TPACK: A Framework for Educators to Implement Technology in their Classrooms

An Honors Thesis (HONRS 499)

by

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Abstract

It is difficult to ignore the impact that technology has on modern society. As educators and educator preparation programs seek to discover effective ways of capitalizing on the prevalence of technology, it becomes necessary to develop frameworks to help teachers learn to implement technology in their classrooms. Three different teacher knowledge bases are identified as crucial to becoming an effective educator — content knowledge, pedagogical knowledge, and technological knowledge. These knowledge bases are formed together to create a unified framework, known as TPACK. The author details the development of the TPACK framework, as well as identifies several methods of successfully developing a teacher’s TPACK. Several barriers to the successful implementation of technology in education are also discussed. A supplementary paper from the author is included that provides his personal TPACK development and strategies for improving the TPACK of other educators.

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As more technologies are developed and implemented in today’s society, some
teachers experiment with the implementation of technology in their classrooms. Several
organizations, including the National Council of Teachers of Mathematics (NCTM, 2011)
and the International Society for Technology in Education (ISTE), have developed
standards to help teachers transition and implement technology in 21st century education.
As a result, it became increasingly necessary for researchers in the field to develop a
framework to outline teacher knowledge in a way that combines a teacher’s pedagogy
and content with meaningful technologies for the benefit of students. Mishra and
Koehler, two educational professors, created a framework known as Technological,
Pedagogical, and Content Knowledge, also known as TPACK. The TPACK framework
is intended as a context for improving educators’ knowledge bases. The goal of this
framework is to go beyond merely learning technology, and focus on tying technology
into the pedagogy and content of the teachers. The TPACK framework functions as a
point of reference for teachers and teacher preparation programs to align to content and
technology standards.

This paper will review the history of the Pedagogical Content Knowledge (PCK)
framework, the development of the TPACK framework and current TPACK publications
that are relevant for teacher education programs. The author will discuss current
programs that strive to successfully develop preservice and inservice teacher’s TPACK,
as well as barriers to the successful implementation of technology in today’s classrooms.
A supplement to this paper is a recent publication by the author, a novice teacher, that
provides personal experiences from a learning by design course and suggestions for the
reader to enhance his or her TPACK for the benefit of students (see Appendix A).
History of Pedagogical Content Knowledge (PCK)

In the late 1980s, a plethora of colleges and universities were preparing their teacher candidates in one of two ways. Teacher candidates were prepared either in their subject area (i.e. mathematics teacher candidates were required to take the same high level mathematics courses as the pure mathematics majors) or they were prepared in courses that focused solely on the pedagogy of the time (Hashweh, 2005). There was an obvious disconnect between the two, which created a dichotomy in the educational world. Some teachers were well prepared to understand and know how to do the coursework, but were unprepared to teach it to younger minds; on the flip side, other teachers were prepared to teach using a variety of pedagogical methods, but were not qualified enough in their subject area to understand the material any better than their students (p. 274-275).

An educational psychology professor from the Stanford University School of Education, Dr. Lee Shulman, detected this dichotomy and created a framework that highlighted a slightly more effective method for teacher education programs. Shulman was focused on defining and observing connections between content and pedagogical knowledge and how they interacted in the classroom to create a highly qualified teacher (Shulman, 1987). Initially, Shulman proposed several constructs that combined to form a “knowledge base of teachers” (p. 5). This knowledge base, according to Shulman, consisted of:

- Content knowledge, which is exactly as it sounds—the teacher’s knowledge of the material he or she is teaching.
- General pedagogical knowledge, which consists of the knowledge of classroom management, discipline, and organizational strategies; the knowledge that, according to Shulman, “appears to transcend subject matter.”
- Curriculum knowledge, which is the knowledge of materials and how things are to be taught and in what sequence.
- Pedagogical content knowledge, which is a combination of a teacher’s pedagogical methods with their knowledge of the material he or she teaches.
- Knowledge of learners and their characteristics, which is an understanding of how students learn and develop.
- Knowledge of educational contexts, which is the knowledge of how school systems work, both financially and organizationally, and how they operate in a community.
- Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds. This includes the reason for educating students, providing education for all students, and how education came to be in its current form. (p. 8)

Shulman was particularly interested in pedagogical content knowledge, as it was an amalgam of how an effective teacher would manage a classroom of students to keep the students on task and learning in ways conducive to each student and a significant knowledge of the material he or she is trying to convey and model for the students. According to Shulman himself, “pedagogical content knowledge is the category most likely to distinguish the understanding of the content specialist from that of the pedagogue” (p. 8).

While Shulman was proposing some effective changes to the teacher education programs of colleges and universities across the nation, other professionals in the field were critiquing his writings. They felt that this idea of pedagogical content knowledge needed further refining and that the interactions among the seven components of a teacher’s knowledge base needed to be emphasized. Wanting to create a better framework for teacher education programs, Shulman allowed others to further the development of his ideas (Hashweh, 2005, p. 276).

After Shulman’s initial research, a whole cast of researchers and professionals in the field expanded on Shulman’s ideas regarding a solid knowledge base for teachers regardless of their content area. Researchers began to combine some of those seven
narrow categories that Shulman had described by compiling them into the larger category of pedagogical content knowledge. It appeared to be an easy adjustment to make; when all of the interconnections among the different categories are made, they all blend into the broader scope of how a teacher teaches specific content and how he or she adjusts the material for his or her own students. Essentially, pedagogical content knowledge was expanded to include all the ideas and experience that teachers accumulate over the years, and how they incorporate this knowledge into their everyday teachings. Figure 1 can be used to summarize the fusion of content knowledge with pedagogical knowledge.

![Figure 1. PCK image from the TPACK Wiki](https://www.tpack.org)

This image, from an article on PCK (Pedagogical Content Knowledge) on the TPACK Wiki website (Koehler & Mishra, 2010), demonstrates the intersection between content knowledge and pedagogical knowledge—two knowledge bases that were, prior to Shulman’s research, considered separate. The new goal was to have all teachers teaching in the middle area, where the two intersect. Shulman’s idea was that an effective teacher should combine all aspects of the material he or she teaches with the features of effective teaching.
pedagogical methods, instead of thinking of content and pedagogy as two distinct knowledge bases.

Development of Technological Pedagogical and Content Knowledge (TPACK)

Over the past two decades, it is difficult to deny the world has evolved technologically. Every year, it seems that a new technology emerges from a developer that revolutionizes how everyday things are done. It was inevitable that technology would begin to have an impact on how teachers instruct their students. As teachers began incorporating technology into their teaching, it became necessary for teacher education programs to follow suit. After five years of studying and observing inservice teachers, masters students, and tenured faculty at the university level and helping those teachers develop the use of technology in their instruction through the creation of online courses and materials, Mishra and Koehler developed a new framework that would become the new way of thinking about and structuring a teacher’s knowledge base and how he or she might develop his or her knowledge—Technological Pedagogical and Content Knowledge, also known as TPACK (Mishra & Koehler, 2006, p. 1024; 1039-1040).

This TPACK framework is another extension of Shulman’s original concept of pedagogical content knowledge. In this framework, a teacher’s technological knowledge is added as a third form of knowledge, which when combined with pedagogical knowledge and content knowledge, required a new illustration of the relationship among the knowledge constructs. Figure 2 demonstrates diagrammatically the close relatedness that exists among the three knowledge bases.
Figure 2. TPACK is the intersection of content, pedagogical, and content knowledge.

Mishra and Koehler not only wanted to stress the nuances that exist among the three knowledge bases, but they also wanted to focus on each pair of knowledge bases as well (p. 1028-1029). These three knowledge pairs are also illustrated in the above diagram. Shulman had previously identified one of these pairs: pedagogical content knowledge (PCK). PCK demonstrates the content knowledge that a teacher has, and how they use that knowledge to structure a class and instruct the material (pedagogical knowledge) to their students in such a way that maximum results are attained.

Technological content knowledge (TCK) is a teacher’s understanding of how available technologies can be utilized to provide new representations or new methods of proof, depending on the implementation of technology. Technological pedagogical knowledge (TPK) is the application of technology in a classroom setting and understanding how technology will impact the execution of instruction. It is a knowledge of how the technology will impact how, and to what degree the technology will help, students understand the material.
Mishra and Koehler recognized that Shulman did not have to concern himself as much with incorporating technology education into teacher education programs, as technology in the late 1980s was definitely underdeveloped compared to today. They also point out that the definition of the word technology has changed somewhat since the 1980s. Technology then was any physical object used in the classroom, including rulers, textbooks, overhead projectors, and the like. Technology today includes both software and hardware; it includes more digital and computer oriented programs that teachers are selecting specifically for use by their students (Mishra & Koehler, 2006, p. 1023).

Koehler and Mishra argued that a teacher’s technological knowledge is often seen as a separate entity from a teacher’s content and pedagogical knowledge. This is a strange repetition, as the same was true for content and pedagogy during Shulman’s time. Quite a few professionals in the field view technology as a category of its own that has no bearing on a subject area and how one teaches that content to students. According to Mishra and Koehler, the three knowledge bases should not be viewed as individual constructs; instead, they should be pictured as a “dynamic transactional relationship” (Mishra & Koehler, 2006, p. 1031). They note that any imbalance in the equilibrium has to be rectified by a change in the overall structure of the TPACK model. For example, suppose an update to a technology arrives with a plethora of new changes. These changes may be so drastic that the classroom teacher is forced to relearn the technology his or herself. The changes with the technology may very well impact how that teacher instructs his or her students and how the material is presented. In this case, a change in technology—which happens quite frequently when new software makes its appearance
year after year—impacted the classroom teacher’s pedagogy and, to an extent, the content that he or she would be teaching.

The concept of TPACK could potentially force some educators, particularly those who have long been in the profession, to examine their own content and pedagogical knowledge and adapt their knowledge by assimilating information and understanding of available and practical technologies (Mishra & Koehler, 2006, p. 1031). Teachers who choose to implement technology in their instruction are obliged to adapt their pedagogy and use their knowledge of their particular content in order to facilitate the use of technology. Technology is a powerful tool for use in the real world, but also in the classroom. However, if technology is to be integrated, the technology must be relevant and meaningful to student learning of the content. As Lawless describes it, effective and meaningful technology integration in classrooms should be used to satisfy specific curriculum goals and academic outcomes; “successful technology-enhanced learning environments allow the curriculum to drive the technology usage, not the technology to drive the curriculum” (Lawless, n. d., p. 3). How do teacher education programs help develop a teacher’s TPACK and thus help teachers discover “meaningful technology integration?”

Developing a Teacher’s TPACK

Mishra and Koehler are quick to point out how carefully a teacher’s technological knowledge must be developed and integrated with pedagogy and content to ensure that teachers’ understanding of technology is not limited to generic and “content-neutral” technologies (p. 1032). As more and more teachers begin to work with technologies, a lot of educational foundations and groups are advocating teacher training and
professional development workshops to enhance their teachers. Despite their good intentions, a good majority of these workshops are, to put in Mishra and Koehler's words, too "content-neutral." These workshops are narrowly focused and don't scratch the surface of how to effectively use technologies in conjunction with content and pedagogy. However, they could balance instruction between the technology, the content, and the pedagogy by concentrating more on how technologies can be used alongside pedagogy. As opposed to focusing on training a wide range of teachers in specific technologies, these workshops and conventions could rely on Mishra and Koehler's view of balancing technology with specific content and pedagogical methods.

An additional roadblock to training teachers to use a specific technology is the rate of change that technologies are developed and accessible to the public. At the very least, newer versions of technologies become available every couple of years. Is it practical to train teachers in a particular technology when that technology will most likely be outdated in a few years? Despite the good intentions of these seminars and workshops, they do not facilitate the effective and meaningful integration of technology. Most "technology workshops" only focus on basic technologies, such as word processors and web searches (Lawless, p. 2). There must be an effective way for educators to be trained to incorporate technology in their classrooms that focuses more on content-specific and pedagogical methods.

A number of research studies have been conducted in the past few years on how to best train teachers to adapt technological knowledge into the existing PCK model. Mishra and Koehler propose their own approach to appropriately educate teachers on how to implement technology in their classrooms (p. 1036). Called "learning by design,"
this approach stresses that teachers learn more about technologies through direct interaction with the various technologies that are experienced in classrooms. Teachers are given tasks to create units centered around their technologies and then reflect on their experiences. This emphasizes the notion that effective teachers should be reflective practitioners. Throughout the learning by design process, teachers have to constantly think about the interactions between content, pedagogy, and the technology. Teachers have to create artifacts that support and demonstrate their learning of the technology. This effectively places teachers in the driver seat of developing their TPACK. The design of units and artifacts also lends nicely to activity-based learning; essentially, teachers can utilize what they have created and learned through learning by design and implement it in their own classrooms.

Hoffer and Harris (2010) proposed a taxonomy called “Learning Activity Types,” which focuses on a content area, then on the activities that are used in that specific content area, and then on the available technologies that can facilitate or enhance those activities. Hoffer and Harris propose a sequence for educators to follow in the planning process (p. 2).

- Identify student learning goals. What do we want students to be able to do after this lesson or unit?
- Consider the classroom context and student learning styles and preferences. What are the students like? What works best for instructing them?
- Select and sequence appropriate learning activity types to combine to form the learning experience. What activities work best to help facilitate and reach our end goal?
- Select formative and summative assessment strategies. How will we assess that students reached their learning goal?
- Select tools and resources that will best help students benefit from the learning experience. What technologies can we use to facilitate this?
The authors are quick to note that these steps are not meant necessarily to flow in that order, but are a list of steps that effective educators should complete at some degree in their planning process. However, they do point out that by identifying the end goals of the lesson or unit first and choosing the appropriate technologies and resources last, a teacher effectively emphasizes and utilizes TPACK in a balanced manner, rather than being focused solely on the technology domain.

Hoffer and Harris logically recognize that inservice teachers have a great deal of experience with content and pedagogy, as they certainly have more experience with students and how to adapt for different learning styles and how to plan lessons around content-centered activities. Their idea is to capitalize on how teachers already plan their instruction, which research indicates is mostly focused on utilizing activities that directly correspond to the material they’re teaching. It is interesting to note that this sentiment is also found in a publication by Wilson, Shulman, and Richert, which dates from 1987. Hoffer and Harris make the case that a teacher’s TPACK should not be developed “technocentrically” (p. 3858), but should be developed through constructing pedagogy with curriculum goals in mind. To put it simply, a teacher’s TPACK should be developed by focusing on curriculum goals, effective pedagogy, and student learning as opposed to focusing solely on implementing technology for the sake of technology. This method allows teachers to build curriculum, not with technology as the focal point, but with technology in mind as an effective resource and tool for enhancing student learning.

The Learning Activity Types taxonomy can also be used to instruct preservice teachers and to develop their TPACK as well. A large number of current preservice teachers grew up with technology. The ability to use new technology is not lost on them,
as they've had to learn how to cope with the changes in computer technology and the Internet. While they suggest that their taxonomy works better with inservice teachers due to their pedagogical knowledge, Hoffer and Harris propose the use of their Learning Activity Types taxonomy with preservice teachers as a way of reinforcing their pedagogical content knowledge and technological knowledge through the increased implementation of technology (p. 5 - 6). Preservice teachers have to learn how to create lesson and unit plans and how to implement activities in a classroom, while also considering the implementation of effective technologies. Their teacher educators have to use scaffolding and modeling to show the preservice teachers how to select appropriate and worthwhile activities and tasks, as well as how to implement them in a classroom setting. Once they become familiar with instructional methods, activities, and how they relate to their content, the preservice teachers have to create a lesson or unit where they utilize those activities while incorporating technology to facilitate and enhance instruction and learning. According to Hoffer and Harris' findings, their methodology allows both preservice and inservice teachers to become more conscious about their planning and more aware of available resources (p. 8).

The learning by design and Learning Activity Type models are probably the most effective for developing a teacher’s TPACK and implanting technology in their classrooms as they allow teachers to use their current knowledge and further build on that knowledge by incorporating technology as another means of representing and making connections with the material. There's nothing too new for the teachers; they are merely using resources differently than they were previously accustomed. Technology becomes increasingly integrated into instruction in these models. Technology is also used
effectively as it is not a replacement for the teacher; instead, technology is used as a supplement to enhance the activities and the overall learning experience of the students, which is the ultimate goal of technology integration.

In addition, these models involve a great deal of reflection and discussion about incorporating technology and the implications of using technology in a classroom environment with real students. Mishra and Koehler argue that a learning by design model helps develop and structure an educator's TPACK through discussion among colleagues and professionals in the field and through analyses of "pedagogical, technological, and content-related issues" (Mishra & Koehler, 2006, p. 1048). Hoffer and Harris' Learning Activity Types model also incorporates good practice by ensuring teachers collaborate and discuss the educational and pedagogical implications of technology integration. Teachers in their program were also asked to examine the usefulness of particular technologies and determine which particular technologies would be available in their schools (Hoffer & Harris, 2010, p. 6). This idea of being a reflective practitioner and constantly evaluating one's choices in the classroom is an important prerequisite in becoming an effective educator (Loughran, 2002, p. 10 - 11).

**Outcomes for TPACK Development**

The TPACK framework provides a guidepost that suggests a teacher's technological, pedagogical, and content knowledge should not be viewed as separate entities, but should be seen as a balanced whole that teachers use to enhance their instruction and thus enhance the learning of their students. It becomes critical then to understand ways to develop a teacher's TPACK through experience and identify how to
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assess a teacher’s TPACK. How do teacher preparation programs determine if a teacher’s TPACK has successfully developed?

Niess (2005) performed a case study with 22 student teachers on the development of TPACK during the student teaching experience. The goal of the study was to analyze how student teachers, in this case in the fields of mathematics and science, develop their TPACK through the implementation of technology during their student teaching experience. Another aim of the study was to determine what works and what doesn’t work in developing the TPACK of preservice teachers (p. 522). The student teachers were required to document and assess their choices of technology use, and verify that their choice assisted students in meeting curriculum goals. Student teachers were also required to research resource materials and align those resources to both content standards and the technology standards established by the International Society for Technology in Education—also known as ISTE (for more information about ISTE, please visit their website at www.iste.org).

As a result of this study, Niess was able to identify a framework with four crucial outcomes. Niess argues that all teacher preparation programs that seek to develop their students’ TPACK should be able to demonstrate these four outcomes, which are:

- An overarching conception of what it means to teach a particular subject integrating technology in the learning.
- Knowledge of instructional strategies and representations for teaching particular topics with technology.
- Knowledge of students’ understandings, thinking, and learning with technology in a particular subject.
- Knowledge of curriculum and curriculum materials that integrate technology with learning in that subject area. (p. 511).

These four outcomes point to the end goal of effectively implementing technology in a classroom. These outcomes don’t highlight a particular technology nor do they
demonstrate how to use and train teachers to use a certain technology. However, these outcomes encompass a more general view of how blended and balanced the implementation of technology is in 21st century education. This further emphasizes Mishra and Koehler’s view that technological knowledge is not a separate entity from pedagogical and content knowledge (p. 1027), but is in fact an amalgam of the three knowledge bases to create a unified whole.

**Why Not Implement Technology?**

In an age where technologies are constantly emerging and evolving, it becomes increasingly more important for teachers to research emerging technologies and develop ways to integrate technology in their instruction (Niess & Van Zee, 2010, p. 1781). While there are multiple methods for helping teachers develop their TPACK and expand their use of resources other than “traditional means,” why aren’t more teachers focusing on developing their TPACK and incorporating technology in their instruction? There are quite a few reasons that opponents to technology integration in education use; however, their arguments are easily debunked with a little research.

Major opponents to incorporating technology into education always seem to make the claim that technology is too expensive to use and that a lot of schools, especially in this economy, can’t afford technologies. Despite this outcry, schools still seem to be able to locate funds, mostly through research and educational grants, to help them purchase iPads for entire schools. Recently, in Charleston, South Carolina, the Charleston County School Board elected to purchase iPads for two schools in their districts (Live 5 News, 2011). According to one of the Charleston teachers, “They [iPads] have made a huge difference in learning. The kids’ test grades have gotten so much better.” Schools can
still find ways to pay for technologies in classrooms. At the very least, teachers can easily locate some free technologies. For example, the mathematics program GeoGebra (www.geogebra.org, 2011) is useful in supporting student investigation of concepts in algebra and geometry due to the dynamic environment and demonstrating a plethora of mathematical concepts. What’s the best part about GeoGebra? It’s free to download and use. Students and teachers can both access it whenever, provided that they have a computer to use.

Another major issue is a lot of teachers do not understand how technology can be balanced with their content and pedagogy to inform both. A lot of teachers just don’t want to try it. Teachers and administrators don’t see it as an essential thing for them or their students to know or be able to use. A lot of teachers also seem to be stuck in the ruts of teaching; once they’ve taught a subject for so many years, and become familiar with the state curriculum standards, teachers feel restricted to an unchanging format year after year to satisfy curriculum goals (Shafer, 2008, p. 40). Shafer also noted that teachers can be spurred into action by having administrator and school personnel support; without that support, this change towards technology integration becomes more difficult to achieve.

Some schools — such as the Charleston, South Carolina schools that are providing iPads and other technologies (including SmartBoards and Mobi boards) — are in fact expecting teachers, both young and old, to adapt their instructional methods to incorporate technology. This appears to be proving a problem, as teachers don’t want to be forced to change their habits, because they’ve already developed methods for use to meet curriculum goals and standards every year. They’ve already created what they need
to teach the material, and they feel they don't have sufficient time to implement anything else, particularly technology (Shafer, 2008, p. 40). Some teachers quickly become frustrated as they try to implement technology in their instruction, but are relatively unimpressed by the initial results. If the first group they try out the technology on fails or doesn’t perform as expected, teachers seem quick to accuse the technology as the cause. Sometimes it is necessary to allow some time and experience, on the part of both the students and the teacher, before successful results are obtained. In “Moving the Mountain: An Impediment to Change,” Mazur (1997) provides an analogy that perfectly summarizes this frustration and how time and practice are necessary before successful results can be expected:

‘A good analogy is that of a tennis coach who discovers that one of her students is not holding his racket correctly. After adopting the correct grip, the student’s performance does not immediately improve—in fact, it gets worse: most balls go into the net or off to another court. The student gets frustrated because he is used to holding his racket differently and, it now appears, played better the old way. The coach, however, knows the student can never improve without the correct grip and that her student’s play will soon improve’ (p. 3).

More or less, the tennis coach in the analogy is played by administrators, teacher education programs, and their instructors who are constantly trying to push the implementation of effective and useful technologies into education. The student is of course an example of those teachers currently in the field that resist change. They feel that their “tried and true” methods worked for them in the past, and thus will continue to work. They disregard any new educational theories or frameworks that attempt to help them better themselves as teachers. One thing that teachers need to remember is that education is a constant learning process, on the part of the students as well as the teacher.
A teacher should constantly be looking for ways to improve their own instruction for the benefit of their students.

Another claim against technology is that students aren’t always making the connection between the technology and the content. This also appears to be true for preservice teachers. Graham, Burgoyne, and Borup (2010) notes that preservice teachers enrolled in a content-centered technology course were capable of completing the course, but upon later findings, did not continue to incorporate their technological knowledge in their methods courses (p. 7). This can be extended; once these preservice teachers are in the field, they probably will continue their lack of technology integration. This isn’t so much a fault of the technology. This issue seems to be more centered around the courses and how they are handled. While the technology instructor is most likely passionate and wants teachers to incorporate technology into their instruction, the methods teacher might not necessarily reinforce those ideas. Perhaps, as was the case back in the 1980s between pedagogy instructors and content professors, technology, methods, and content instructors across the board need to collaborate and strive for the same goal rather than working independently. Regardless, technology and technology integration in classrooms is not the problem; the issue seems to lie more in the attitudes of those who don’t wish to seek this type of change in education.

Summary

Mishra and Koehler’s framework of Technological, Pedagogical, and Content Knowledge, otherwise known as TPACK, is a representation of what encompasses an effective educator. While it doesn’t particularly spell out what qualities are necessary to become a successful teacher (if only it were so easy), the TPACK framework provides a
guide to work with that helps represent the three different knowledge bases of an educator. Originally, these were three separate entities; in practice, this was not the case. An effective educator has to use their knowledge of the material he or she is teaching in conjunction with his or her knowledge of pedagogy to best impact his or her students.

Now with the "technological age," educators need to also incorporate their knowledge of technology and understand how that knowledge affects their pedagogical knowledge and content knowledge.

The TPACK framework provides insights into how teachers think and how they should balance their knowledge of content, pedagogy, and technology to strengthen their own teaching for the benefit of students. The TPACK framework is an extension of Shulman's original research into teacher education programs from the 1980s. As a result of the development of technologies and their use in the classroom, the TPACK framework had to be developed to scaffold the successful balance and integration of technology in classrooms. Many researchers in the field are creating ways to effectively develop a teacher's TPACK. Two such models—learning by design and Learning Activity Types—were presented and analyzed to demonstrate how teacher education programs can better prepare their teachers to be continual learners and effectively implement technology in their instruction. In addition, a discussion of why teachers and administrators are resistant to the integration of technology in schools were presented and discussed.

In a companion publication (Cruze & Shafer, 2011), the author (a novice teacher) shared his perspective on several personal experiences with TPACK and a university technology course that followed the learning by design methodology. Recommendations
and suggestions for an educator interested in developing his or her TPACK and effectively implementing technology in education are presented in the companion publication (included here as Appendix A).
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Appendix A.

Technology in the Mathematics Classroom:
A Teacher Candidate's Perspective

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Abstract: This article documents the author's (a teacher candidate) shift in beliefs in regard to the use of technology in mathematics education. The author's Technological, Pedagogical, and Content Knowledge, or TPACK, developed as a result of three components in a course on technology in secondary mathematics. The components were course readings, reflections on those readings, and contextual examples from in-service teachers, which introduced the author to the importance and role of technology as a tool for enriching and developing students' mathematical understanding. The paper discusses factors that influence technology use, including practical applications of technology and possible complications that could arise from a misuse of technology, and provides suggestions on how teachers, both current and future, can develop their own TPACK for the benefit of their students.

Introduction

It is undeniable that we are living in one of the most technologically driven societies in human history. Most tasks people complete can be done easily and more efficiently through technology. People can instantly communicate with others thousands of miles away through the Internet, update their Facebook statuses from anywhere through handheld devices, and even save people's lives via microscopic robots. Since technology is so important and often required for even the simplest jobs today, some might say it is important to use technology in mathematics classrooms across the nation
so that students can become familiar with the intricacies and practical uses of technology. There are others who would argue that this is unnecessary, and that technology is not useful for teaching mathematics.

Historically, has technology impacted much of the work of the greatest mathematicians? A number of the greatest mathematical accomplishments were made without any technology beyond simple tools like a straightedge and compass. Yet, some who argue against technology in the classroom use this point to make the claim that since technology wasn’t absolutely necessary to create or transfer mathematical ideas in the past, it shouldn’t be necessary now. This was how I felt before entering a course titled “Technology in the Teaching of Secondary Mathematics” which is required to graduate with a degree in secondary mathematics education from Ball State University.

**Personal Technology Use: Past and Present**

As a pre-service teacher, I was initially guilty of condemning technology in the mathematics classroom. Mathematical technology was virtually unknown to me as my middle and high school mathematics experience involved very little technology. Most of my teachers used typical instructional methods—mostly stand and deliver, but occasionally small group work and guided discovery lessons—and often times used manipulatives to explore mathematics. My classmates and I would occasionally be granted permission to use calculators, but not as a tool to explore mathematics deeper; we were only allowed to use them for simple arithmetic and to check answers. Beyond that, calculators were off limits as they were seen as something that too many students become dependent on. Basically, since I didn’t use technology much in my mathematics experience, I didn’t see a need for my future students to use technology either.

The Technology in the Teaching of Secondary Mathematics course was an eye-opening experience for me. Beyond some technologies that I knew existed in the mathematical world—common technologies like Mathematica, Microsoft Excel, and of course graphing calculators—I was not fully aware of the plethora of technologies that exist, nor did I know how to incorporate them into my classroom. I remember thinking to myself, “Why bother? I’ve never planned on using much technology in my teaching anyway, so what’s the use?” Right from the get-go, we were expected to choose a
technology that we would like to explore for the semester (a list of available technologies was provided). This demonstrated to us that there are technologies, both free and costly, that are available for teachers to use in their instruction, and that it is important to know how to research them and read feedback which current teachers using the technology provide.

What is TPACK?

By the second week of the technology course, I began to see a change in my views toward technology. For some reason, I held the misconception that mathematics teachers who incorporated technology in their classroom used technology exclusively, instead of balancing it with non-technology work. In the technology course, the professor required that each student read pre-selected articles weekly and write reflections, either in a Google Docs spreadsheet, blog post, or a Word document, so that each student would put careful thought into the readings. One of the first required readings was an article by Mishra, Koehler, and Kereluik (2009) entitled "The song remains the same: Looking back to the future of educational technology." This article introduced me to a construct known as TPACK, which stands for Technological, Pedagogical, and Content Knowledge. The TPACK teaching framework, created by Matt Koehler and Punya Mishra (2006), emphasizes technology integration into education while still incorporating a teacher’s own knowledge and understanding of the material they are teaching and their knowledge of pedagogical methods that tell them how to best instruct their students.

TPACK was developed from an earlier concept known as PCK (Shulman 1986). PCK, or Pedagogical Content Knowledge, was introduced in the 1980’s as an alternate way of preparing teacher candidates. At that time, education programs focused heavily on either content or pedagogical knowledge, and there was hardly any overlap. This resulted in a huge dichotomy in the education world—should teachers know the material they’re teaching or should they know how to teach effectively? Shulman proposed a somewhat obvious solution: merge the two into a “necessary relationship.” The two go hand-in-hand: a teacher cannot teach effectively if they don’t understand the content, nor can their students learn the content if it is not taught effectively. Instead of being isolated
disciplines, Shulman merged content knowledge and pedagogical knowledge into what became known as PCK.

TPACK was eventually developed as a natural result of technological developments over the next twenty years. Technology became more and more useful and widespread, so some teachers began exploring the usefulness of technology in their classroom. Technology eventually emerged as another bridge for integrating content knowledge and pedagogical knowledge. Koehler and Mishra just expanded on Shulman’s ideas and developed TPACK. TPACK, like education in general, is an ongoing learning process. As a teacher’s TPACK develops, he or she learns how to negotiate and make connections among their knowledge of the content they’re teaching, how best to teach it so students are engaged and will understand it, and how to include technology as a method of teaching students effectively.

After reflecting on a few other reading assignments from this course—including Gee’s (2005) article “Learning by design: Good video games as learning machines,” McGraw and Grant’s (2005) “Investigating mathematics with technology: Lesson structures that encourage a range of methods and solutions,” and Sprenger’s (2010) “Brain-based teaching in the digital age”—I began to develop my TPACK. Each reading demonstrated in different ways how technology could be a tool for mathematical exploration. By reflecting on each and every reading in the course, I was demonstrating to myself and to my professor how each reading changed my viewpoint on technology. Reflecting challenged my misconceptions, made me think cognitively about technology and its possible uses, and allowed my professor to get insights into my thinking. As my TPACK developed through the readings, I became aware that technology should at least be a part of mathematics education, but I wasn’t sure exactly how to incorporate it. As a student of the mathematical sciences, I needed a few contextual examples to further realize how technology could be used in my future classroom.

**Learning from In-Service Teachers**

Our class had a lot of special guest speakers meet with us either face-to-face or in our online classroom on an almost weekly basis. These guest speakers were teachers currently in the field who regularly incorporated technology in their mathematics
classrooms. Some of the specific technologies these speakers used regularly included Mobi Boards, Microsoft PowerPoint, TI-Nspires, and Geometer’s Sketchpad. Essentially, the teachers demonstrated practical examples of technology integration in real mathematics classrooms, and the reactions that students had as a result. As I noted in my blog reflection from week 4 of the course, “...it’s hard for me to imagine some of our technologies used in the classroom, but after [listening to Mr. R talk] I began to see that technologies really are used.” A lot of our guest speakers emphasized that students can really become engaged with the technology.

Another of our speakers, Mr. S, taught for an online high school with a large student population. Since his classes were online, students from around the world were able to communicate with their teacher at any time (not just during “school hours”) and the teacher could often get instant feedback about how students were doing and who did not understand the material as well. It helped my fellow teacher candidates and me see practicing teachers using technology on a regular basis, and the impact it had on their teaching and the learning of their students.

One specific example of technology that was demonstrated in the course was the TI-Navigator system. Mr. B demonstrated this technology as he uses it regularly with his students in his classroom. The Navigator allows the teacher to connect student-operated TI-Nspires to his or her computer. The teacher can then view students’ individual work on their calculators and make sure students are on task or doing the work accurately. Furthermore, the teacher can create quizzes for students to answer through the TI technology, and receive immediate feedback from the student’s handheld devices, similar to how a clicker functions. This allows the teacher to see who exactly is struggling with specific topics, which leads to a quicker and more efficient response to instruction than is usually provided from traditional assessment methods. Mr. B showed us explicit examples of trigonometry lessons that he has taught with the TI-Navigator and TI-Nspires. Mr. B’s presentation, as well as the presentations of the other guest teachers, validated the use of technology in mathematics classrooms by showing my classmates and me how technology can help enhance student engagement and learning of mathematics.
**Overdependence on the Technology**

Despite the practical uses of technology that I was introduced to in my Technology in the Teaching of Secondary Mathematics course, I still realized that students could come to develop an overdependence on these technologies. It's not uncommon to see or hear stories about students relying so much on calculators that they can't compute $4$ divided by $4$, for example, without a calculator, when the computation should come intuitively if they truly understood the mathematics behind the problem. I expressed this fear of mine on multiple occasions to my professor through my weekly reflections. This one was from week 5: “[Mr. P] brought this out when he mentioned that his students made connections and discoveries when using the technology, but they couldn’t transfer these connections or make new ones back in the classroom.” It was reassuring to know that even teachers who actively use technology in the field also acknowledge that a disconnect might still exist between discoveries in the classroom and those in the computer lab. Mr. P’s comment made me realize that, while technology is useful, it lacks meaning without the classroom teacher. The classroom teacher must still function as a facilitator in order to establish those connections between the content and the technology, which further emphasizes the idea of TPACK and equality among technology, content, and pedagogy.

I have personally experienced an overdependence on technology. In a university level differential equations class, my classmates and I decided to use a homework help website known as Cramster. Our original motive for using Cramster was to double check our homework answers and make sure that we were doing the difficult work correctly. Things started out well, but as the semester went on, my peers and I came to rely on the answers Cramster provided. Eventually, I stopped doing the work for myself and just began to copy work and answers directly from Cramster to turn in for a grade. I would be in dire straits if Cramster didn’t have the answer worked out for a specific problem, because I lacked the content knowledge to complete my work without the technology. Through this personal experience, I became all too cognizant of the overdependence on technology that students can come to develop through an overexposure to technology.

**A Technology Integration Goal**
Now that I have seen how technology can be incorporated into the classroom and the advantages it can have on students, I now want to discover my own ways of including technology in my classroom to enhance student learning of mathematics. One of the technologies that I am fascinated with and want to integrate in my future classroom is the SMART Board technology. This technology allows teachers to program lessons in advance, click, drag, and write things with an interactive pen and whiteboard, and even prerecord lessons that substitute teachers can play whenever a teacher is not present. This allows student learning to continue even without the physical presence of the teacher. While this technology is expensive, I would still like to incorporate an interactive whiteboard (IWB) into my future classroom for several reasons. Many of these reasons were articulated by Bell (2002):

- “The interactive electronic whiteboard is a colorful tool. Research indicates that students respond to displays where color is employed, and marking can be customized both in the pen and in the highlighter features to display a number of different colors. Width of lines can also be adjusted to add flexible marking choices.” (#2)
- “The interactive whiteboard is an excellent tool for the constructivist educator. Author David Johassen coined the word “mindtool” to describe devices or applications which encourage use of technology to encourage critical thinking in students. Attributes of mindtools include ease of use, group interaction, ready availability of software to be used. Since the boards can be used with any software, they are extremely adaptable for numerous uses and do not require acquisition of additional software. Their creative use is limited only by the imaginations of teachers and students.” (#7)
- “The board can accommodate different learning styles. Tactile learners can benefit from touching and marking at the board, audio learners can have the class discussion, visual learners can see what is taking place as it develops at the board.” (#3)
- “One-computer classrooms can maximize the use of limited computer access by using the whiteboard. Students can work together with individuals contributing at the board, other participants at the computer, and the group as a whole discussing the activity. While it is true that acquiring the board and the projector is an expense, the use of this
set-up can be viewed as a cost-cutter when it makes it possible for one computer to serve multiple students.” (#6)

Since the SMART technology is so versatile and useful for mathematics teachers to use to actively engage every student, regardless of their individual learning styles, it is one of the most useful and versatile technological tools that I want to integrate into my future classroom.

**Personal Reflections**

Overall, my TPACK developed through personal exposure to and discussions about the technology and how it can impact my pedagogy. I was able to bridge the gap between my content knowledge, bolstered by the plethora of math courses I had taken, and my pedagogical knowledge, which was not as well rounded since I hadn’t taken many methods courses at the time. In other words, I knew the math but not so much how to teach the material in a way that students would understand and enjoy learning it, which is very important to my personal philosophy of education. I had taken an impressive assortment of high-level mathematics courses, including Differential Equations and Non-Euclidean Geometries, but I had only taken a couple methods courses where I learned how to teach the typical secondary level mathematics curriculum. The Technology in the Teaching of Secondary Mathematics course opened my eyes not only to the technology itself, but also how I could improve my pedagogy through the use of technologies.

An example of how technology bridged the content and pedagogical knowledge gap was the capstone Statistics lesson assignment. The assignment was to teach a specific Statistics topic and teach it to the class with essentially only one requirement—technology must be used as the main tool for teaching the topic. This assignment was designed as a final summative assessment of how the teacher candidates enrolled in the course utilized the technology in their teaching and how effectively the use of the technology aided the class in learning the material. In this assignment, candidates were assigned a random Statistics topic, but were allowed to utilize whichever technology they deemed appropriate for the task. I was given the topic of chi-square test of independence. I elected to use (in my opinion) the best statistical software available, Fathom, to present my lesson. The lesson was mostly lecture driven, but I was able to incorporate Fathom
TPACK FRAMEWORK

and use its functions to calculate two examples of chi-square tests of independence. Through these examples, I was able to point out specific requirements of the test as well as its limitations; for example, Fathom provided an error message in one of my examples because each cell in the frequency table did not have an expected value of at least 5, which is a requirement for the test to be statistically significant.

This was one of the many chances in the course where my classmates and I were able to develop our pedagogical, as well as our content knowledge, through the use of technology. I feel it's important to stress at this point that technology is a fantastic tool for combining the teacher's content knowledge with their knowledge of how to teach the material. It not only enhances the material itself, but it enhances the transference of that material from one individual to many. A lot of naysayers might argue that technology advocates push for only technology education, which could lead to the removal of teachers from the classroom. This is simply not true. As a result of the course, mostly through assignments like the Statistics lesson, I have come to realize that effective teachers do not rely solely on technology, just as they don't rely solely on lectures and rote work. Those teachers don't want to be replaced by anything, yet they still utilize technology as a means to engage their students in mathematical discussions and activities. Instead, they capitalize on their resources and combine them to create an enhanced learning environment for their students. One could put it this way: technology itself doesn't teach students, but effective teachers use technology to teach their students effectively.

Summary

By the end of the semester, I had been exposed to more mathematical technologies than I knew existed, heard from individuals in the field who use technology in their classrooms consistently, and learned ways to integrate technology into my future classroom to extend student learning and understanding. I always thought I would never use technology in my classroom, and I thought that technology wouldn't be all that useful for students. However, I have now seen both sides of the issue of technology. I see now how technology can enrich student's mathematics experience and help them see different mathematical representations of concepts. I understand how easy it is to become
overwhelmed by technology and disregard its usefulness, especially for teachers who have educated students for years without technology.

However, I think in this changing world where technology is becoming used in virtually every field, it is important for teachers to keep in mind one thing when considering using technology in their classrooms: in the end, what is best for the students’ overall learning experience? Based on my experience in this course, I would recommend for anyone interested in enriching their own teaching to help their students that they start researching how to use technology in the classroom. Use every available resource! It would be a good idea to start with Mishra and Koehler’s articles (2006 and 2009) to learn about the TPACK construct. From there, one should read articles by professionals in the field that use technology in their classrooms on a regular basis, and keep a journal or a blog of reactions to these readings. Finally, I would encourage teachers to communicate with one another and share ideas on how to incorporate various technologies in their classrooms and how each benefits the students in various ways. Through constant reading, reflection, and collaboration with those already integrating technology in their classroom, teachers all across the world can improve their own teaching and further enhance their students’ learning of mathematics.

I would personally encourage and challenge all teachers in the field to at the very least branch out and try new methods of teaching, with particular emphasis on technology. I understand that it is difficult to change one’s ways especially after many years of teaching; in the end however, education is not about how comfortable the classroom teacher feels teaching the same way they have taught for thirty years, but is more about how to best inspire, engage, and teach the students. Teachers should “think outside the box” and actively search out technologies that can aid their teaching through any means.

References


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