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INVESTIGATING TPACK: KNOWLEDGE GROWTH IN TEACHING WITH TECHNOLOGY

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ABSTRACT

Technological pedagogical and content knowledge (TPACK) presents a dynamic framework for describing teachers' knowledge required for designing, implementing, and evaluating curriculum and instruction with technology. TPACK strategic thinking includes knowing when, where, and how to use domain-specific knowledge and strategies for guiding students' learning with appropriate information and communication technologies. Multiple visual and verbal descriptions reflect evolving recognitions of teacher educators and educational researchers as they have struggled to respond to the challenges in describing and developing teachers' TPACK. This extensive reflection maps the historical acceptance of pedagogical content knowledge (PCK) with the emerging views of and challenges with TPACK. A review of empirical progress in the investigation of TPACK serves to illuminate potential insights, values, and challenges for directing future educational implementations designed to identify a teacher's learning trajectory in the development of a more robust and mature TPACK for supporting them in teaching with current and emerging technologies.

New and emerging digital technologies are more accessible for incorporation in educational programs with increased access and societal uses in day-to-day actions. Teachers are confronted with challenges and questions of how and when to incorporate such technologies for teaching and learning various subject matter topics. Rather than focusing on the features, affordances, and constraints

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of particular technologies, their attention has shifted to students' thinking, curriculum content, and pedagogical approaches within the context of learning with the new technologies.

This redirection exposes the importance of teachers' strategic thinking and actions with respect to integrating technologies as learning tools. Teacher educators are, therefore, confronted with redesigning their programs toward the development of the knowledge teachers need for rethinking how technologies might be integrated and acting upon their decisions. Teacher educators raise valid questions and concerns in the search for pre-service, in-service, and professional development experiences to more effectively reshape teachers' thinking and actions. What experiences and preparation are essential for developing the teacher knowledge for guiding learning in the various subject areas with new and more powerful digital technologies? Does a teacher's knowledge of subject matter automatically transfer to knowledge for incorporating appropriate technologies? Aside from learning about the capabilities of the technologies, what experiences do teachers need for teaching and learning with the technologies in various content areas?

Many questions are emerging as scholars have proposed a new view on teacher knowledge required for teaching in the 21st century. Technological pedagogical and content knowledge (TPACK) is a framework for thinking about the knowledge teachers need for making instructional decisions with respect to integrating digital technologies as learning tools. Teacher educators are expected to provide the necessary experiences required for developing the knowledge, skills, and dispositions that teachers need. Meanwhile, educational scholars and researchers are engaged in framing and clarifying this knowledge construct along with a search for answers to teacher educators' emerging questions and concerns. This article describes the evolution of TPACK as the knowledge teachers require and how the TPACK development mirrors the history of the development of the understanding and application of the parent construct-pedagogical content knowledge or PCK. Synthesis of early research efforts on the design of teacher education programs directed toward the knowledge development highlights current and emerging questions and challenges: What instructional methods provide necessary experiences for understanding and developing the knowledge for teaching needed for teaching with technologies? How is in-service teacher preparation different from that of pre-service teacher preparation with respect to developing TPACK? Since teachers have primarily learned in traditional educational systems, how are they prepared for teaching with technologies in online educational systems? How is the knowledge described in TPACK assessed? What is assessed within the TPACK framework? What research is important for accurately describing learning trajectories that support quality teaching and learning in the 21st century as digital technologies continue to emerge and impact what future citizens needs to know and be able to do?

TEACHER KNOWLEDGE FOR TEACHING WITH 21ST CENTURY TECHNOLOGIES

While teacher preparation programs struggled with engaging teachers in actively integrating appropriate technologies, a new framework for envisioning teacher knowledge has emerged. Recognizing the need for a broader perspective, numerous researchers have proposed thinking about the integration of technology, content, and pedagogy in much the same way that Shulman (1987) did when proposing PCK. Technological pedagogical content knowledge (TPCK) was proposed as the interconnection and intersection of content, pedagogy (teaching and student learning), and technology (Margerum-Leys & Marx, 2002; Mishra & Koehler, 2006; Niess, 2005; Pierson, 2001; Zhao, 2003). Over time the acronym of TPCK was recast as TPACK (pronounced "tee-pack") to redirect attention to the total package required for teaching—a package that integrates **t**echnology, **p**edagogy, **a**nd **c**ontent **k**nowledge (Niess, 2008b; Thompson & Mishra, 2007). TPACK is viewed as a dynamic framework describing the knowledge that teachers must rely on to design and implement curriculum and instruction while guiding their students' thinking and learning with digital technologies in various subjects.

Multiple graphics have been proposed to represent the essence of TPACK. An early visual image (see Figure 1) directed attention to the intersection of three disciplines—content, technology, and teaching and learning—as TPACK (Niess, 2006). Since the term "pedagogy" did not clearly represent the multiplicity of inputs to teaching and learning, the phrase "teaching and learning" was used to incorporate the knowledge of curriculum, learners, and schools along with pedagogy.

Koehler and Mishra (2008) revised the representation in their chapter in the *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators*. As shown in Figure 2, their revision highlights the seven components in the TPACK framework: content knowledge (C), pedagogical knowledge (P), technological knowledge (T), and the overlaps of these distinct knowledge bases as pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPACK). They also encircled the image within multiple disciplinary and other social and institutional contexts to convey the complexity of technology integration.

Doering, Veletsianos, and Scharber (2009) modified the Koehler and Mishra representation, as in Figure 3, to situate TPACK in an educational context incorporating the multiple knowledge domains. From this perspective, the educational context is an essential variable "in the way teachers' knowledge is *applied* and *used* in the classroom . . . both teaching knowledge and practice. In turn, teacher knowledge influences practice, and practice influences which types of knowledge are used more in the classroom" (Doering et al., 2009, p. 19).

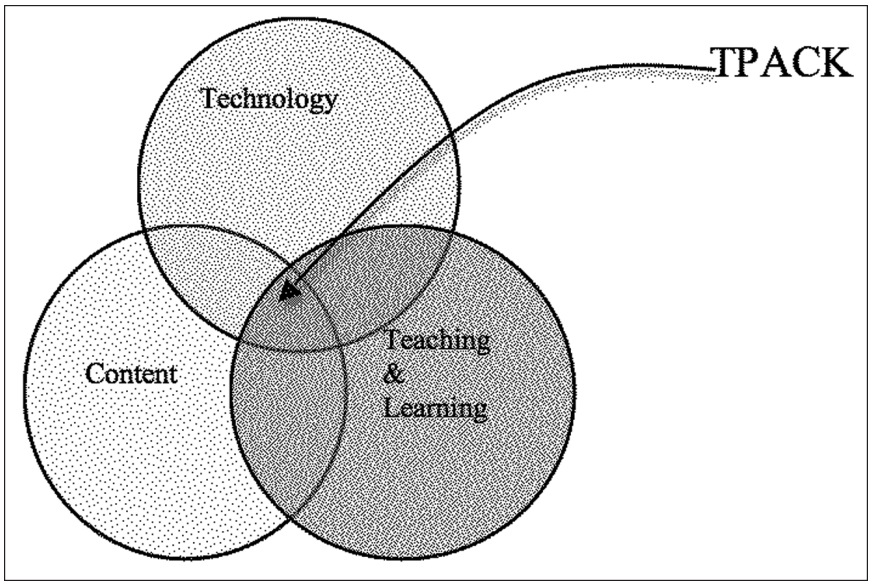

Figure 1. Niess (2006) model presents TPACK as the intersection of the knowledge domains that teachers need for teaching with technology.

Angeli and Valanides (2009) reframed a description through an interaction of five ellipses. While accepting the pedagogy and content domains, they renamed the technology domain as Information and Communication Technologies (ICT) to emphasize the type of technology considered in the model. They added two knowledge domains as a result of their research studies with in-service teachers: the knowledge of students and the knowledge of the context within which learning takes place. From their perspective, as teachers teach with ICT, they draw upon knowledge of students' content-related difficulties as well as the intricacies of the relevant context—what works and does not work in their classrooms—and how they believe they need to teach to facilitate students' learning.

These multiple visual representations for describing TPACK have been complicated with multiple ways in naming the construct. In my research, I initially called the construct "technology pedagogical content knowledge" hoping to emphasize the impact of technology on PCK (Niess, 2005). The construct was also referred to as "technological pedagogical content knowledge" (arguably a more grammatically correct version) or TPCK. TPCK was difficult to say and remember, resulting in more confusion. At a meeting of National Technology Leadership Institute in September 2007, the acronym was changed to TPACK (Niess, 2008b; Thompson & Mishra, 2007). However, the TPACK acronym has

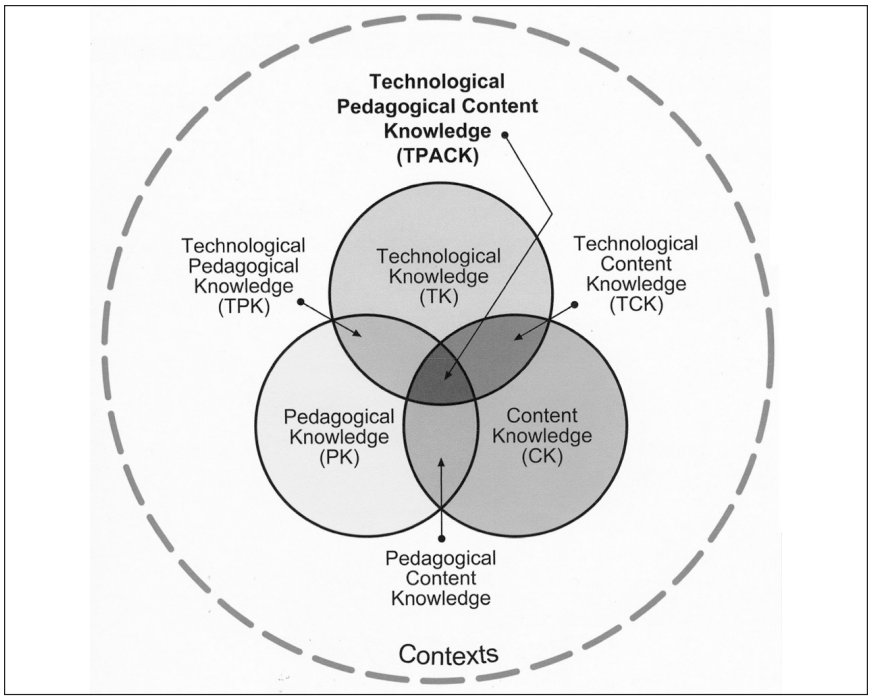

Figure 2. Koehler and Mishra (2008) TPACK model highlighting its knowledge components. (Permission from author granted)

been identified differently in many publications: Technological Pedagogical Content Knowledge; Technological, Pedagogical, and Content Knowledge; Technology, Pedagogy, and Content Knowledge; Information and Communication Technological Pedagogical Content Knowledge.

TPACK and PCK: Emergence Similarities

Why have the differences in both the visual and verbal descriptions of the proposed TPACK construct arisen? Recall the historical descriptions of the "parent" construct, PCK. An understanding of PCK emerged through discussions, research, and implementations in teacher preparation programs. As teacher educators and educational researchers struggled with acceptance and implementation of the PCK construct, various understandings were communicated. My institution claimed to prepare teachers with a PCK through the various courses and expectations for developing teacher knowledge. I was charged with describing the knowledge construct to the pre-service students (Niess, 2001). At that time, the literature often referred to five domains of knowledge that impacted

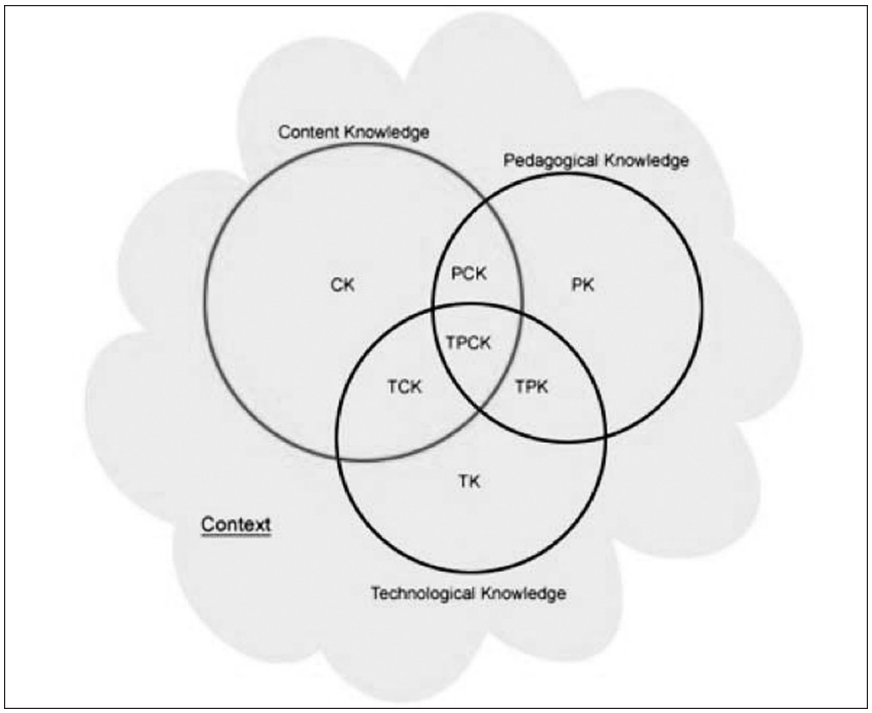

Figure 3. The Doering et al. (2009) TPACK model embedded in an educational context. (Permission from author granted)

PCK—subject matter, curriculum, pedagogy, learners, and schools. Much of the discussion at meetings and in the literature concerned the interaction of the five knowledge domains with each other and with the new construct of PCK. The five domains were represented through the image in Figure 4 to describe the framework upon which our teacher preparation program was redesigned. As with the TPACK struggle, an attempt was made to recognize the variables of the educational context, depicting five knowledge domains surrounding the PCK domain—learners, schools, subject matter, curriculum and pedagogy. The connecting lines were intended to indicate the forces pulling the five domains into an integrated knowledge structure called PCK.

While the image in Figure 4 described the multiple domains impacting PCK, additional images displayed the evolution of a teacher's knowledge into a more integrated knowledge structure (Figure 5). The idea was to emphasize the dynamic nature of the interaction among the different knowledge domains, highlighting how the experiences in the program were directed toward merging and integrating the knowledge domains. The teacher preparation experiences

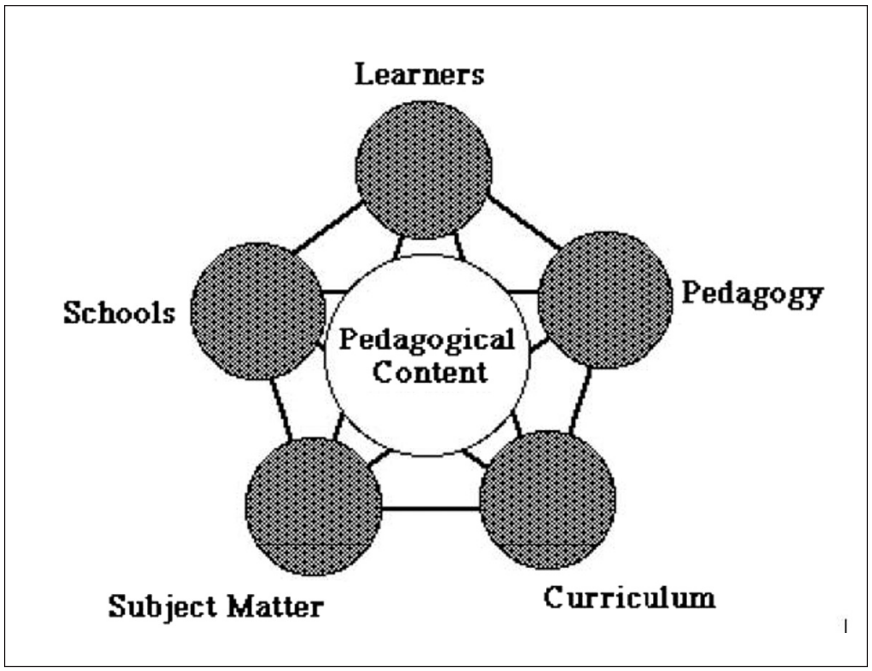

Figure 4. PCK visual of the relationship and interaction of multiple knowledge domains.

were designed to assist in the evolution toward a complex and integrated structure with no domain totally distinct or separate from the other, with the relative amount of overlap and interaction among the domains as constantly changing as the pre-service teachers made sense of and prioritized the multiple factors affecting student learning (Niess, 2001). With teaching experiences beyond the teacher preparation program, the lines connecting the domains were intentionally blurred to describe PCK as emerging as an amalgam of the domains, such that teachers' thinking and decision-making reflected the interaction and integration of the domains.

This portrayal was not unique among all teacher educators' attempts to describe PCK as a new way of thinking about knowledge growth in teaching. Cochran, DeRuiter, and King (1993) referred to the actions of teachers as *pedagogical content knowing* (PCKg); they described an action-oriented intersection of the knowledge of subject area, knowledge of students, pedagogical knowledge and knowledge of the environmental context as teachers engaged in planning, teaching, and assessing activities. They purposely used arrows between each of the domains to display the dynamic nature of PCKg as drawing upon the other domains of knowledge.

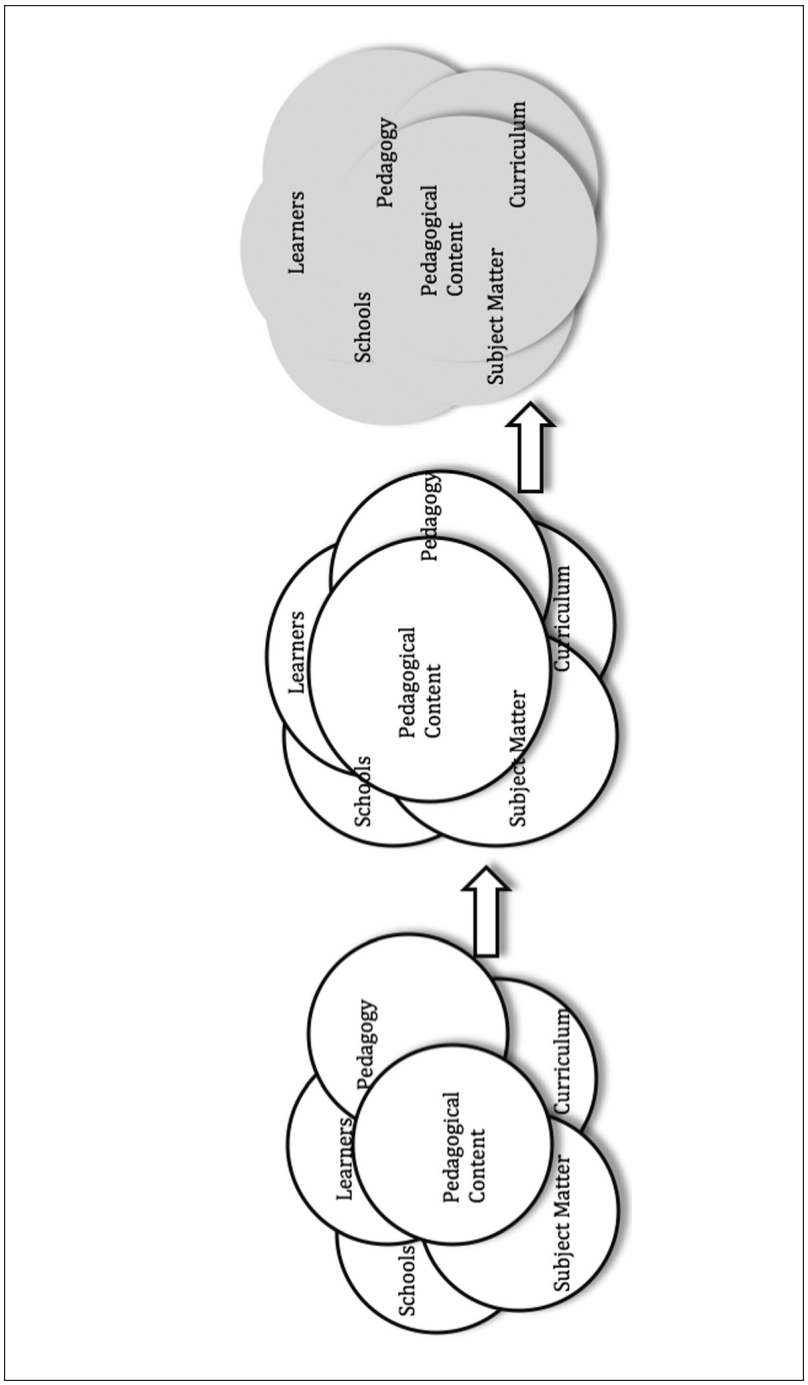

Figure 5. Evolution of PCK toward an integrated knowledge structure.

This succession of different characterizations for PCK is similar to the evolution of multiple representations of the knowledge construct called TPACK. The different visuals of PCK helped teacher educators in reconstructing their visions of developing the knowledge for teaching in the 1990s and beyond. Each of the TPACK representations has been an important aspect in the process of developing a more comprehensive understanding among the broader education and research communities.

TPACK Key Attributes

The various images and their perspectives have resulted in the identification of key attributes of TPACK. Doering et al. (2009) emphasized the dynamic nature of TPACK, an evolving and multi-faceted (rather than static) representation of teacher knowledge, as new technologies emerge for integration into particular content areas. Angeli and Valanides (2009) provided two important insights. First, they believed the use of the word "technology" was misleading, rephrasing it as Information and Communication Technologies (ICT). Second, they represented TPACK as "a tool invoked by its users to reconstruct the subject matter from the knowledge of the teacher into the content of instruction" (pp. 8-9). They suggested, "mere development of one or more of its knowledge bases does not guarantee and does not imply concurrent development of ICT-TPCK" (p. 14). The use of "technology pedagogical content knowledge" was purposeful in highlighting TPACK as an extension of PCK with the addition of intersection of the technology domain with the PCK intersection of content and pedagogy (Niess, 2005). The phrase "teaching and learning" rather than "pedagogy" highlighted the breadth and impact of pedagogical variables (Niess, 2005). Multiple models focused attention on the educational context within which teachers are asked to integrate technology (Angeli & Valanides, 2009; Doering et al., 2009; Koehler & Mishra, 2008). The descriptions of the interactions directed attention to teachers' thinking as concurrently drawing upon the multiple domains in the construct. Niess (2008a) framed TPACK strategic thinking as knowing when, where, and how to use domain-specific knowledge and strategies (Shavelson, Ruiz-Primo, Li, & Ayala, 2003) when guiding student learning with appropriate information and communication technologies.

Conceivably, at some future point, the attention will be redirected to PCK as the knowledge that teachers need for teaching where digital technologies are included among the many other technological resources teachers have for teaching. However, at this point teacher educators are confronted with a "wicked problem" (Rittel & Webber, 1973)—a problem they must recognize and respond to within the realm of teacher education in the 21st century. As Koehler and Mishra (2008) explained, integrating technologies in the classroom is, "a complex and ill-structured problem involving the convoluted interaction of multiple factors, with few hard and fast rules that apply across contexts and cases" (p. 10).

Information and communication technologies are increasingly emerging and impacting ways that society operates. Teachers are charged with preparing future citizens with new and emerging technologies. The problem is that today's teachers have not learned their content with these technologies. They do not have essential experiences in learning with these technologies nor have they been prepared to teach their content with these new and emerging technologies; they have not been prepared to engage in the strategic thinking for knowing when, where, and how to use domain-specific knowledge and strategies for teaching with the technologies. Today's teachers must utilize TPACK strategic thinking as they plan and prepare to guide students in exploring content topics with technologies. The wickedness of the problem is contained in this question: How and when do teachers develop this TPACK strategic thinking ability if they have not learned the content with these technologies?

TPACK AND RESEARCH DIRECTIONS

Educational researchers are obviously confronted with many potential research directions and questions when considering potential program designs that elicit learning trajectories in support of teachers developing a robust TPACK for teaching. What is a TPACK-based teacher preparation program? How do pre-service and in-service teachers develop TPACK? What are the essential experiences needed for integrating pedagogy, content, and technology within the educational contexts? How is a teacher's TPACK recognized? Are there different levels of TPACK? What is the effect on a teacher's TPACK as new technologies are introduced for incorporation in their curriculum? How is a teacher's TPACK assessed? Such questions challenge researchers as they attempt to clarify the TPACK construct.

Researchers are also confronted with a "wicked problem." Where should they begin? As Mishra and Koehler (2006) note, "while attempting to solve a wicked problem, the solution of one of its aspects may reveal or create another, even more complex problem" (p. 11). Careful attention must be paid to what is learned and what is questioned from the studies about TPACK to clarify and develop a more robust and mature understanding of the TPACK construct and what it means for preparing teachers to guide student learning with technologies. An examination of some current studies serves to illuminate potential insights, values, and challenges for research.

Methods for Developing TPACK

What instructional methods are useful in guiding teachers toward the development of a robust knowledge for teaching with technology? Roblyer and Doering (2010) promoted self-assessment as a first step for instructional decision-making where they reflected on their understandings and thinking about teaching with

technologies. Alternatively, Mishra, Koehler, Shin, Wolf, and DeSchryver (2010) proposed a learning-by-design trajectory to TPACK development through a spiraling of stages of more complex instructional design where TPACK reflection is at the end of the process. After explorations with micro-design problems followed by macro-design problems, teachers are prepared to reflect on pedagogy, technology, and content and their interrelationships when considering a specific difficult instructional problem. Other researchers offered content and technology-based approaches, such as instructional modeling (Niess, 2005), collaborative lesson studies (Groth, Spickler, Bergner, & Bardzell, 2009), and metacognitive exploration of TPACK emerging from curricula and technologies shifts (Hughes & Scharber, 2008). Others, such as Dawson (2007) and Pierson (2008), suggested TPACK as a focus for teachers' action research. Mouza and Wong (2009) proposed a TPACK-based case development strategy in which teachers learn from their practice. The challenge for teacher educators and researchers is to continue to investigate methods for integrating development of TPACK amid the other teacher preparation courses. The instructional methods, lesson planning, classroom management, and even student practicum experiences need to be re-envisioned with a recognition of the impact and influence of technologies as well as other teaching resources.

Angeli and Valanides (2009) investigated Technology Mapping (TM) and peer assessment learning experiences on the development of TPACK competency in the first and second year of the preparation of pre-service primary teachers. The lectures and laboratories focused on making "visible and explicit . . . interconnections among tool affordances, learners, content, and teaching strategies" (p. 27). While the lectures emphasized instructional design processes, students were engaged in TM activities in the laboratories where they mapped software affordances with content representations and pedagogical uses. In the TM activities, students were engaged in strategic thinking around integrating technologies in lessons as they designed their lessons after completing the TM activities. When they worked in their peer-assessment groups, the instructor directed their attention to researcher-identified ICT-TPCK criteria:

1. the identification of suitable topics to be taught with technology;
2. the identification of appropriate representations to transform content;
3. the identification of teaching strategies difficult to be implemented by traditional means;
4. the selection of appropriate tools and appropriate pedagogical uses of their affordances; and
5. the identification of appropriate integration strategies.

The value of the social exchanges among the students during the peer-assessment experiences was highlighted as needing further examination with the importance of the instruction on their thinking about teaching with technologies.

Given that in-service teachers have been teaching their content at the specific grade levels as multiple advancements in the information and communication technologies have occurred, their instruction in the development of TPACK must recognize and take advantage of a more advanced teacher knowledge gained through their teaching experiences. As indicated by Harris and Hofer (2009), in-service teachers need learning experiences in:

1. selecting and using learning activities and technologies in a more conscious, strategic, and varied manner;
2. instructional planning that is more student-centered, focusing on students' intellectual, rather than affective, engagement; and
3. making deliberate decisions for more judicious educational technology use.

They also recognized that the development of TPACK must be flexible and accommodating within the complete range of curricula and teaching approaches. As Mishra and Koehler (2006) stated:

> *There is no single technological solution that applies for every teacher, every course, or for every view of teaching*. Quality teaching requires developing a nuanced understanding of the complex relationship [among technology, content, and pedagogy], and using this understanding to develop appropriate, context-specific strategies and representations. (p. 1029)

Relying on this perspective, Harris and Hofer (2009) directed a 5-month study of experienced secondary social studies teachers' planning to incorporate appropriate technologies in their instructional plans. Through interviews, unit plans, and reflections on their planning, the researchers focused an investigation on the PCK, TPK, TCK, and TPACK components in the planning processes within the social studies curriculum. They noted that the teachers' planning priorities had been limited by their early teaching activities and that by the end of the program they had developed "a whole new toolbox" for teaching social studies, where the technologies served as tools for learning rather than simply incorporating technology "for the sake of technology." The key finding in this study was the importance of the curriculum content as the primary focus of the instruction while the "digital tools and resources to support different types of learning" are a secondary aspect for guiding the teachers in integrating appropriate technologies as learning tools.

The Harris and Hofer study raised important questions about guiding TPACK development within a content-specific context by focusing teachers' thinking toward the specific components. Since the teachers were experienced, presumably their PCK was more developed than that of pre-service teachers. How did the in-service teachers' beliefs about how the topics needed to be learned impact what they discussed about how students could learn in their revised plans? How might their thinking shift as they implement their ideas in their classes?

Grossman (1989, 1990, 1991) identified four components of PCK to focus the description and understanding of the knowledge needing development in teacher preparation programs:

1. an overarching conception of what it means to teach a particular subject matter context;
2. knowledge of instructional strategies and representations for teaching particular subject matter topics;
3. knowledge of students' understandings, thinking, and learning in specific content areas; and
4. knowledge of curriculum and curriculum materials with learning in specific subject matter contexts.

Niess (2005) rephrased these four components toward integrating technology when describing TPACK.

Given the extension of the four PCK components to TPACK components, the differences between PCK and TPACK in the Harris and Hofer study may be less identifiable for the experienced teachers. The question is whether reflections on PCK, TPK, TCK, and TPACK were merged such that they were no longer distinct when thinking about information and communication technologies. This challenge suggests that when investigating in-service teachers' attainment of TPACK, the evidence that researchers gather through teacher interviews may be addressing a refinement of their PCK. Or, were they reflecting on their TPACK as distinct from PCK? As a teacher's TPACK matures, is it a reflection of the maturation of PCK, much as was depicted in Figure 5? Researchers need to investigate whether such a conjecture is plausible.

TPACK and Pedagogical Strategies in Online Environments

Today's technological advancements have resulted in evolutions in potential educational environments where teachers are able to access continuing learning opportunities through online programs. Since most teachers have not learned content in online environments, they lack experiences in pedagogical strategies for adding online learning opportunities for their students. This conundrum presents another wicked problem for teachers, teacher educators, and researchers.

Doering, Veletsianos, and Scharber (2009) planned to enhance K-12 students' geographic literacy through an inquiry-based approach for solving authentic geographic problems using online geospatial technologies (such as Google Earth™). The online program contained multiple modules for directing inquiry-based geographic problem investigations. To assist the teachers unprepared for guiding students in online learning, the researchers provided a 1-day professional development workshop to introduce teachers to the learning modules and the concept of TPACK with respect to the technology (online learning environment with other geospatial technologies), pedagogy (problem-based to engage students

in higher-level thinking with the technology), and content (authentic geoscience problems related to the National Geography Standards). After completing the workshop, the teachers returned to their classrooms and taught three of the modules using three different pedagogical models.

Through the open-ended responses and interviews, all the teachers indicated that their knowledge of geography (the content) was enhanced as they engaged in learning about this particular online environment. The focus of the workshop on TPACK challenged them to reflect on and reconsider their instructional practices. The majority of the teachers responded that the professional development with online environments grounded in the TPACK emphasis improved their confidence of actually using such environments for teaching geoscience.

While the researchers designed their workshop to focus the teachers' meta-cognition on the separate domains of TPACK (technology, pedagogy, and content knowledge), depending "on the context of a situation and the various levels of knowledge a teacher has, certain domains of knowledge may be used more than others" (Doering et al., 2009, p. 19). The researchers concluded that

> . . . perhaps we should view professional development programs as an opportunity to bring areas of technology, pedagogy, and content knowledge together as one knowledge base. Rather than separating knowledge related to three areas, it may be more valuable to transform professional development programs into modern inventions aimed at enhancing the intersection of knowledge domains that guide effective teaching. (Doering et al., 2009, p. 16)

This conjecture needs clarification as it raises questions about the types of experiences that in-service teachers may need for enhancing their TPACK. What types of experiences enhance the TPACK intersection? What is the importance of content-specific learning experiences? Are experiences for teaching with the technology within the content-specific experiences needed for establishing a more integrated knowledge?

Assessing Teacher Knowledge

Doering et al. (2009) noted the importance of measuring changes in teachers' TPACK as they are engaged in professional development and educational experiences to more accurately determine the impact of the experiences. However, measuring changes in TPACK assumes a well-defined construct.

Niess, Lee, and Sadri (2007) described a developmental progression in TPACK resulting from observations over 3 years of in-service professional development. Five levels were proposed:

1. *Recognizing* (knowledge) where teachers are able to use the technology and recognize the alignment of the technology with subject matter content, yet do not integrate the technology in teaching and learning of the content.

2. *Accepting* (persuasion) where teachers form a favorable or unfavorable attitude toward teaching and learning specific content topics with an appropriate technology.
3. *Adapting* (decision) where teachers engage in activities that lead to a choice to adopt or reject teaching and learning specific content topics with an appropriate technology.
4. *Exploring* (implementation) where teachers actively integrate teaching and learning of specific content topics with an appropriate technology.
5. *Advancing* (confirmation) where teachers redesign the curricula and evaluate the results of the decision to integrate teaching and learning specific content topics with an appropriate technology.

Recognition of levels of knowledge progression provides further clarification. Assessment focused on such clarifications calls for assessments that validly and reliably identify teachers' growth and development through specific educational expectations.

Schmidt, Baran, Thompson, Koehler, Mishra, and Shin (2009) undertook the task of developing and validating an instrument to gather pre-service teachers' self-assessment of their TPACK and related knowledge domains as described in the model in Figure 2. Their instrument provided a starting point for examining and supporting pre-service teachers' development of TPACK. A quantitative factor analyses of the admittedly small sample's responses to 75 items resulted in a reduction to a 47-item instrument that was judged to have internal consistency reliability. The study provided an important beginning in the development of reliable instruments for assessing TPACK. Further refinements are needed to include a larger sample size and validation through classroom observation procedures in order for the instrument to be used for elementary pre-service teachers' self-assessments of developing TPACK. The design of the instrument focused on the multiple content areas that pre-service teachers were preparing to teach (i.e., literacy, mathematics, science, social studies), where the items were framed around each of the separate content areas. A question arises as to the interdisciplinary thinking that may be an important aspect of the pre-service teachers' TPACK when teaching with technology.

When thinking about assessing TPACK, another important question is directed toward who is completing the assessment. Doering et al. (2009) had in-service teachers judge their TPACK based on their understanding of TPACK. Schmidt et al. (2009) developed a self-assessment survey based on pre-service teachers' assessment of statements judged to incorporate the related domains in TPACK. Harris, Grandgenett, and Hofer (2010) developed a valid and reliable rubric for teacher educators to assess teaching artifacts such as lesson plans and are engaged in developing an observation instrument for assessing teachers' TPACK while teaching. The efforts provide a beginning for assessing TPACK but future research must identify ways that teacher educators can measure the knowledge

development of their participants through specific instructional interventions, specific courses, and entire programs if they are to be able to make adequate revisions for guiding the development of TPACK. With the emergence of the TPACK construct, the work in developing assessment mechanisms will impact the thinking about the meaning and recognition of TPACK.

FUTURE DIRECTIONS

Efforts in identifying and describing the knowledge that teachers must rely on for teaching with current and emerging technologies such as TPACK has energized the teacher education community in reconsidering how the teacher preparation programs needed to be redesigned. The publication of a handbook (*Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators*) called for "schools, colleges, and departments of education to engage their professors, cooperating teachers, and teacher-students in constructive exploration of and dialogue about the flow of technological pedagogical content knowledge in facilitating high-quality, effective instruction for all learners" (Brown & Cato, 2008, p. viii).

Researchers are framing and tackling important research questions with respect to TPACK and, as they do, a clearer recognition and understanding is evolving, much as what happened with the evolution of the understandings of PCK. Teacher educators are reframing their educational programs in order to more directly consider pathways for developing this specialized teacher knowledge, much as with the redesign of teacher preparation programs to develop the teacher knowledge called PCK. Engaging in an iterative process of research and design is important for understanding and extending TPACK. Continued challenges and issues will arise with efforts to engage teachers in TPACK strategic thinking as they plan, implement, and evaluate their teaching with new and emerging technologies. All efforts must be concerned with how the teachers plan and implement their knowledge.

Research is needed to assess teachers' beliefs about their content and how that content is learned in connection with using appropriate technologies for engaging students in learning the content. Research is needed to describe teachers' learning trajectories in developing the knowledge, skills, and dispositions for incorporating new and emerging technologies as learning and teaching tools in various subject areas such that children's knowledge is strengthened and enhanced. It is critically important that the research utilize systematic, empirical methods to more appropriately direct and support policy and large-scale changes in teacher education. The research studies must truly reflect the intersection of technology, pedagogy, and content—technological pedagogical and content knowledge or TPACK—amidst quality teaching and learning in the 21st century, where information and communication technologies have become increasingly accessible and valued for educational purposes.

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