicates, it is difficult to evaluate a teacher's TPACK because there are so many variables involved. Their observable knowledge is dependent on what technology is used and how it is used. In this study, teachers evaluated their own TPACK using general statements. The statements did not specify a technology, pedagogical perspective, or content standard. An observational study could produce different results by analyzing a teacher's TPACK using a specific technology and content standard with a particular pedagogical perspective. The findings in this study are consistent with Kirikcilar and Yildiz's (2018) conclusion that teachers struggle with the combination of technology and pedagogy. Although this study did not examine the TPK specifically, it did indicate a decrease in TPACK from the PK of the teachers involved in the study.

The study indicates that teachers' use of technology for students' conceptual understanding of mathematics is consistent with the goals of CCSS and NCTM. It is also consistent with Pierce and Ball's (2009) findings that technology helps students gain deeper understandings of mathematical concepts and assists in the application of concepts. Most of the teachers in this study expressed a positive attitude toward technology integration and many indicated a desire to improve. Some even stated that their own lack of knowledge was a barrier. This is consistent with Hennessy, Ruthven, and Brindley's (2007) study which showed that many teachers believed the students would benefit more from technology when the teachers' confidence in their own technological abilities improved.

Recommendations

As the data showed, teachers were least confident in their TK and TPACK. This indicates that schools and districts should focus on providing professional development (PD) for teachers to learn strategies for effectively using the technology available to enhance student learning. The PD should provide teachers with strategies that support their current pedagogical methods in addition to new ideas for pedagogy. Given that many teachers expressed a need for more time to learn the technology this PD should include time for teachers to learn how to use the technology and address any issues that may arise, as well as how apply the technology in the classroom. Leaders in schools and districts may also want to consider providing continuous support for teachers throughout the school year and during the school day to address needs that may arise in the classroom. This study focused on the self-assessment of TPACK and technology integration by teachers. Therefore, the data is very subjective as teachers may interpret the statements or questions differently. Observational studies of the TPACK and technology integration would provide a more objective view and could give a more detailed picture of the how the teachers' TPACK is reflected in the technology integration. Also, this study focused on middle and high school math teachers in a rural school district. The results may vary across subject areas, grade levels, and geographic location. Other school systems may have more access to resources or professional development for teachers. Research in other school systems would provide a broader picture technology integration in middle and high school math classrooms.

References

Ball, L., & Stacey, K. (2005). Teaching strategies for developing judicious technology use. In W. J. Masalski & P. C. Elliott (Eds.), Technology-supported mathematics learning environments (2005 National Council of Teachers of Mathematics Yearbook) (pp. 3–15). Reston, VA: NCTM.

Celik, I., Antonenko, P., Kiray, S.A., & Sahin, I. (2016). An examination of teachers' interactive whiteboards use within the scope of Technological, Pedagogical, and Content Knowledge (TPACK). *International Journal of Educational and Pedagogical Sciences, 10*(12). Retrieved from https://publications.waset.org/abstracts/60488/pdf

Celik, I., Sahin, I., & Akturk, A. O. (2014). Analysis of the relations among the components of technological pedagogical and content knowledge (TPACK): A structural equation model. *Journal of Educational Computing Research, 51*(1), 1-22.

Celik, I., Sahin, I., Kiray, A., & Simsek, H. (2015). Case studies for educators based on TPACK framework. *New directions in technological pedagogical content knowledge research: Multiple perspectives*, 377-376.

Cox, S. M. (2008). A conceptual analysis of technological pedagogical content knowledge. Unpublished doctoral dissertation. Provo, UT: Brigham Young University.

Creswell, J.W., & Plano-Clark, V.L. (2011). Choosing a mixed methods design. In *Designing and Conducting Mixed Methods Research* (2nd ed.) (pp. 53-106). Thousand Oaks, CA: SAGE Publications, Inc.

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge (TPACK) in action: A descriptive study of secondary teachers' curriculum-based, technology-related instructional planning. *Journal of Research on Technology in Education*, *43*(3), 211-229.

Hennessy, S., Ruthven, K., & Brindley, S. (2007). Teacher perspectives on integrating ICT into subject teaching: commitment, constraints, caution, and change. *Journal of Curriculum Studies* http://doi.org/10.1080/0022027032000276961

Howard, S. K. (2013). Risk-aversion: Understanding teachers' resistance to technology integration. *Technology, Pedagogy and Education*, *22*(3), 357–372. https://doi.org/10.1080/1475939X.2013.802995

Howard, S., & Maton, K. (2011). Theorising knowledge practices : a missing piece of the educational technology puzzle. *Research in Learning Technology*, *19*(3), 191–206.

Hsu, P. S. (2016). Examining current beliefs, practices and barriers about technology integration: A case study. *TechTrends*, *60*(1), 30–40. https://doi.org/10.1007/s11528-015-0014-3

Inan, F. A., & Lowther, D. L. (2010). Factors affecting technology integration in K-12 classrooms: A path model. *Educational Technology Research and Development*, *58*(2), 137–154. https://doi.org/10.1007/s11423-009-9132-y

John, P. D., & La Velle, L. B. (2004). Devices and desires: Subject subcultures, pedagogical identity and the challenge of information and communications technology. *Technology, Pedagogy and Education*, *13*(3), 307-326.

Kirikcilar, R. G., & Yildiz, A. (2018). Technological pedagogical content knowledge (Tpack) craft : Utilization of the tpack when designing the geogebra. *Acta Didactica Napocensia*, *11*(1), 101–116. http://doi.org/10.24193/adn.11.1.8

Koehler, M. J., & Mishra, P. (2009). What is Technological Pedagogical Content Knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60–70. https://doi.org/10.1016/j.compedu.2010.07.009

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education*, *193*(3), 13–19. http://doi.org/10.1177/002205741319300303

Leggett, W. P., & Persichitte, K. a. (1998). Blood, sweat, and TEARS: 50 years of technology implementation obstacles. *TechTrends*, *43*(3), 33–36. https://doi.org/10.1007/BF02824053

Minshew, L., & Anderson, J. (2015). Teacher self-efficacy in 1:1 iPad integration in middle school science and math classrooms. *Contemporary Issues in Technology and Teacher Education*, 15(3), 334-367.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054. http://doi.org/10.1111/j.1467-9620.2006.00684.x

National Council of Teachers of Mathematics (NCTM). (2015). *Strategic Use of Technology in Teaching and Learning Mathematics*. Reston, VA. Retrieved from https://www.nctm.org/Standards-and-Positions/Position-Statements/Strategic-Use-of-Technology-in-Teaching-and-Learning-Mathematics/

National Governors Association Center for Best Practices, & Council of Chief State School Officers. (2018). Common core state standards for mathematics. Retrieved from http://www.corestandards.org/Math/Practice/

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509–523. http://doi.org/10.1016/j.tate.2005.03.006

Patahuddin, S. M., Lowrie, T., & Dalgarno, B. (2016). Analysing mathematics teachers' TPACK through observation of practice. *Asia-Pacific Education Researcher*, *25*(5–6), 863–872. http://doi.org/10.1007/s40299-016-0305-2

Pea, R. D. (1985). Beyond amplification: Using the computer to reorganise mental function. *Educational Psychologist*, *20*(4), 167–182.

Pierce, R., & Ball, L. (2009). Perceptions that may affect teachers' intention to use technology in secondary mathematics classes. Educational Studies in Mathematics, 71(3), 299–317. http://doi.org/10.1007/s10649-008-9177-6

Sahin, I. (2011). Development of survey of technological pedagogical and content knowledge (TPACK). *Turkish Online Journal of Educational Technology-TOJET*, *10*(1), 97-105.

Saldana, J. (2013). *The coding manual for qualitative researchers* (2nd ed.). Los Angeles: SAGE Publications.

Saltan, F., & Arslan, K. (2017). A comparison of in-service and pre-service teachers' technological pedagogical content knowledge self-confidence. *Cogent Education*, *4*(1), 1–13. https://doi.org/10.1080/2331186X.2017.1311501

Zelkowski, J., Gleason, J., Cox, D. C., & Bismark, S. (2013). Developing and validating a reliable TPACK instrument for secondary mathematics preservice teachers. *Journal of Research on Technology in Education*, *46*(2), 173–206.

Author Information

Julia Eden Hill
Boise State University
1910 W University Dr.
Boise, ID 83725
United States
Contact e-mail: *juliahill@u.boisestate.edu*

Lida Uribe-Florez
Boise State University
1910 W University Dr.
Boise, ID 83725
United States

Appendix. TPACK Survey

Demographic Information

Years of Experience:
a. 0 - 4 years
b. 5 - 10 years
c. 11+ years

Grade level:
a. Middle school
b. High school

Certification (select all that apply):
a. Elementary Education
b. Middle School Math
c. High School Math
d. Special Education

Technology is a broad concept that can mean a lot of different things. For the purpose of this questionnaire, technology is referring to digital technology/technologies—that is, the digital tools we use, such as computers, laptops, iPods, handhelds, interactive whiteboards, computer software programs, graphing calculators, etc.

Please answer all of the questions. The response selections are "strongly disagree," "disagree," "neither agree nor disagree," "agree," and "strongly agree."

TK1 I know how to solve my own technical problems.

TK2 I can learn technology easily.

TK3 I keep up with important new technologies.

TK4 I frequently play around with the technology.

TK5 I know about a lot of different technologies.

TK6 I have the technical skills I need to use technology.

CK9 I have sufficient knowledge about mathematics.

CK11 I have various strategies for developing my understanding of mathematics.

CK12 I know about various examples of how mathematics applies in the real world.

CK13 I have a deep and wide understanding of algebra.

CK14 I have a deep and wide understanding of geometry.

PK17 I know how to assess student performance in a classroom.

PK18 I can adapt my teaching based upon what students currently understand or do not understand.

PK19 I can adapt my teaching style to different learners.

PK20 I can assess student learning in multiple ways.

PK21 I can use a wide range of teaching approaches in a classroom setting.

TPACK51 I can use strategies that combine mathematics, technologies, and teaching approaches in my classroom.

TPACK52 I can choose technologies that enhance the mathematics for a lesson.

TPACK53 I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.

TPACK55 I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches.

TPACK59 I can teach lessons that appropriately combine algebra, technologies, and teaching approaches.

TPACK60 I can teach lessons that appropriately combine geometry, technologies, and teaching approaches.

Check the box next to each of the devices or programs you use in your classroom.

☐ Laptop
☐ Chromebook
☐ iPad
☐ TI-84 Calculator
☐ Other:____
Please list other devices you use to integrate technology into your math classroom.

☐ Engrade
☐ Discovery Math Techbook
☐ Open Up Resources
☐ MyLabsPlus
☐ WebAssign
☐ Desmos
☐ Google Classroom
☐ Wolfram
☐ Geogebra
☐ Geometer's Sketchpad
☐ Other:____
Please list other programs you use to integrate technology into your math classroom.

Open-ended questions

How has technology changed the way you teach math? Please include an example.

How has technology changed the way your students learn math? Please include an example.

How has technology changed or broadened the "curricular knowledge" to be gained, learned, or applied? Please include an example.

Do you currently feel that you are effectively integrating technology into your math classroom and why?

What are some barriers that prevent you from more effectively integrating technology into your math lessons?