

Evolution of Preparing Preservice and Inservice Teachers for Teaching Mathematics and Science With Appropriate Technologies

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Abstract: Preservice and inservice teacher education programs have recently been directed toward the idea of developing the knowledge teachers need for teaching their content with technology – technological pedagogical content knowledge or TPCK. The challenge is to understand the nature of TPCK. During the last five years, more in depth analyses of the TPCK framework has been undertaken. Substantial qualitative differences in the preservice and inservice science and mathematics teachers' TPCK have resulted in proposal for five incrementally increasing levels of TPCK: recognizing, accepting, adapting, exploring and advancing. A pooled data analysis of multiple and varied inservice science and mathematics teacher education programs in developing their TPCK has extended the descriptions for each of the levels with the hope of clarifying the complexity of TPCK and providing guidance for teacher education programs in establishing learning experiences that support teachers in developing their TPCK.

Beginning with 1980s, calculator and computer technologies became accessible for educational activities in elementary and secondary schools. These technologies were quickly recognized as bringing new and more powerful capabilities for doing mathematics and science. Of course a myriad of questions were raised about what mathematics and science might students do with the technologies. But, other questions were raised as serious concerns for teacher preparation programs. What knowledge do teachers need to teach mathematics or science with appropriate technologies? Does knowledge of the mathematics or science automatically include knowledge of incorporating the technologies in teaching and learning? How is this knowledge developed? Is learning about the capabilities of the technologies sufficient for developing the knowledge needed for applying these technologies for learning in mathematics or science?

Developing Teacher Knowledge: A First Approach

With the initial acceptance of computer technologies for education, the understanding of the knowledge teachers needed for teaching with appropriate technologies implied that knowledge of the technologies and their capabilities was sufficient for classroom application. The notion seemed to be that a computer course in a teacher preparation program provided the preservice teachers with the necessary knowledge to integrate various computer technologies in their content areas. Early in the

80s BASIC (followed by Logo) programming provided preservice teachers with experiences with computer technology and its potential. Problem solving through programming was considered closely linked to mathematical and scientific thinking and processes. Thus, the belief was that the preservice teachers would gain the necessary knowledge and skills for integrating computers technologies in their instruction in science and mathematics.

As computer software advanced, applications such as word processors, spreadsheets and databases, shifted the curriculum in the one computer course to engaging these newer applications as productivity tools – for both the teacher and the students. Soon, the Internet emerged as a technology for consideration in preparing preservice teachers to teach mathematics and science. This evolution of the technology course emphasized a combination of the various applications (particularly spreadsheets), creating webpages and using the web as a research resource (in addition to school libraries). As the technological capabilities expanded, graphing calculators and spreadsheets were considered as having capabilities for exploring both mathematical and scientific ideas. After all, science and industry increasingly used hand-held, real-time data collection devices capable of measuring, storing, and analyzing the data began impacting the types of technologies that might be available in science and mathematics classrooms. What if students were provided with various sensors (temperature, pH, microphones and motion detectors) to gather real time data to engage students in scientific inquiry or mathematical problem solving research projects? The handheld devices connected with calculators or computers provided features for collecting, analyzing data and communicating results through graphical representations. In many cases, the capabilities opened up new avenues for learning and thinking about mathematical and scientific ideas in a more visual, natural manner. Even with the incorporation of all the newer technologies and encouraging the integration of these technologies in science and mathematics instruction during the teacher preparation programs, little evidence existed of the incorporation of technologies as tools for learning of science and mathematics in student teaching or in the following teaching positions.

By 1997, the preservice science and mathematics teacher preparation program at Oregon State University envisioned a different approach to the single technology course. Influenced by the challenge for developing the preservice teachers' pedagogical content knowledge (PCK), the faculty redesigned the entire teacher preparation program to more directly influence the teaching of science or mathematics with technologies. The faculty added the capstone requirement that the preservice teachers must teach a unit of at least three consecutive lessons during student teaching with technology and that the lessons must engage the students in hands on activities with the technologies. To support this new requirement, the program integrated methods courses throughout the program with a focus on the development of PCK accompanied by multiple technology methods courses directed toward guiding them in developing the technology unit and lessons for their student teaching. These courses focused students on science/mathematics instruction that maintained essential dimensions of science literacy and mathematics problem solving in four primary areas: science/mathematics (1) as a way of thinking, (2) as a way of investigating, (3) as a body of knowledge, and (4) and its interaction with technology and society (Chiappetta & Koballa, 2002; National Council of Teachers of Mathematics (NCTM), 2000). Since access to sufficient handheld technologies was a potential barrier,

the program provided classroom sets of graphing calculators as well as classroom sets of real-time data collection devices connected to calculators and including access to multiple probes including temperature, pH, and motion detection.

In 2000, a yearlong qualitative study of the students' knowledge development for integrating technology in teaching through this revised program was conducted, including in depth case studies of the work of the preservice mathematics and science teachers' PCK development with respect to integrating technology. Niess (2005) found that extending Grossman's (1989, 1991) four central components of pedagogical content knowledge (PCK) aided in understanding and describing the knowledge and beliefs that science and mathematics preservice teachers demonstrated for integrating technology, which at that time, she referred to a technology PCK, or TPCK. These central components of TPCK were further described as:

1. An overarching conception about the purposes for incorporating technology in teaching mathematics or science.
 - This conception is what the teacher knows and believes about the nature of mathematics/science, what is important for students to learn, and how technology supports learning mathematics/science. These foundations of the teacher's knowledge and beliefs about teaching mathematics/science with technology serve as a basis for their decisions about classroom instruction (objective, strategies, assignments, curriculum and text, and evaluation of student learning).
2. Knowledge of students' understandings, thinking, and learning in mathematics/science with technology.
 - In this area, the teacher relies on and operates from knowledge about how students learn mathematics/science with technologies and believes that technologies are useful in learning appropriate mathematics/science.
3. Knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics/science.
 - With respect to the curriculum, the teacher discusses and implements various technologies available for teaching particular topics and how the topics and ideas in a technology-enhanced environment with concern for how the activities are organized, scaffolded, structured, and assessed throughout the curriculum.
4. Knowledge of instructional strategies and representations for teaching and learning mathematics/science with technologies.
 - With respect to teaching and learning, the teacher adapts mathematical/scientific representations with technologies in multiple ways to meet specific instructional goals and the needs of the breadth of learners in the class.

The conclusions from this work suggested that preservice science and mathematics teachers be engaged in reconsidering their subject matter content and the impact of technology on the development of that subject itself as well as on teaching and learning that subject. The results challenged the assumption that in depth knowledge in the content area such as mathematics or science was sufficient for teaching that content with technology. The results challenged the assumption that developing PCK with no

attention to teaching with technology was sufficient for learning to teach with technology was also challenged. Using Shreiter and Ammon's (1989) argument, preservice teachers' adaptation of new instructional practices integrating appropriate technologies to support learning must be a process of assimilation and accommodation resulting in changes in their thinking and personal experiences. Developing TPCK was posed as a "constructive and iterative" process where preservice teachers needed to reflect on and carefully revise multiple experiences and events for teaching their content with appropriate technologies based on their "existing knowledge, beliefs, and dispositions" (Borko & Putnam, 1996). In essence, teacher preparation programs need to attend to the knowledge, beliefs and dispositions that preservice teachers brought to the programs if the programs are to guide the development of TPCK.

Developing Teacher Knowledge: Including Inservice Teacher Preparation

Around 2003, communication with multiple researchers throughout the nation advanced the notion of technological pedagogical content knowledge (TPCK) as defining that body of knowledge that teachers needed for teaching with and about technology in their assigned subject area (such as mathematics or science) and grade levels. TPCK was depicted as the interconnection and intersection of content, pedagogy (teaching and student learning), and technology (Margerum-Leys and Marx, 2002; Mishra, and Koehler, 2006; Niess, 2005; Pierson, 2001; Zhao, 2003). From this perspective, TPCK was viewed as more than a set of multiple domains of knowledge and skills that teachers needed for teaching their students particular subjects at specific grade levels. TPCK was described as a way of thinking that integrated the multiple domains of knowledge – content, technology and pedagogy.

Unpacking this conception of the knowledge for teachers need began with the understanding that knowledge is "the amount of information necessary to function and achieve goals; the capacity to make information from data and to transform it into useful and meaningful information; the capacity with which one thinks creatively, interprets and acts; and an attitude that makes people want to think, interpret and act" (uit Beijerse, 2000). Continued investigations served to sharpen the thinking about TPCK and the directions for continued research. Shavelson et al. (2003) delineated various ways of knowing: *declarative* (knowing that, including definitions, terms, facts, and descriptions), *procedural* (knowing how that refers to sequences of steps to complete a task or subtask), *schematic* (knowing why by drawing on both declarative and procedural knowledge, such as principles and mental models), and *strategic* (knowing when and where to use domain-specific knowledge and strategies, such as planning and problem solving together with monitoring progress towards a goal). The vision of TPCK emerged as teachers' strategic way of knowing. Teachers need to be able to organize, implement, critique results and abstract plans for specific science and mathematics content and student needs when integrating appropriate technologies.

Since many teachers have not been taught their content with the newer technologies, the notion of engaging the development of TPCK was raised as critical for both preservice and inservice teachers. Questions focused on inservice teacher preparation helped in the expansion of this knowledge of TPCK. What type of program would best serve the development of this strategic knowledge and strategies for teaching

mathematics and science with appropriate technologies for inservice teachers? The goal must be to guide the development of science and mathematics teacher's TPCK by engaging them in thinking strategically in planning, organizing, implementing, critiquing results and abstracting plans for specific mathematics content and student needs. But what type of program is needed and what duration is necessary for the development of TPCK?

Besides this concern for developing inservice teachers' TPCK, differences had been observed in the preservice teachers' actions when learning to teach mathematics and science with various technologies (Niess, 2005). Clearly, neither inservice nor preservice teachers demonstrate that they either have or do not have TPCK for teaching their content with technology. They differ in their actions with respect to each of the four components as they are confronted with whether to accept or reject the use of various technologies in teaching mathematics or science. These differences are surely a function of their knowledge of the content, their knowledge of the particular technologies, and their knowledge of pedagogy (teaching and learning).

Everett Rogers (1995) identified potential differences in his discussion of innovators when working with technological innovations much as teachers are when considering teaching with technologies. He envisioned a five-step process in the ultimate decision of whether to accept or reject a particular innovation such as teaching mathematics and science with spreadsheets. This five-step process provided a beginning framework for considering the teachers' development of TPCK focused on teaching mathematics and science with technologies:

1. *Knowledge* where teachers become aware of integrating specific technologies with learning mathematics and science and have some idea of how that functions.
2. *Persuasion* where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics and science with specific technologies.
3. *Decision* where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics and science with specific technologies.
4. *Implementation* where teachers actively integrate teaching and learning of mathematics and science with specific technologies.
5. *Confirmation* where teachers evaluate the results of the decision to integrate teaching and learning mathematics and science with specific technologies.

Certainly, teachers' development of TPCK for teaching mathematics and science with technologies must be considered a developmental process. Inservice professional development programs focused on developing TPCK must establish some way to think about the teachers' developing TPCK. These teachers are confronting an innovation – an innovation that integrates a new technology tool, new teaching and learning strategies, and revision of how they know their subject matter content as a result of the availability of the new technology.

With this understanding, the design of a professional development program for supporting inservice science and mathematics teachers for teaching with spreadsheet commenced. For both mathematics and science teachers, spreadsheets are often indicated as valuable learning tools. Sidebars in the textbooks suggest incorporating spreadsheets.

Yet, most inservice science and mathematics teachers are unfamiliar with the basic features of spreadsheets; more importantly, they have not learned their science or mathematics with spreadsheets. They are clearly novices when it comes to using spreadsheets as learning tools in mathematics and science.

Thus, when thinking about a professional development program to support them, the design of the program was focused on ways to guide the teachers' development of TPCK, recognizing and planning for their progression through levels of acceptance and implementation. The challenge was to describe these differences and how they influenced teachers' growth and development in TPCK for teaching their content in a technology-enhanced curriculum. This program design also launched a plan to identify and propose a descriptive model for analyzing teachers' TPCK development. It was envisioned that such a model would eventually aid educators in (1) assessing teachers' progress in meeting the needs of their students in technology-enhanced classroom environments, (2) assessing initial and extended teacher education programs, and (3) educational accreditation programs, such as National Council for the Accreditation of Teacher Education (NCATE), to clarify directions for improving all teacher education programs.

Early studies (Niess et al., 2006) on professional development inservice education directed at developing teachers' TPCK preparing them for teaching mathematics and science with spreadsheets identified and described five levels (similar to those of Rogers, 1995) of teachers' developing TPCK for teaching mathematics with spreadsheets. Their initial descriptions were described as:

1. *Recognizing* (knowledge) where teachers are able to use spreadsheets and recognize alignment of spreadsheets with mathematics and science content.
2. *Accepting* (persuasion) where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics and science with spreadsheets.
3. *Adapting* (decision) where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics and science with spreadsheets.
4. *Exploring* (implementation) where teachers actively integrate teaching and learning of mathematics and science with spreadsheets.
5. *Advancing* (confirmation) where teachers evaluate the results of the decision to integrate teaching and learning mathematics and science with spreadsheets.

Given this beginning, the various inservice programs were designed to align the model with the four central components of TPCK that Niess had used in describing TPCK. Examples of the inservice programs over the period of 2003-2007 focused on improving teachers' TPCK including:

- A four week, 30-hour summer program (2003, 2004, 2005) focused on learning about spreadsheets, scaffolding mathematics lessons to teach with and about spreadsheets, practice teaching with their peers and with small groups of school-aged students, reflecting on teaching, and preparing plans to teach during the following year. Teachers in the 2005 program were involved in follow-up mentoring as they implemented and revised their ideas during the academic year.

- A one week, 30-hour summer program (2006) focused on learning about spreadsheets with an emphasis on scaffolding ideas for teaching in grade level curricula, mathematics or science. Teachers were involved in follow-up mentoring as they implemented and revised their ideas when teaching during the academic year.
- A two week, 30-hour summer program (2007) focused on learning about spreadsheets, scaffolding mathematics and science lessons to teach with and about spreadsheets, practice teaching with a summer class of middle school students, reflecting on teaching and preparing plans to teach in mathematics or science classes during the following year. Teachers were involved in follow-up mentoring as they implemented and revised their ideas when teaching during the academic year.

The TPCK levels for all teachers in the programs were identified using the five levels proposed through the research by Niess, et al. (2006). Individual, in-depth descriptions for all teachers in each program were developed, identifying their content area knowledge, beliefs and dispositions, teaching preparation and implementations, their instructional strategies, their thinking before, during, and after teaching with spreadsheets, and their knowledge of student thinking and learning with specific technologies. The data for these descriptions included background questionnaires, daily journal prompts during summer program, pre- and post-attitude surveys, class assignments (resources, and lesson plans), observations of teaching (during the summer and during their school-based teaching), and videotapes and interviews before and after teaching in their own classrooms. The TPCK lens that Niess (2005) used in extending Grossman's central components of PCK was used in framing the extended descriptions. These in-depth descriptions were developed through triangulation of the data and analyzed by TPCK level resulting in the following extended descriptions that also added sample teacher comments to illustrate the level. These extended descriptions are provided only as examples to frame the levels rather than as check-off items for the particular levels.

1. Recognizing

- Recognizes mathematics/science ideas displayed with the technology.
- Views technology activities as focused on learning about the technology within a mathematics/science context as a tool that does the mathematics /science rather than teaching the mathematics/science.
- Knowledge and beliefs about learning and teaching mathematics/science describes mathematics/science as a subject learned through memorization of rules, algorithms and procedures without the use of technologies.
- Retains fundamental beliefs about how students learn mathematics/science.
- Motivation for exploring, experimenting and practicing integrating technologies in learning mathematics/science is challenged by beliefs about how students learn mathematics/science.
- Resists consideration of changes in the curriculum to integrate technology without further investigation about the technology.
- Instructional strategies for teaching mathematics/science based on teacher-directed lectures followed by individual student practice and repetition to solidify ideas.

Teacher comment:

The idea of organizing the information to help them solve math problems is a key to helping students learn math. Another feature that is difficult to learn in its intricacies but easy to start with is graphing. The graphical representation of spreadsheet data is very helpful especially for the visual learners in the class... I can see a student using spreadsheet skills to help them solve a mathematical problem if they already understand the underlying mathematical concepts. But I can see only limited, observational understanding being developed through their use.

Spreadsheets will allow me to teach concepts using much larger data sets than doing analysis by hand. This allows for better results from experiments and more possibility of problems relating to 'the real world

2. *Accepting*

- Accepts the idea that some technologies can be useful tools for teaching and learning mathematics/science.
- Concerns about:
 - Students' attention to and learning appropriate mathematics/science being diverted to a focus on the technology in the activities
 - Students' thinking in mathematics/science when the technology is used as a tool for exploring the mathematics/science
 - Technology classroom access and management
 - The need to teach about the technology as taking away time for teaching mathematics/science
- Mimics mathematics/science curricular ideas for incorporating the technologies that were experienced in the professional development.
- More apt to accept the technology as a teaching tool than a learning tool.
- Expresses desire but demonstrates difficulty in identifying topics in own curriculum for including technology as a tool.
- Tightly manages and orchestrates instruction with technology with the focus on technology in first lesson and the focus on mathematics/science in subsequent lessons after students have sufficient knowledge and skill with the technology.

Teacher comment:

My overall impression of using the spreadsheets in lessons and trying to integrate them with the mathematical concepts is that the students have a very difficult time learning the mathematical concepts when they are attempting to learn about using spreadsheets at the same time. The mechanics of producing the spreadsheets overshadows the mathematical concepts for many of the students. The only ones which seemed successful mastering both were the students that were fairly competent with spreadsheets prior to using them in my class.

I think students can use the graphing abilities of Excel to solve science problems quite easily. It is relatively easy to learn how to turn raw data from the spreadsheet into graphs. This seems to result in students feeling successful and engaging them better than graphing on paper

3. *Adapting*

- Recognizes some benefits of incorporating technology as a tool for teaching and learning the mathematics/science curriculum.
- Discusses desire to explore, experiment and practice integrating technologies as mathematics/science learning and teaching tools.
- Considers the technology as a tool to enhance a mathematics/science lesson, primarily as a means of providing students with a new way to approach the mathematics/science.
- Thinks of the technology as enhancing mathematics/science ideas that students have previously learned prior to using the technology.
- Expresses questions about student thinking with the technology as a tool in learning mathematics/science.
- Mimics the professional development activities with the technologies but does attempt to adapt lessons for his/her mathematics/science classes.
- Actions for implementing technologies in teaching mathematics/science are restricted by the challenges/barriers for teaching/learning with technologies.
- Instructional strategies with technologies are primarily deductive, teacher-directed in order to maintain control of the how the activity progresses.

Teachers' comments:

Overall, I thought the experience of using Excel for teaching math concepts was worthwhile, both for myself as a teacher and for the students. They were able to see the math concepts we were working on applied in a real problem-solving environment, they felt successful when they applied those concepts in a spreadsheet and got a physical result (immediate feedback), and I was able to monitor their progress at a glance, which is not always obvious when they are working with pencil and paper.

The number one barrier I envision would be my own limited abilities in using spreadsheets. While I am teaching the students to use spreadsheets, I will also be learning as I go. Over time as I become more familiar with the programs this won't be as much of a problem.

4. *Exploring*

- Motivated to explore, experiment and practice integrating technologies as mathematics/science learning and teaching tools.
- Accepts technologies as tools for learning and teaching specific topics in the mathematics/science curriculum.

- Plans, implements, and reflects on teaching and learning in the implementations with concern for guiding students in understanding mathematics/science using the technology as a tool.
- Recognizes challenges for teaching mathematics/science with technologies but willingly explores strategies and ideas for minimizing the impact of the challenges.
- Explores ideas for placing technology in a more integral role for the development of the mathematics/science that students are learning.
- Tentative willingness to engage students in explorations of mathematics/science with the technology tool where the teacher is in role of guide rather than director of the exploration.
- Explores various instructional strategies (including both deductive and inductive strategies) with technologies to engage students in thinking about the mathematics/science.
- Manages technology-enhanced activities towards directing student engagement in learning the mathematics/science.
- Continues to learn and explore ideas for teaching and learning mathematics/science emphasizing the one technology (such as spreadsheets).

Teachers' comments:

I was somewhat anxious to introduce spreadsheets into my curriculum. It was a new concept for me and I wasn't sure how my students would adapt to it. I was also unsure as to how the marriage of spreadsheets and mathematics would look in my classroom. After the first lesson with my students, I knew I had nothing to worry about. Although none of them had ever used spreadsheets before, most had used the computer before and were very fluent with this technology. By keeping the math skills at a minimum in the beginning, students were able to focus more intently on learning the skills necessary for spreadsheets which later translated into being able to integrate more difficult math concepts with Excel.

Even students who had made it very clear that they did not especially enjoy math, found themselves very involved in their learning when spreadsheets were integrated. A second success was seen, as we were able to look more closely at certain topics that required graphing. By being able to quickly change variables that had an immediate effect on the graph, gave students a first-hand look at how each of the parts of the equations play a role. If students had to graph by hand, there would not have been nearly the amount of time and attention given to the changes of variables.

Guiding students to learn spreadsheets throughout the year is a challenge given limited computer availability. I think the key in my particular case to not require too much, too fast. My plan to take much smaller steps and provide more scaffolding so as not to turn the students off initially

5. *Advancing*

- Sustained motivation and carry through in exploring, experimenting and practicing integrating technologies as mathematics/science learning and teaching tools.
- Active, consistent acceptance of technologies as tools for learning and teaching mathematics/science in ways that accurately translate mathematical concepts and processes into forms understandable by students.
- Plans, implements, and reflects on teaching and learning in the implementations with concern and personal conviction for student thinking and understanding of the mathematics/science to be enhanced through integration of the various technologies.
- Recognizes challenges in teaching with technology and resolves the challenges through extended planning and preparation for maximizing the use of available resources and tools.
- Technology-integration is integral (rather than in addition) to development of the mathematics/science students are learning.
- Engages students in high-level thinking activities (such as project-based and problem solving and decision making activities) for learning mathematics/science using the technology as a learning tool.
- Adapts from a breadth of instructional strategies (including both deductive and inductive strategies) with technologies to engage students in thinking about the mathematics/science.
- Manages technology-enhanced activities in ways that maintains student engagement in learning the mathematics/science.
- Continues to learn and explore ideas for teaching and learning mathematics/science with multiple technologies.

Teachers' comments:

I think that many students will feel like they are getting out of doing math by making the computer do it! Little do they know that they actually have to do much higher-level math and higher-level thinking and letting the computer do the basic arithmetic. Also anytime students get to interact with technology, they are engaged. Spreadsheets make students responsible for their learning while keeping them accountable. It's a relatively easy way to engage students in mathematics learning.

Another thing that I think worked out well was you know, the tendency for us to give students answers and I've been really trying to watch myself on that, knowing that if I just give answers to somebody, I haven't really had them learn, I've only helped them memorize. So, I had to restrain myself a few times today just giving people the formulas and stuff like that.

Conclusion

Preparing teachers to teach in the 21st century has been significantly affected by the emergence of more and more powerful computer technologies. Today, preservice students come to their teacher preparation programs without having learned their mathematics and science content with the technologies as learning tools throughout their K-12 education. They lack some important learning experiences. However, the students they will be teaching will enter the classrooms with more understanding and facility with the emerging technologies. The question is how they will be taught to use these emerging technologies as mathematics and science learning tools if their teachers have not developed the level of TPCK they need for teaching their content with appropriate technologies. The recognition of TPCK has raised the awareness that if teachers plan to teach with appropriate technologies, they need to develop a strategic way of thinking that integrates their knowledge of the content, the technologies and the pedagogy. This line of research has focused on the development of a more in depth understanding of the nature of this knowledge for mathematics and science teachers. Developmental levels of TPCK have been proposed but should not be considered as necessarily linear. With each new technology, the teachers must reconsider whether to accept the technology as appropriate for teaching and learning in mathematics. Certainly, these teachers will be able to rely on their previous knowledge as support in developing appropriate curricular and instructional ideas. They will be able to rely on their previous work with students with other technologies as they consider their students' understandings, thinking, and learning in mathematics and science with this new technology. They will need to rely on their understanding of the nature of the content in order to determine if the technology is appropriate for supporting that content. In the process, their own understanding of the content will evolve and develop. With multiple experiences, the integration of their knowledge of the content, technology and pedagogy will continue to evolve and develop. Recognition of the iterative nature in the development of TPCK is essential in the continued development of preservice and inservice teacher preparation programs for teaching mathematics and science. Just as the content of mathematics and science evolves, so does TPCK. Just as the content of teaching and learning evolves, so does TPCK. And, just as the content of technology evolves, so does TPCK. In fact the three content areas may in fact merge more and more as teachers' TPCK extends.

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